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TRANSACTIONS OF THE ROYAL SOCIETY OF SOUTH AUSTRALIA

INCORPORATED

ADELAIDE

PUBLISHED AND SOLD AT THE SOCIETY'S ROOMS
KINTORE AVENUE, ADELAIDE

Registered at the General Post Office, Adelaide,
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VOL. 73 PART 1 DECEMBER 1949

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THE EPIPHYSEAL COMPLEX IN A TRACHYSAURUS RUGOSUS

BY D. A. SIMPSON

Summary

Gladstone and Wakeley (1940), quoting earlier workers (Spencer 1886 and Legge 1897), describe the epiphyseal complex of two skinks, Cyclodus gigas and Gengylus ocellatus. In these lizards the parietal eye appears to be a degenerate structure. Cyclodus gigas has a long, well-developed pineal organ, and a parietal foramen, but no parietal eye. In Gengylus ocellatus, a parietal eye was found in the embryo only ; in the adult there was a large pineal organ, but again no parietal eye. A drawing of the parietal eye of Sincus officinalis, from Calvet (1934), is reprinted ; the nerve, lens and retina seem well developed, but the epidermal scale covering the eye is densely pigmented and quite opaque. Gladstone and Wakeley therefore conclude that in the Scincidae, the parietal eye is atrophied and purely vestigial.

THE EPIPHYSEAL COMPLEX IN TRACHYSAURUS RUGOSUS

By D. A. Simpson*
(Communicated by A. A. Abbie)

[Read 14 April 1949]

INTRODUCTION

Gladstone and Wakeley (1940), quoting earlier workers (Spencer 1886 and Legge 1897), describe the epiphyseal complex of two skinks, *Cyclodus gigas* and *Gengylus ocellatus*. In these lizards the parietal eye appears to be a degenerate structure. *Cyclodus gigas* has a long, well-developed pineal organ, and a parietal foramen, but no parietal eye. In *Gengylus ocellatus*, a parietal eye was found in the embryo only; in the adult there was a large pineal organ, but again no parietal eye. A drawing of the parietal eye of *Scincus officinalis*, from Calvet (1934), is reprinted; the nerve, lens, and retina seem well developed, but the epidermal scale covering the eye is densely pigmented and quite opaque. Gladstone and Wakeley therefore conclude that in the Scincidae, the parietal eye is atrophied and purely vestigial.

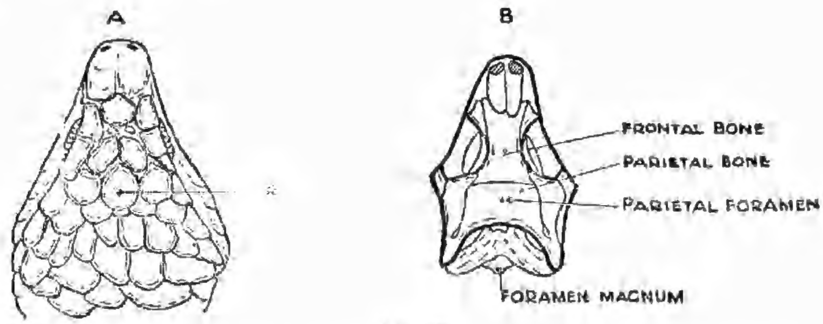

Fig. 1

A. Dorsal aspect of head of *Trachysaurus rugosus* showing parietal fleck and foramen (x ½).
B. Dorsal aspect of skull showing parietal foramen (x ½).

The epiphyseal complex in its fullest development, as seen in *Sphenodon*, comprises the following structures:

I. The pineal organ proper, a sac-like ependymal diverticulum, with an enlarged end-vesicle probably representing an eye which has failed to emerge from the cranial cavity. The organ sends nerve fibres to the habenular ganglia (right nucleus in *Sphenodon*).

II. The parietal eye, a simple vesicular organ lying in the parietal foramen. It shows:

(i) a retina of three layers: an inner layer of cylindrical neurosensory cells, a middle of plexiform nerve fibres, and an outer layer of ganglion cells;
(ii) a lens, of translucent columnar cells;
(iii) a parietal nerve, ending in the left habenular ganglion in *Sphenodon*, but in the right in the Lacertilia.

The parietal eye lies anterior to the pineal organ; it is suggested that in the earliest vertebrates, both lay side by side as dorsal paired eyes (Dendy, 1911).

It is of some interest, therefore, to find that all these structures noted in *Sphenodon* can be found in the skink *Trachysaurus rugosus*. Moreover, they are quite as well differentiated.

* Department of Anatomy, University of Adelaide.

MATERIAL AND METHODS

The material comprised four adult lizards, and one 60 mm. foetus. These were investigated by gross dissection, and also microscopically. Both transverse and longitudinal sections were employed and they were stained with haematoxylin and eosin, picro-indigo-carmine, Weigert-Pal, or De Castro's silver stain, according to requirements.

FINDINGS

1. The dorsum of the skull shows a *parietal foramen,* less than ½ mm. in diameter on the surface, but expanding to a cup-like recess on the inner aspect (fig. 1).

2. In the *parietal scale* over this foramen there is a depression, in some lizards markedly paler than in the rest of the scale. E. R. Waite's (1929) description of the "pineal area" as a group of nine small scales may prove a little misleading, since the actual scale covering the parietal eye is single, constant and relatively large.

3. Sagittal sections show a *parietal eye,* a vesicle of columnar cells lying in the inner part of the foramen, in loose and extremely vascular connective tissue (fig.2). The vesicle shows regional differentiation. The superior quadrant consists mainly of very tall columnar cells, with a few interspersed sphenoidal cells not attached to either basement membrane. This arrangement provides a biconvex lens entirely free from pigment. The remainder of the vesicle forms a retina, sharply defined from the lens and heavily pigmented. Three rather indistinct layers, comparable with those described in *Sphenodon,* can be identified: an inner, of heavily pigmented columnar cells, sending irregular processes towards the centre of the eye; a middle of tangential fibres, and an ill-defined outer layer of ganglion cells, with strands of pigment. The hyaline external limiting membrane is very well developed. Whether the black pigment of the retina was intracellular could not be determined. Some debris in the centre of the vesicle may represent a vitreous body.

The epidermis over the foramen is less pigmented than elsewhere (in the section, fig. 2, the epidermis has slipped to the left where the unpigmented area is clearly visible at *). The connective tissue filling the foramen between eye and skin is devoid of pigment. This tissue has a strongly lamellar structure in fixed material and seems comparable with the more massive parietal plug seen in *Sphenodon.*

Connective tissue immediately around the eye is condensed to form an ill-defined capsule and in the region of the foramen contains many melanophores.

In the foetal specimen, the eye is represented by only a simple diverticulum from the roof of the third ventricle, extending up to the parietal region (fig. 4).

4. The *pineal organ* proper, as distinct from the parietal eye, lies more posteriorly. It is a twisted cylindrical diverticulum, arising from the caudal end of the roof of the third ventricle. The cells are apparently ependymal, being clear and columnar, and they rest on a very clear basement membrane (fig. 3*).

The sac is continuous with a spherical terminal vesicle, very closely resembling the parietal eye; there is even a lens-like thickening of the superior wall. However, the rest of the vesicle is almost devoid of pigment and, unlike the parietal eye, contains no true ganglion cells. There is no gap in the skull over this pineal vesicle.

The stalk of the pineal sac is related anteriorly to the dorsal sac, which reaches almost to the terminal vesicle; it is a thin walled diverticulum, adherent in its turn to the paraphysis. The paraphysis is lined with cuboidal cells and is in continuity with the choroidal plexus of the lateral ventricles. In the foetal specimen the paraphysis was extremely well developed.

5. The *nervous connections* were not satisfactorily established. A nerve was seen to leave the parietal eye from its postero-ventral quadrant, but could not be traced to the habenular region, where presumably it arose. No nerves attached to the pineal sac could be found.

The epithalamic structures, habenular nuclei and commissures are, however, well developed, with a large median habenular nucleus. Nerve fibres ascend from these nuclei in the direction of the parietal eye; but their destination could not be determined.

The whole complex is embedded in a loose connective tissue which is enclosed within a tubular meningeal sheath (fig. 5).

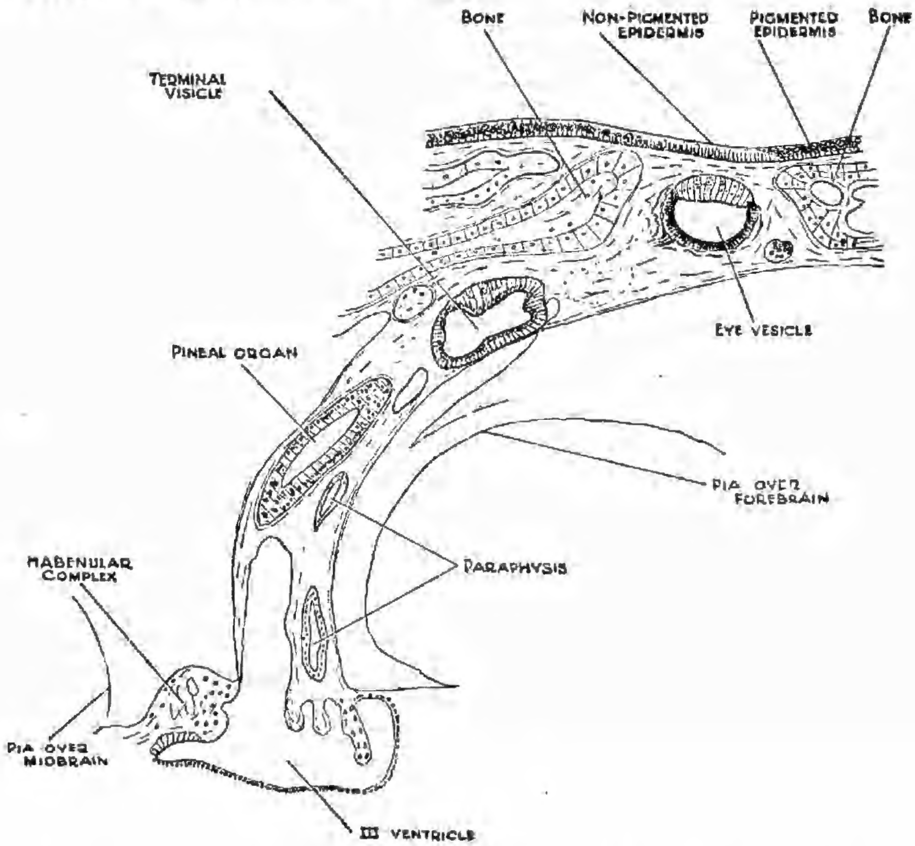

Fig. 5

Composite figure to illustrate most of the features of the epiphyseal complex (x 25 approx.).

DISCUSSION

Trachysaurus rugosus has thus a well-developed parietal eye, with no obvious signs of degeneration, and at least the equal of that in *Sphenodon*. Like other vertebrate parietal eyes, it is very primitive, with no equipment for focussing.

It has been much disputed whether the pineal sac and the parietal eye are developed from two bilateral eyes—later becoming median (Dendy, 1911), or from primarily median diverticula (Tilney and Warren, 1919). Both theories are equally compatible with the observations made in *Trachysaurus*, and this investigation does nothing to settle the controversy.

It is impossible in a discussion of form to avoid speculation on function. Anatomically, the parietal eye of these lizards seems well adapted to act as a simple light receptor, though most writers deny such function in living reptiles. The pineal sac may conceivably have a glandular function; the paraphysis is so evidently part of the choroidal system that it may be presumed to secrete cerebrospinal fluid.

No physiological proof of a pineal glandular activity in reptiles is available; the only real evidence for a photo-receptive function comes from the work of Clausen and Mofshin (1939). These authors studied the oxygen consumption of lizards (*Anolis carolinensis*) in the light and in the dark, before and after pinealectomy, and found that pineal "vision" makes a significant difference.

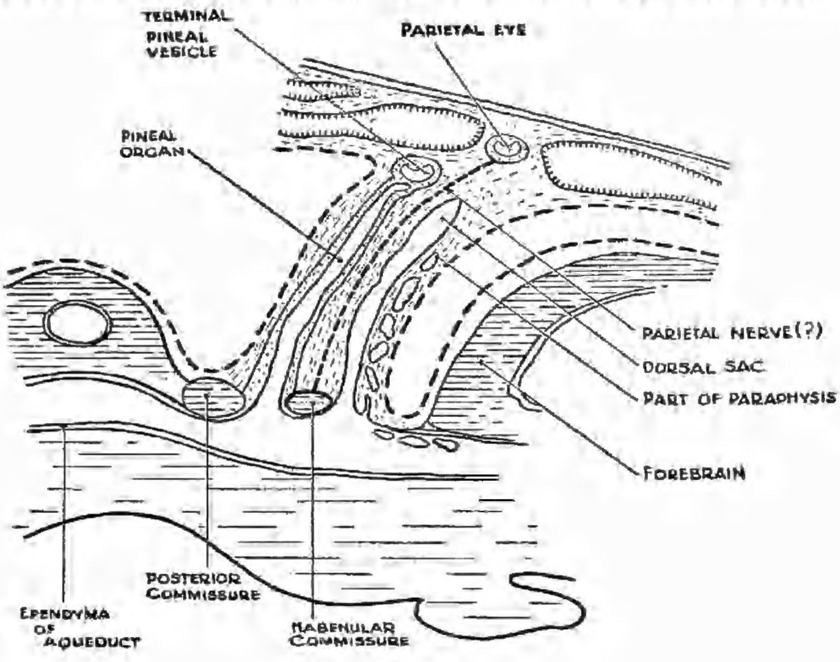

Fig. 6

Diagrammatic reconstruction of the epiphyseal complex.
The course of the parietal nerve and the relations of the dorsal sac and paraphysis are partly hypothetical. (Not drawn to scale.)

From an anatomical view, one may say for *Trachysaurus* what Dendy (1911) said for *Sphenodon*:

"I think we must admit that the pineal eye of *Sphenodon* is no longer at the summit of its career as a light percipient organ, but the evidences of degeneration are very slight. . . . It is impossible for me to believe that an organ which retains such a complex histological structure . . . can be entirely functionless."

ACKNOWLEDGMENTS

I am indebted to Professor A. A. Abbie, who first came upon this eye during an operation and suggested it as a subject for investigation; he has also assisted me with advice throughout this work. Dr. Adey has helped me with the microphotographs of sections kindly prepared by Mr. T. Canny. Miss G. Walsh was good enough to make the drawings from my draft sketches. I wish to express my gratitude for all this assistance.

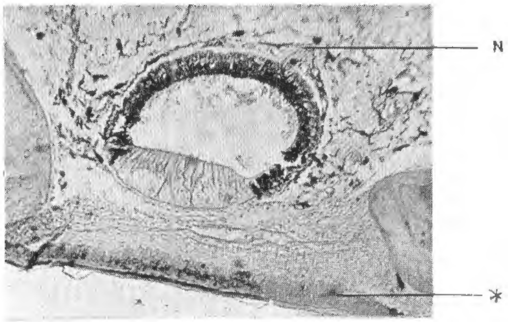

Fig. 2

Photomicrograph of parietal eye. Note overlying parietal foramen, pigmentation in retina and commencement of nerve (N). Haematoxylin and eosin, x 55.

N.B.—During preparation of this section unpigmented epidermis over parietal foramen has slipped to the left (*).

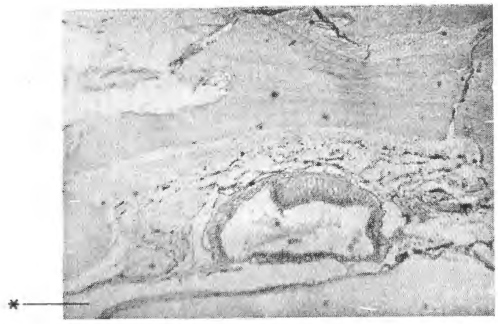

Fig. 3

"Pseudoparietal eye" or terminal vesicle of pineal organ (H. and E., x 32).

Note:

(a) eye-like structure except for pigmentation and nervous connexion;

(b) attached, saccular, pineal organ (*).

(c) that the magnification is less than in fig. 2 in order to show the absence of a foramen in the overlying bone.

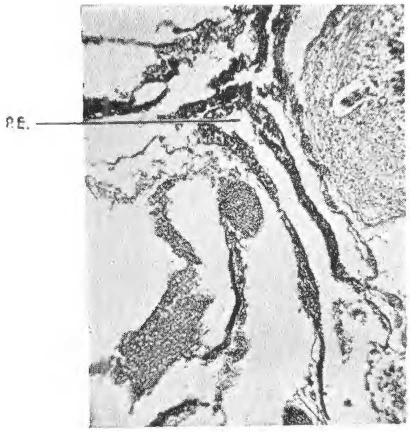

Fig. 4

Sagittal section of the region in a 60 mm. foetus to show the dorsal diverticulum from the root of the third ventricle from the terminal portion of which the parietal eye (P.E.) appears to differentiate (H. & E., x 52).

SUMMARY

1. The cerebro-epiphyseal complex in the lizard, *Trachysaurus rugosus*, is described.
2. Contrary to all previous opinion on this system in skinks, the complex in *Trachysaurus* equals in development the classical example found in *Sphenodon*.

REFERENCES

CALVET, J. (1934) L'Epiphyse, Paris (J. B. Bailliere et Fils), quoted by Gladstone and Wakeley (1940)

CLAUSEN, H. J. and MOFSHIN, B. (1939) "The pineal eye of the lizard (Anolis carolinensis), a photo-receptor as revealed by oxygen consumption studies," J. Cell. and Comp. Physiol., **19**, (1), 29-41

DENDY, A. S. (1911) "On the Structure, Development and Morphological Interpretation of the Pineal Organs and Adjacent Parts of the Brain in the Tuatara," Philos. Trans., Ser. B., **201**, 227-331

GLADSTONE, R. J., and WAKELEY, C. P. G. (1940) The Pineal Organ, London (Bailliere, Tindall and Cox)

TILNEY, F., and WARREN, L. F. (1919) "The Pineal Body. Part I. Morphology and Evolutionary Significance." Amer. Anat. Mem., No. 9

WAITE, E. R. (1929) The Reptiles and Amphibians of South Australia, p. 140, Adelaide (Government Printer)

ADDITIONS TO THE FLORA OF SOUTH AUSTRALIA

BY J. M. BLACK

Summary

EPACRIDACEAE Conostephium halmaturinum, nov. sp. – Frutex erectus tenuis ramosus fere glaber; folia rigida, erecta, subimbricata, linear-lanceolata circa 5 mm. Longa supra concava, infra 3-nervia; flores parvi penduli axillares; sepala pallida, 3 mm. Longa 2 mm. Lata ciliolata; bracteolis dimidio brevioribus quam sepala; corolla conica sepala vix-superans intus villosa; antherae 1½ mm. Longae cum filamentis prope basin corollae affixis; ovarium oblongum glabrum in disco annulari situm; fructus non visus.

ADDITIONS TO THE FLORA OF SOUTH AUSTRALIA
No. 45

By J. M. Black, A.L.S.

[Read 14 April 1949]

Epacridaceae

Conostephium halmaturinum, nov. sp.—Frutex erectus tenuis ramosus fere glaber; folia rigida, erecta, subimbricata, linear-lanceolata circa 5 mm. longa supra concava, infra 3-nervia; flores parvi penduli axillares; sepala pallida, 3 mm. longa 2 mm. lata ciliolata; bracteolis dimidio brevioribus quam sepala; corolla conica sepala vix-superans intus villosa; antherae $1\frac{1}{2}$ mm. longae cum filamentis prope basin corollae affixis; ovarium oblongum glabrum in disco annulari situm; fructus non visus.

Hundred of Heddon, Kangaroo Island—The only species hitherto found in South Australia. Appears nearest to the West Australian *C. planifolium,* F. v. M., but has much smaller leaves and flowers, bracteoles scarcely half as long as the sepals, a glabrous ovary and a prominent annular disk (*C. planifolium* has no disk). Collector, J. B. Cleland.

Leguminosae

Acacia quornensis sp. nova.—Frutex gracilis circiter 2 m. altus; phyllodia plana, lanceolata, pallide viridula, 2-5 cm. longa, 4-5 mm. lata, uninervia, superne in mucronem inferne in petiolum brevem angustata; capitula numerosa, in racemis quam phyllodia brevioribus disposita; flores 8-15 in quoque capitulo; calyx cyathiformis 4-5 lobis, petala 4-5, glabra; legumen planiusculum, super semina turgidum, 5-10 cm. longum, 8-10 mm. latum; semina ovata, nigra, 6-7 mm. longa, funiculo duplicato cincta, in arillum parvulum desinentia.

Hills near Quorn (Flinders Range). Nearest to *A. retinodes,* but has smaller phyllodes, fewer flowers in head and glabrous calyx. Collector, M. E. Groves.

AUSTRALITES, PART V

TEKTITES IN THE SOUTH AUSTRALIAN MUSEUM, WITH SOME NOTES ON THEORIES OF ORIGIN

BY CHARLES FENNER

Summary

Tektites are small glassy objects, averaging about 10 to 40 grams in weight, but ranging down to 0.15 grams and very rarely up to hundreds of grams, found widespread and in considerable numbers in nine known localities in the world. The group in which occurs the specimens of largest size is the Indochinite collection; one of these, in the Paris Museum of Natural History, is broken, but originally weighed four kilograms. Nothing comparable to this is known from any other group. The source and mode of origin of tektites has puzzled the minds of a multitude of workers. Australites have, for the past century, attracted particular attention, perhaps because they are so abundant and widespread and because they are able to be classified within a small number of regular forms. Moreover, as will be shown later, the australite forms show distinct evidence of two phases in their development, as was recognised by some of the earliest investigators (Walcott, ref 1, 1898).

AUSTRALITES, PART V

TEKTITES IN THE SOUTH AUSTRALIAN MUSEUM, WITH SOME NOTES ON THEORIES OF ORIGIN

By CHARLES FENNER *

[Read 14 April 1949]

PRELIMINARY NOTE

Tektites are small glassy objects, averaging about 10 to 40 grams in weight, but ranging down to 0·15 grams and very rarely up to hundreds of grams, found widespread and in considerable numbers in nine known localities in the world. The group in which occurs the specimens of largest size is the Indochinite collection; one of these, in the Paris Museum of Natural History, is broken, but originally weighed four kilograms. Nothing comparable to this is known from any other group. The source and mode of origin of tektites has puzzled the minds of a multitude of workers. Australites have, for the past century, attracted particular attention, perhaps because they are so abundant and widespread and because they are able to be classified within a small number of regular forms. Moreover, as will be shown later, the australite forms show distinct evidence of two phases in their development, as was recognised by some of the earliest investigators (Walcott, ref 1, 1898).

Barnes (1940) records that the first printed word regarding tektites (Moldavites) was a note by Joseph Mayer, 1787, and in the subsequent 160 years over 250 scientific papers have been written on these objects, most of the papers being published in the past 40 or 50 years. Charles Darwin (1844) was the first scientist to theorize on the origin of Australites; his theory, like many others, has long been discarded.

The present writer was attracted by the australite problem about 40 years ago (1907), a time when research on these objects in Australia was very active and when the majority of Australian workers considered these glass blobs as being originated by a vast shower of glass meteorites. Since then the study of australites has been linked up with analogous swarms of glassy blobs found elsewhere, and many fascinating facts have been collected and much interesting conjecture put forward.

The "accepted" tektite groups or swarms referred to in this paper are, in the general order of their discovery: Moldavites (Moldavia), Billitonites (Billiton, etc., East Indies), Australites (Southern Australia and Tasmania), Indochinites (Indo-China), Rizalites (Philippine Islands), Javanites (Java), South American tektites (Colombia), Ivory Coast tektites (Africa), and Bediasites (Texas, U.S.A.). Thus each continent has its share, and though there are distinct differences between each group, the possibility of some overlap in south-eastern Asia and the adjacent islands must not be overlooked. In the "Rocks and Minerals Magazine," September-October 1949, there is reference to green and blue objects found in North Queensland by H. H. Batchelor, of Hughenden, Queensland, and referred to by him as "Australian Tektites." Mr. Batchelor has kindly presented to me two of these so-called tektites. On examination I classify them as jasperoid fragments, such as are found in many places on the gibber plains of Australia, particularly on those formed on the Cretaceous rocks. They reveal no signs of their being melted glass, as true tektites are, and there is no indication whatever of the internal flow-line structure that is one of the most striking characteristics of tektites.

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* South Australian Museum.

Largely through the interest of Sir Douglas Mawson, a special effort has been made by the Board of the South Australian Museum to build up as comprehensive a collection as possible of australites and other tektites in that institution. The collection now numbers over 18,000 (March 1949), including 17,323 australites, 430 foreign tektites, and 364 other silica glass objects, and it was considered worth while to describe the collection as a whole. One of the dangers that besets public and private collections of these curious objects is that they tend to be dissipated by gifts, loans and exchanges. For instance, the very fine Shaw collection, purchased by the South Australian Museum (Fenner, 1934), consisted originally of 3,920 pieces; it now consists of only 3,370 pieces. The larger and more recently purchased Kennett collection (Fenner, 1940) as originally described contained 7,184 pieces, is now reduced to 7,135. It is probable that less than 10 per cent. of collected specimens are in registered collections, and many of the latter are abraded, flaked or fragmentary.

The total number of australites that fell on Southern Australia has been estimated as at least one million, and at most ten millions, spread over 2,000,000 square miles (Fenner, 1935, pp. 128-129).

GENERAL DETAILS OF THE SPECIMENS DEALT WITH IN THIS PAPER

1. Australites, General Collection, 919 specimens. — This general collection includes smaller collections by Mrs. Leggitt, J. E. Johnson, J. H. Johnston, A. H. Warren, J. H. Nicholls, C. Fenner and other persons named in the register of the tektite collections.
2. Australites, Florieton (Penn) Collection, 339 specimens. — These were collected in an area north of Morgan, S. Aust., under the supervision of Sir Douglas Mawson.
3. Australites, Shaw Collection, 3,370 specimens. — These are from the Nullarbor Plains and southern Western Australia. They have been described in detail (Fenner, 1934).
4. Australites, Kennett Collection, 7,135 specimens — These are from a vast area of Central Australia, centred around Charlotte Waters. They have been described in detail (C. Fenner, 1940).
5. Australites, Cook Collection, 5,186 specimens. — These are from the Goldfields area of Western Australia, centred around Kalgoorlie, W. Aust.
6. Australites, Warren Collection, 368 specimens. — These are from the area surrounding Marree and Oodnadatta, South Australia.

TOTAL AUSTRALITES: 17,323 specimens.

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7. Other tektites, Moldavite Collection, from Bohemia, etc., 89 specimens, mainly from Prof. Slavik, Prague.
8. Other tektites, Billitonite Collection, Billiton Island, 1 specimen from Dr. Shenton, F.M.S.
9. Other tektites, Javan tektites, Java, 47 specimens, from Dr. G. von Koenigswald, Java.
10. Other tektites, Indo-chinite collection, Indo-china, 42 specimens, from Prof. A. Lacroix, Paris.
11. Other tektites, Rizalites, etc., collection, Philippine Islands, 212 specimens, mainly from Prof. Otley Beyer, P.I.
12. Other tektites, Bediasite Collection, Texas, U.S.A., 39 specimens, from Prof. Virgil Barnes, Texas, and F. W. Cassirer, Paris.

TOTAL OTHER TEKTITES: 430 specimens

13. Other natural silica glasses, Darwin Glass Collection, Tasmania, 29 specimens (from Launceston Museum).
14. Other natural silica glasses, Libyan Glass Collection, Libya, 2 pieces (from Dr. L. J. Spencer).
15. Other natural silica glasses, Impactite Collection, Arabia and Australia, 4 pieces, from various sources.

TOTAL OTHER NATURAL SILICA GLASSES: 35.

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16. General related material, Straw Silica Glass, South Australia, 11 pieces, collected by the author. Trinityite (atom-bomb silica glass).
17. General related material, Sand-tube fulgurites, 115 pieces, separately described (Fenner, 1949).
18. General related material, Pseudo-tektites, smoke bombs from steam trains and steam-boats, etc, (ref. 8) (Fenner, 1938), 200 pieces.
19. General related material, plaster casts of australites from the Walter Howchin collection, 103 pieces.

TOTAL GENERAL RELATED MATERIAL: 429 pieces.

GRAND TOTAL OF PIECES REFERRED TO IN THIS PAPER: 18,217.

PROPORTION OF VARIOUS AUSTRALITE SHAPES

Australites have been classified according to their various forms by the writer (Fenner, 1934 and 1940) (refs. 4 and 6), and this classification has been found to fit in with the various collections subsequently described. Nevertheless, it must be remembered that only a small proportion of australites found are quite complete. There are three outstanding reasons for this:

(a) All australites have passed through two phases; in the first phase the glass apparently cooled slowly, and that part is stable; the anterior portion, which was melted a second time, appears to have cooled rapidly and is very liable to break or crack; in all forms except the medium and small lenses this portion flakes off (see Fenner, 1935, p. 131, and 1938, pp. 200-204). This double melting does not apply to any other tektites, as far as is known.

(b) In the wetter areas of the strewn field, many specimens were swept by rain into recent streams and have accordingly become somewhat waterworn; many of these were recovered from gold-bearing and tin-bearing gravels.

(c) In the sand-dune areas of the strewn field sand-blasting has played a part in the abrasion. Insolation and consequent fracture and flaking must also be considered.

Round forms (flanged buttons and lenses) have been found to be the most abundant in all collections hitherto described. Elongate forms are second in number, and there is a third group of unusual forms, mostly of small size.

Of 17,000 specimens taken at random in the South Australian Museum collection, the following gives an idea of the proportion of the various best known types; apart from a number of broken chips, anyone familiar with large numbers of australites can readily detect the group to which a flaked or abraded form belongs. Those called "indicators" were originally larger lenses or ovals, with rims, the equatorial and anterior parts of which have flaked away, leaving just enough of the original rim to "indicate" the shape of the form when it finally cooled (Fenner, 1935, vide ref. 5). In the South Australian Museum collection there are many specimens in which this flaking has proceeded far but has not been completed, one in particular is a fine large flanged dumbbell, No. T. 512.

An analysis of these 17,000 selected forms is given in the following table:

TABLE A

			Percentage of round forms	Percentage of total collection
Round forms	Flanged buttons, whole	108	1·1	0·64
	Flanged buttons, chipped	968	9·9	5·7
	Flanged button fragments	397	4·1	2·34
	Lenses, complete	1914	19·5	11·2
	Lenses, slightly chipped or abraded	744	7·6	4·38
	Lens cores, front and margins flaked off	4147	42·4	24·4
	Other round forms, partly broken	1505	15·4	8·9
	Total common round forms:	9783	100·0	57·56
Elongate forms	Ovals, broad	573	12·2	3·38
	Ovals, narrow	674	14·3	3·97
	Ovals, general	339	7·2	2·0
	Boats	600	12·7	3·52
	Canoes	146	3·1	0·86
	Elongates, general	1514	32·0	8·9
	Dumbbells, complete	264	5·5	1·55
	Dumbbells, broken	499	10·6	2·94
	Ladles, and other unusual elongate forms	115	2·4	0·68
	Total common elongate forms:	4724	100·0	27·8
Teardrops	Teardrops, typical	331	98·6	1·95
	Teardrops, unusual	5	1·4	0·03
		336	100·0	1·98
Rare forms	Pitted discs	5	2·14	0·03
	"Spheres", probably deep lens cores	9	3·85	0·05
	Crinkly tops	23	9·83	0·14
	Helmets, trays and other small forms	50	21·42	0·30
	Pear-shape, an asymmetrical dumbbell	1	0·4	—
	Flat-tops (special type of lenses)	53	22·64	0·31
	"Indicators" as elsewhere described	74	31·62	0·43
	Air-bombs	19	8·1	0·11
		234	100·0	1·37
Unclassified fragments	Australite fragments	1923		11·3
	Grand Total:	17000		100·0

An interesting comparison may be drawn from the three largest collections that have been classified according to shape, namely, the Shaw Collection (Fenner 1934, ref. 4), the Kennett Collection (Fenner 1940, ref. 6), and the South Australian Museum Collection, which includes the Shaw and Kennett Collections, plus more than 7,000 additional specimens. The conclusion may be drawn that the various types shown in the following table occur throughout the strewn-field in about the same proportions. The absence of "rare and unusual forms" from the Shaw Collection may be due to the inexperience of the writer at that time, for many of the figured Shaw specimens (Fenner, 1934, ref. 4) would otherwise have been included in that group:

TABLE B

	Shaw	Kennett	S.A. Museum
1. Round forms - - -	1369	3935	9783
2. Elongate forms - - -	490	1140	4724
3. Teardrops - - - -	134	62	336
4. Rare forms - - -	not classified	102	234
5. Unclassified fragments - -	1927	1943	1923
Total forms considered -	3920	7182	17000

There is another group of collectors about which little has been written. These are the native birds that wander over the tektite-sprinkled area, particularly emus and "plain turkeys". So many australites were found in the crops and gizzards of emus that in earlier years the popular name given to australites by the people of the Outback was "emu-stones", a name which still persists here and there. The Australian Bustard or Plain Turkey (*Eupodotis australis*) was also a collector. Somewhere about 1940 or earlier one of these birds was shot and dressed by Mr. M. Kirkham, as seen and attested to by Mr. H. McDonald, of Port Augusta, South Australia. There were 49 australites and two other black stones in the crop of the bird. The author has one specimen from this collection and a photograph of 41 others. Seven were retained as souvenirs by members of the party. The total weight of the specimens was 4½ ounces. Of these 42, round forms were in the majority, as follows: 31 rounds, 6 elongates, 1 probable teardrop, 1 unusual form, and 3 fragments. This collection was, of course, a specially selected one, but it indicates the abundance of australites among the rock fragments of the salt-bush and mulga plains, and the predominance of round forms.

The largest and least abundant of the round forms are those called "bungs", 2·1 to 4·2 cm. major diameter, 1·6 to 3·3 cm. minor diameter. Next in size and abundance are the "small cores", originally lenses as were the bungs, 1·6 cm. to 2·3 cm. major diameter, 1·1 cm. to 1·7 cm. minor diameter. The beautiful and interesting group called "flanged buttons" cluster in the small range of 1·3 cm. to 1·9 cm. major diameter, ·7 cm. to 1·1 cm. minor diameter. The most abundant in numbers, and those which most commonly retain an unbroken shape, are the lenses, which are also the smallest of the round forms, ·6 cm. to 1·6 cm. major diameter, ·3 cm. to 1·0 cm. minor diameter. In weight, the smallest lenses are less than ·3 grams, and the largest bung is over 100 grams.

The measurements and weights shown in the foregoing paragraph and in the graph (Fenner 1938, ref. 8, pp. 199-202) were done in 1938 on a selected representative series of 189 unbroken shapes. An application of these conclusions to the whole of the round specimens, over 9,000, in the South Australian Museum Collection, confirms the sizes and relative abundance of these types in a large and comprehensive collection. A careful examination, without individual measurements, of the ovals, boats, lenses, flanged buttons, canoes, dumbbells and teardrops in the South Australian Museum collection also suggests strongly that the variations in size and weight of the elongate types are in a practically similar proportion. There are very large, very small, and intermediate types of lenses, ovals, boats, dumbbells, and teardrops, though there appear to be fewer very large canoes, and fewer very small teardrops.

It will be understood that the observations made and the conclusions reached in this paper are specially based on the 18,217 specimens in the South Australian Museum, but not without consideration of the collections in other Australian, European, British and American Museums.

OTHER NATURAL SILICA GLASSES

Passing reference should be made to the other natural silica glasses in the South Australian Museum Collection.

Darwin Glass—This has commonly been accepted as a tektite, but it presents peculiar differences of composition, form and distribution. It occurs within the Australite strewnfield, but is limited to Mount Darwin, in North-west Tasmania. It consists of light-green, shapeless, small masses of flung glass. There is no evidence that it is an impactite and it occurs much more abundantly than impactites do, and there is no sign of a crater. It has distinct differences from tektites (Fenner 1940, ref. 6), and though it may be of cosmic origin it presents many difficulties of inclusion among the tektites so far as our present knowledge goes.

Libyan Glass—This has been fully described by Dr. L. J. Spencer, who visited the area and collected much material. Dr. Spencer does not consider it a tektite. It appears indeed to present a more puzzling problem than the accepted tektites. Its composition is much more siliceous and its shapes quite different from those of tektites. Its distribution suggests a cosmic origin, but there appears to be no other fellowship with the tektites.

Impactites—These are usually fused country rock found in or in close association with meteorite craters. Some microscopic forms figured by Spencer have the shapes of some tektites. There is no doubt of their origin either at Wabar, Henbury, or elsewhere. But their numbers and distribution show them to have no bearing on the origin of the vast tektite swarms found in other parts of the world.

Straw Silica Glass—This is found where haystacks or strawstacks have been burnt. The silica of the straw accumulates in shapeless masses. Analyses shows a high soda-potash content. There is no doubt of their origin (Fenner 1940, ref. 6), and they are mentioned only because they are included in the collection.

Sandtube Fulgurites—Associated with these are rock-face fulgurites. They are due to lightning and occur where sands or rocks are struck by lightning. Their forms are interesting, and their compositions are those of the rocks or sands affected. There is no evidence of their relation to tektites (Fenner 1949).

Smoke Bombs—These are small siliceous forms, mostly spherical, but also with many dumbbell and teardrop forms. They are "coughed" up from the funnels of steamtrains or steamships and may be found by careful looking on railway tarpaulins and along beaches wherever steamships or steamtrains ply.

They are the product of the silica content of steam coal and are of microscopic size. There is no doubt of their origin, and they have been adequately described and figured (Fenner 1938, ref. 8).

Pseudo-Tektites—In every collection examined by the author there has been a number of specimens which look like tektites but which are waterworn pieces of lydianite or ironstone, or other curiously shaped geological or mineralogical specimens. Their origin is undoubted, and they are of no special interest except that they persistently occur, even when the collectors have been as keen and observant as are the aboriginal folk of Australia.

Trinityite—This is the name given to the silica glass formed on the desert surface from the melt produced by the firing of the first test atom bomb near Alamogordo, New Mexico. Several small specimens were presented by Lincoln La Paz, Director of the Institute of Meteorites, Albuquerque, New Mexico. To bring the collection up to date, the Director of the South Australian Museum, Mr. H. M. Hale, has received from the Officer Commanding the British Commonwealth Occupational Forces in Japan samples of silica glass that resulted from the fusion of tiles and building stones by the atom-bomb at Hiroshima.

Plaster casts—The casts of the Howchin collection prove to be quite typical, except that one specimen has a very large central burst gas bubble. The original Howchin collection, with a large number of other fine specimens, is in the Tate Museum of the University of Adelaide.

DISTRIBUTION OF AUSTRALITES

E. J. Dunn published a map in 1912, showing 70 spots where one or many australites had been found. Dr. Thorp, in 1914, showed 85 locality spots.

Using these two maps and much subsequent information (Fenner 1935, ref. 5, pp. 134, etc.) the writer published a map showing about 300 spots or localities, but with many spaces where it would appear that none had been found. Since then, from an examination of thousands more specimens, and from information received, it would appear that there are few, if any, spaces south of the line drawn on the 1935 map where no australites have been found. This limitation is of special interest.

With some hesitation the idea is put forward that there are many areas where australites are more abundant, such as Kalgoorlie; Charlotte Waters, Nullarbor Plains, Lake Eyre and district, Yorke Peninsula, Floricton, South Australia; Western Victoria; Northern Tasmania; Port Campbell (Victoria); and the goldfields of eastern New South Wales. On the other hand, collecting may have been easier or more carefully carried out in these areas.

It is curious that the large collection made by Sergeant Kennett should consist of specimens so much larger than the average (x 7 in some groups) of those collected by W. H. C. Cook mostly on the southern Nullarbor Plains. Yet large specimens, as well as very small, are found everywhere within the strewnfield. From the South Australian Museum collection one gets the idea that the very largest are found in the north and north-west areas, but this cannot be proven, for the very large ones of other more populated localities may have been retained as souvenirs or curiosities by the finders.

CHEMICAL COMPOSITION OF TEKTITES

A large number of chemical compositions is available, as set out in Summers (Summers 1908; Barnes 1940) and several others, such as Suess, Lacroix and Michel. Summers, earlier, and Barnes, later, have graphed these various analyses in a number of informative ways. The definite facts that emerge from these analyses is that the recognised tektite swarms are very similar to each other within that swarm, and that differences occur between the characters of one swarm and those of another. There may be discerned considerable differences between the accepted tektites and such glasses as Libyan Glass and Darwin Glass. Also there may be some overlap within the four groups that occur in South-east Asia, the Billitonites, Indo-chinites, Philippine Island tektites, and the Java tektites; this has never been suggested or proved. Specific gravity and refractive index comparisons do not contradict these findings. Summers held a belief, founded on a small number of analyses, that australites increased in density towards the west, and Baker and Forster suggested (1943) "that the extra-terrestrial body from which the australites were shed travelled from north of west to the south of east across the Australian continent, since the specific gravity values of australites decrease from north of west to south of east." That means, and it is a point of importance, the australite swarm travelled with the rotation of the earth. The writer has nothing to add to the excellent and comprehensive work done by Barnes (1940) and others concerning the chemical composition of tektites and related bodies.

RADIOACTIVITY OF TEKTITES

In 1933, V. S. Dubey (*Nature*, 28 October 1933, p. 678) determined the radioactivity of several silica glasses, mostly tektites. He concluded that, apart from Darwin Glass, there was a significant correspondence in radioactivity, measured in radium and thorium per gram. His results were:

		$Ra \times 10^{-12}$ per gram.	$Th \times 10^{-5}$ per gram
1.	Moldavite - - - - - -	1·07	1·08
2.	Moldavite (Habri) - - -	1·02	1·60
3.	Moldavite (Probsch) - - -	0·78	1·60
4.	Moldavite (Radomolice) - -	0·99	1·86
5.	Billitonite - - - - -	0·96	0·96
6.	Australite (Lake Eyre) - -	0·96	0·50
7.	Australite (Victoria) - - -	0·85	1·84
8.	Darwin Glass (Tasmania) - -	0·50	1·13
9.	Glass (old beads) - - - -	0·48	—

Facilities were not available to carry out a radioactive comparison in the terms of this table, but excellent instruments were at hand to make a comparison in terms of beta particles, using whole specimens, and the result is set out in the following report. The results cover a wider range than those of Dubey, and are somewhat similar except so far as Darwin Glass is concerned. Though the radioactivity in terms of beta particles is in general low, Libyan Glass is practically non-radioactive. The report by W. G. Fenner is as follows:

"The examinations were carried out using a beta-particle counting tube, totally enclosed, plus specimen, in a lead-chamber. The background count was obtained in three separate runs of ten minutes each, distributed throughout the examinations, and was consistently within the expected random distribution.

"Because of limited time, and as it was not permissible to break or crush the specimens, several major causes exist for discrepancies and for some lack of consistency, and make it impossible to take the figures at their face value. These causes are:

"(i) Differences in geometry of the various tektites with respect to the Geiger-Muller tube "(ii) Possible variation in distribution of the radio-active material through the different specimens.

"(iii) Varying densities between specimens and within each specimen. No allowance has been made for absorption.

"The different weights of the specimens used is of little importance compared with the above irregularities.

"Despite these drawbacks, however, it seems reasonable, on the actual results, to assign a general order of degree of radioactivity. More specimens, and proper control, are required to confirm this.

TABLE C

"Column 1 gives the weight in grams; column 2 gives the count per minute; column 3 gives the duration of the test in minutes; column 4 gives the excess count per minute for each specimen or group of specimens.

			1	2	3	4
Reg. No.	Locality	Background	—	7·9	30	0·0
T. 806	Libya, Africa	One piece of sand-polished Libyan Glass	15·0	9·2	10	1·3
T. 899	Texas, U.S.A.	Two Bediasites	48·6	10·0	10	2·1
T. 424	N.W. Tasmania	Four pieces of Darwin Glass	10·7	11·0	10	3·1
T. 264 T. 266	Central Australia	Two medium lens core Australites	62·5	10·7	10	2·8
T. 283	Central Australia	Two large narrow oval Australites	73·5	12·3	10	4·4
T. 692	Indo-China	Large fragment of Indochinite	72·2	10·8	10	2·9
T. 685	Indo-China	Large fragment of Indochinite	30·4	12·3	10	4·4
T. 708	Philippine Islands	Three medium Rizalites	21·2	11·5	10	3·6
T. 857 T. 860	Philippine Islands	Two large regular Rizalites	78·5	12·0	10	4·1
T. 885	Lhanice Bohemia	Three Moldavites	17·2	13·2	20	5·3
T. 821	Te Wairoa, New Zealand	Large piece of volcanic obsidian	56·4	15·7	30	7·8

TABLE D

"Extracting certain of the above and combining them we get the following results; the numbers at the heads of the columns have the same significance as in the preceding table.

			2	3	4	
T. 424	Nth.-West Tasmania	Darwin Glass	11·0	10	3·1	Darwin Glass count
T. 264 T. 266 T. 283	Central Australia	Australites	11·5	20	3·6	Australite mean count
T. 685 T. 692	Indo-China	Indochinites	11·6	20	3·7	Indochinite mean count
T. 708 T. 857 T. 860	Philippine Islands	Rizalites	11·8	20	3·9	Rizalite mean count

"*Conclusions*— From these results there would appear to be a radioactive similarity between Darwin Glass, Australites, Indochinites, and Rizalites. It would be of interest to compare their overall chemical compositions, particularly the rarer elements.

Libyan Glass is lacking in any positive radioactivity while the volcanic obsidian is positively radioactive to the greatest degree of the specimens tested; all others lie between these extremes. It must be remembered however that even the volcanic obsidian has but a minute trace of radioactive material present; it must also be remembered that in each case the material in a portion of the surface layer of about 1 mm. thick only has been subject to examination, due to the softness of the beta particles. Assuming it to be uranium in equilibrium, that present in the obsidian is certainly less than 0·003% U_3O_8. Many igneous rocks of the earth's surface have the same and greater orders of radioactivity."

No spectroscopical analyses were available for inclusion, but my attention has been drawn to a separately published paper by Ekkehard Preuss, of Jena. Although not mentioned in the bibliographies quoted, this is a thorough and valuable contribution to the tektite problem. Incidentally, Preuss mentions Borneo tektites, which were to be expected but had not previously been reported

SHAPES AND STRUCTURES OF AUSTRALITES

Australites have the most regular shapes of all the tektites, and as most of these shapes have been dealt with and figured fairly abundantly by various authors, little comment is necessary except to say that the greater the number of specimens examined, the more remarkable appears the regularity of the forms. Professor Skeats wrote about two unusual types, the "disc" and the "pine-seed" and George Baker (ref. 1946) figured several special forms. Two of these (13 and 14) are abraded elongate indicators, and several of the others are variants of the teardrop form: there is always a good deal of variety in this group. The most interesting are figures 3A and 3B. In the larger S.A. Museum collection there are about 50 such forms. They are all very small and very complete. The writer has called them helmets, trays, scoops, etc. Mr. Baker calls the ones he figures "bowls," which is a very appropriate name for what have elsewhere been called "helmets." In Fenner 1940, plate XIX, several of these small forms are figured.

Before passing on to a brief comment concerning the shapes and structures of other tektites, mention should be made of a very beautiful and informative series of photographs of sections, especially of flanged buttons, published by George Baker (Baker 1944, plates I, II, III). In a plunge into the theory of the evolution of round forms (ref. 8) the author drew a diagram (fig. 2) and graphs (figs. 1 and 3), to illustrate his ideas. It is of much interest to find the very definite (Becke line effect) internal flow structure just as would have been expected on the basis of the two phase (twice-melted) theory of origin. Other tektite forms show equally definite internal flow lines, but no signs of two meltings.

Apart from flanges, which mostly occur on buttons of the sizes already stated, but which also occasionally but rarely occur on ovals, dumbbells, ladles, and so on, there is little notable or characteristic external markings. Abrasion is common, but erosion grooves are rare; the most notable of these erosion grooves which resemble arabic writing, and in some cases cuneiform markings, which are generally considered to be evidence of long burial in moist earth, are seen on those from the moister parts of the strewnfield. The curious and obviously incorrect belief that australites are still falling is held by a few people, who are unfamiliar with well-known facts about tektite strewnfields (Fenner 1935, pp. 138-139).

Other interesting exterior features are the flow lines visible on the anterior surfaces of many forms, the pitting of the posterior surfaces mainly due to small burst gas bubbles, and the spiral or concentric flow-ridges that occur on the anterior surfaces of flanges, lenses, ovals, etc. Such markings are absent from flaked lenses or oval cores.

Baker infers that australites with anterior concentric flow ridges did not rotate in flight; if this is true, the whole question of form as evidence of origin must be reconsidered. Practically every australite, except very small forms has, or had, anterior flow ridges. There is a remarkable and convincing example of a fairly large flanged dumbbell indicator (No. T.512) in the South Australian Museum collection, as already mentioned.

SHAPES AND EXTERIOR SURFACES OF OTHER TEKTITES

Moldavites have structures and beauty of colour found in no other tektites. A striking shape is a flattish, disc-like, radially ridged rosette. Many are vesicular, some appear to be considerably corroded, the greater number are practically shapeless, many are sharply broken across at right angles to the axis, some are tear-drops of a long and special type. The general character of the surfaces, with their wrinkles, grooves, and pits, is very characteristic. In a large collection, as in that at Prague, one may detect groups or types, but not in any way comparable with the regularity and symmetry of australites. Moldavites are possibly the oldest, as well as the first known of the tektites.

Indo-chinites are extremely abundant, and in Professor Lacroix' museum in Paris there may be seen the greatest part of the largest known tektite, as well as a remarkably fine collection of indochinites generally. The surface is usually rough and vesicular. Beautifully round flat ovals occur, also large teardrop forms. The surface structure is of great variety, as figured by Lacroix (1935). Surface corrosion is of much importance on the Indo-chinites, as it is on the Moldavites, but it is not nearly so general nor so important on the Australites and the other tektite groups.

The Billitonites, of which the writer has examined only the British Museum collection and one specimen in Adelaide, do not reveal so much character as other groups. The Adelaide specimen is a flat oval, with bubble pits and possible corrosion marks. Although there may be some overlap between the Billitonites, Javan tektites, Indochinites, and Rizalites (P.I.), yet in the well formed specimens they can be detected one from the other. All are shiny and pitchblack, with many forms approximating to spheres, ovals, lenses and an occasional dumbbell. But the surface markings described and figured by Lacroix, Barnes, Beyer, Hodge-Smith, and von Koenigswald and those in the S.A. Museum collection show distinct differences.

The writer has handled specimens from the Ivory Coast and from Colombia, but has not considered them closely enough to justify comment. They are black, glassy blobs, quite foreign to the places where they were found. On chemical and physical characters they have been accepted by several leading European authorities. On this evidence we also may tentatively accept them as tektites until such time as material is available for comparison and enquiry.

The latest group of tektites, the Bediasites, has been well described and figured by Virgil Barnes (1940). They are black, like all other tektites except Moldavites, and while many of the shapes approximate to flat rounds, ovals, rounded cylinders, and teardrops, many are shapeless and fragmentary. Many also have very deep U-shaped and V-shaped grooves. Though black, they have a light purple tinge, but are green in transmitted light. Both externally and in section, as well as in chemical composition and in distribution, they may well be accepted as true tektites. Barnes did not regard them as cosmic objects, but suggested a possible lightning origin. This, wrote Barnes, was an effort "to create enough interest to cause the investigation of all the terrestrial possibilities before accepting the meteoritic origin with all its unproven and unprovable postulates." In response to this the writer has published a paper (Fenner 1949) on lightning-formed silica glass tubes. The unproven and unprovable postulates to a terrestrial origin for tektites have been closely considered and rejected by many high and competent authorities.

Two groups, Libyan Glass and Darwin Glass, are so different in many ways from accepted tektites that they are not considered in this paper. If the origin of tektites constitutes an enigma, as has so often been stated, there are facts associated with Darwin Glass and Libyan Glass that are even more puzzling. Impactites are not considered, also, but for the very definite reasons that their origins and distribution are so clear and indisputable; they are not tektites.

The first people to collect and name australites were the Australian aborigines. By these folk they were carried as curiosities, and also as objects of mystery and magic, as shown by the collection that had been thus used, now displayed in the British Museum at Bloomsbury. The aborigines called them by various names meaning "staring eyes" or "emu eyes."

N. B. Tindale, ethnologist of the South Australian Museum, has pointed out that in some cases aborigines made small implements from this obsidian material, but so far as is known none was made from the larger specimens.

It is significant that all such implements as are known, from the Broken Hill and Yorke Peninsula areas, first appear in the Mudukian culture. This is the latest but one of the aboriginal culture sequences and lends support to the fact, indicated by all other available evidence, that the fall of the australite swarm was a comparatively recent occurrence.

Different tektite swarms are of different ages, but the australites appear to have been one of the last to occur.

Concerning the age of the australite fall, all the evidence is that this was a quite recent occurrence, though before the coming of the white men and probably also before the coming of the aborigines. Practically all forms are lying on the surface of the rocks, or if buried they are under blown sand or shallow recent alluvium. Early in 1949, Mounted-constable Homes, then stationed at Marree, picked up a "pickle-bottle full" of typical australites on the dry flat surface of eastern Lake Eyre. This area is a salt-pan or playa, covered by shallow water only at times of exceptional floods. Constable Homes's find thus provides additional evidence of the recent origin of the australite swarm.

In "Nature," 50, 1894, pp. 184 and 206, Dr. (later Sir) Edward Stirling described in detail the finding of skeletons of the giant extinct bird *Genyornis newtoni*, at Lake Callabonna, South Australia. Associated with the skeletons, which were practically on the surface of the "lake," were numerous "gizzard stones," totalling in weight 14 ounces. All these stones were of materials common to the desert plains of the interior; but, though carefully examined and recorded, include nothing resembling obsidian or australite material.

The area where *Genyornis* lived was well within the australite strewn-field, and living birds (emus, plain turkeys, etc.) are well known for their selection of australites as gizzard stones. *Genyornis* was of very late Pleistocene to Recent age, so that we have here another item of evidence suggesting that the fall of the australites was post-*Genyornis;* that is, as has been concluded from other available evidence, "geologically recent but historically remote."

FINAL CONSIDERATIONS

There is no need to include a bibliography, except where special reference has been made in this paper, as excellent lists have been included in the publications referred to, the best and latest being that of Virgil Barnes (1940) where he lists about 250 references. Through all this literature the "problem" remains, as it does in subsequent publications. The theories put forward may be classified as terrestrial volcanic, meteorite impact, lunar volcanic, electrical, and meteoritic.

The exponents of terrestrial origin have shown masterly ingenuity in their theories. Every conceivable possibility has been explored in the effort to avoid acceptance of a cosmic theory. But three facts might be noted in this matter:

(1) Robert Hooke (1665) quoted by Spencer (1937) discredited the fall of iron meteorites from the sky. Fourcroy (and Biot?) in 1803, quoted by Paneth (1940), found difficulty in persuading their French colleagues of the authenticity of stone meteorites.

(2) Most modern authorities who are familiar with the numbers and conditions of distribution of tektites (such as Lacroix, Suess, Michel, Paneth, Beyer, von Konigswald, as well as all Australian workers for the past 30 years) have accepted tektites as "glass meteorites." Virgil Barnes is apparently an exception.

(3) Lightning, meteoritic impact, and lunar theories (except that of H. H. Nininger) would not account for distribution. Lightning and dust storms occur all over the world, but tektites occur only in special areas and with definitely distinct form and distribution. Meteoritic impact is too weak an agent to have done the work, except for the few small impactites recorded from Wabar and Henbury.

Tektites, like meteorites, have not been found in ancient geological systems. Doubtless they fell, and possibly they have devitrified, just as the ancient iron-nickel and stony meteorites have less slowly rusted away.

The bibliography of tektites shows several interesting variations of the cosmic theory. A most interesting paper by Hardcastle (1926) should not be overlooked; his paper embodies his theory in its sub-title: "Plastic sweepings of a meteorite." Forty years or so ago most Australian workers thought of tektites as a swarm of glass blobs, part of the solar system, arriving upon the earth. Michel, Suess, Lacroix, and others brought in the idea of a light-metal meteorite, shedding its silica content as it blazed across the sky: this is a modification of Hardcastle's theory, who thought only of stony meteorites, all of which have siliceous "skins," and some of which may have shed siliceous blobs.

Now, H. H. Nininger, in a booklet entitled "Chips from the Moon," (1940) puts forward the idea that the tektite swarms were formed by the impact of huge meteorites on the loose "lunite" chips of the moon, sending off showers, some of which reached the earth. Dr. Nininger does the writer the honour of saying that the cosmic theory advocated by this author would, if true, explain the presence of the australites, with similar occurrences explaining the presence of tektites in other parts of the world. The writer can do no less than admit that Dr Nininger's complicated and ingenious theory would, if true, also explain the same puzzling facts.

But Lincoln La Paz writes of the "Chips from the Moon" theory (Popular Astronomy, No. 5, May, 1941, p. 267), as follows: "*If* the lunar craters were known to be due to the impact of meteorites, and *if* such impacts on the surface of our satellite were known to produce molten masses, from which bodies with the chemical composition of the tektites could be derived, and to impart to these masses velocities sufficient to enable them to escape from the attraction of the Moon, and *if* certain other essential conditions were known to be fulfilled, then Nininger's conjecture, in his own words, "might indeed afford a very handy solution to many baffling problems."

On the other hand, La Paz himself (Abstracts Geological Society of America, 1940, p. 1919) leans definitely to the lightning hypothesis. To the writer, who has written on lightning-fused rocks and sands as well as on tektites, this appears as a theory which is not only unsupported by evidence, but is quite beyond belief. Consider the australites alone, which occur almost everywhere over 2,000,000 square miles of southern Australia, south of a line going from S.E. to N.W., in a land where heavy duststorms and electrical storms occur with at least equal frequency over the northern areas. Why should such storms always form one kind of object, in form and composition in the south, and never produce any such forms in the north?

The writer falls back on Paneth's comprehensive paper on "The Origin of Meteorites" and retains the theory of the Cosmic Origin of Tektites, recalling the sapient words of de Fourcroy (1940, p. 6): "By eliminating the absurd or impossible, one finds oneself compelled to adopt what would previously have appeared to be almost incredible." Paneth's authoritative paper is especially recommended to sceptics of the cosmic theory.

One may be pardoned, perhaps, for quoting oneself (C.F. 1940, p. 324). "The present job before students (of tektites), it seems to me, is tentatively to accept tektites on the (well-known and accepted) evidence of distribution, form, composition, etc., as being glass meteorites, and to devote attention to a study of the details of their possible derivation (within the solar system), so far as this may be revealed by physical examination and facts of distribution." In this way may be added something to "the complete story of the origin of meteorites," and to a wider knowledge of the solar system itself.

Harrison Brown (1948) suggests that "in meteorites scientists possess a Rosetta stone that may well prove to be a major key in answering" some of the problems of the solar system, and perhaps of the Universe itself. Brown makes no mention of tektites, but indicates that the earth's composition is probably equivalent to the mean composition of meteoritic or planetary matter. In this, the highly siliceous tektite swarms may well find their place.

Careful consideration of the South Australian Museum collection of tektites has strengthened the cosmic theory of the origin of tektites. All the available evidence tends to confirm the opinion that tektites are of extra-terrestrial origin.

ACKNOWLEDGMENTS

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1 Walcott, R. H. 1898 "The occurrence of so-called Obsidian Bombs in Australia." Proc. Roy. Soc. Vict., 11 (n.s.), (1), 25-53, with plates and analyses.

2 Barnes, Virgil E. 1940 "North American Tektites." Univ. of Texas Publication 3945, 477-583, with plates and analyses.

3 DARWIN, CHARLES 1844 "Geological Observation on Volcanic Islands." London, **44**, (p. 38, 2nd ed., 1876), with figure.

4 FENNER, C. 1934 "Australites, Part I. Classification of the W. H. C. Shaw Collection." Trans. Roy. Soc. S. Aust., **52**, 62-79, with plates and figs.

5 FENNER, C. 1935 "Australites, Part II. Numbers, forms, distribution and origin." Trans. Roy. Soc. S. Aust., **59**, 125-140, with maps and figs.

6 FENNER, C. 1940 "Australites, Part IV. The John Kennett Collection, with notes on Darwin Glass, Bediasites, etc." Trans. Roy. Soc. S. Aust., **64**, (2), 305-324, with plate and figure.

7 FENNER, C. 1949 "Sandtube Fulgurites, and their bearing on the Tektite problem." Records Sth. Aust. Mus., with plates and figure, **9**, No. 2.

8 FENNER, C. 1938 "Australites, Part III. A contribution to the problem of the origin of Tektites." Trans. Roy. Soc. S. Aust., **62**, (2), 192-216, with plates and figures.

9 SUMMERS, H. S. 1908. "Obsidianites, their origin from the Chemical Standpoint." Proc. Roy. Soc. Vict., **21** (n.s.), (11), 423-443, with analyses.

10 BAKER GEORGE, 1946 "Some unusual shapes and features of Australites (Tektites)". Mem. Nat. Mus., Melb., **14**, (2), with plates.

11. BAKER, GEORGE 1944 "Flanges of Australites." Mem. Nat. Mus., Melb., **14**, (1), with plates and figures.

12 LACROIX, ALBERT 1935 "Les Tektites de l' Indo-chine et de ses abords et celles de la Cote d'Ivoire." Archives du museum d'histoire naturelle, Paris, vol. du Tricenteniare, Tom XII, 151-170, with plates.

13 SPENCER, L. J. 1937 "Meteorites and the Craters on the Moon." Nature, **139**, 655, 17 April 1937.

14 PANETH, F. A. 1940 "The Origin of Meteorites." Halley Lecture, 16 May 1940. Clarendon Press, Oxford, with plate.

15. HARDCASTLE, H. 1926 "The Origin of Australites: Plastic Sweepings of a Meteorite." N.Z. Journ. of Sci. and Tech., **8**, No. 2, 62-75.

16 NININGER, H. H. 1940 "Moon as a Source of Tektites." Geol. Soc. of Am. Bull., **51**, Abstracts, p. 1936; also booklet, "Chips from the Moon."

17 SUESS, FRANZ ED. 1932 "Zur Beleuchtung des Meteoritenproblems." Mitteil. der Geol. Gesellsch. in Wien," Band XXV, 115-143, with figure and analyses.

18 BROWN, HARRISON 1948 "Meteorites, relative Abundances, and Planet Structures." Scientific Monthly, U.S.A., **67**, No. 6, Dec. 1948.

19 PREUSS, EKKEHARD 1935 "Spektralanalytische Untersuchung der Tektite." Published at Jena, Mineralogical Institute, with Plates.

LARVAL TREMATODES FROM AUSTRALIAN FRESHWATER MOLLUSCS PART III

BY T. HARVEY JOHNSTON AND L. MADELINE ANGEL

Summary

Cercaria beckwithae n. sp. On 27 October 1948, 6 of 49 Planorbis isingis collected from a small artificial rock pool in the garden of Mr. G. Jaensch, Tailem Bend, were found to be giving off stylet cercariae of a type of not previously encountered by us. This pool is fed with water pumped from the neighbouring swamps, being filled up approximately once per fortnight during the summer months. It is several years since snails were introduced into the pool by Mr. Jaensch, and as the life span of Panorbis isingi appears to be under two years, it follows that infection of the snails must have occurred in the pond itself.

LARVAL TREMATODES FROM AUSTRALIAN FRESHWATER MOLLUSCS PART XIII

By T. Harvey Johnston and L. Madeline Angel*

[Read 12 May 1949]

Cercaria beckwithae n. sp.

On 27 October 1948, 6 of 49 *Planorbis isingi* collected from a small artificial rock pool in the garden of Mr. G. Jaensch, Tailem Bend, were found to be giving off stylet cercariae of a type not previously encountered by us. This pool is fed with water pumped from the neighbouring swamps, being filled up approximately once per fortnight during the summer months. It is several years since snails were introduced into the pool by Mr. Jaensch, and as the life span of *Panorbis isingi* appears to be under two years, it follows that infection of the snails must have occurred in the pond itself.

From 27 October 1948 to 24 January 1949 *C. beckwithae* has been identified from 16 of 403 snails—approximately a 4% infection. It was not present in any of 431 *Planorbis* collected from the same pond at the end of February 1949. It is of interest that the only other kind of gastropod present in the pond, *Ameriauna* sp., is evidently not a suitable host for this cercaria since none of these snails was found infected with it. This cercaria has not been found in *Planorbis* collected from the swamps along the lower River Murray. As will be discussed later, we expect to find that the adult is a frog lung fluke and experiments to ascertain the life history will be continued. That the infection was not an isolated case is indicated by the following facts:—(1) that of 69 *Planorbis* collected on 30 November 1948 and apparently negative when tested then, and again a week later, one was found to be giving *C. beckwithae* when next tested on 23 December; (2) that the one *Planorbis* which was positive from among 180 collected on 24 January 1949, was not quite half-grown. This latter must certainly have been extremely small when the original infection found by us had taken place, and would have been unlikely to survive an infection at that stage.

The Cercaria

The cercaria is small, an average of 20 specimens fixed in boiling 10% formalin in the standard manner being 165μ by 100μ wide. The range (105μ by 105μ to 240μ by 86μ) is considerable, because some cercariae are fixed in greatly extended position, while others are completely contracted. The tail averaged 162μ by 32μ; range 112μ by 30μ to 202μ by 37μ. The oral sucker averaged 47μ long by 49μ wide, while the acetabulum was 29μ by 32μ, giving an approximate sucker ratio of 5 : 3. The acetabulum lies in the posterior half of the body. The stylet is rather delicate in appearance; length 32μ; width at base $5{\cdot}3\mu$; width at rim, formed approximately at the end of the anterior third, $4{\cdot}9\mu$.(1) The tail is inserted on the ventral surface of the body and is provided with a transparent finfold dorso-ventrally placed and extending a very little distance around the tip on the dorsal side, but for about a third of the length of the tail on the ventral

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(1) In this regard we may state that observations on xiphidiocercariae examined in this department corroborate the observation of Brooks (1943) that he has been "impressed with the uniformity of the dimensions of the stylets of various species" and believes that "greater use can be made both of the shape and length of the stylet in describing and identifying cercariae of this group." Further, the size of the stylet is not altered by prolonged immersion in formalin, as we have verified with at least two kinds of xiphidiocercariae.

(fig. 5). When the tail is at rest, the flange is fluted. Under coverslip pressure, the tail tends to keel over to give the appearance of a laterally placed flange. The tail stains blue with nile blue sulphate but is uncoloured with neutral red.

The body is fairly clear; there are no coloured refractile granules as are seen in many xiphidiocercariae. The surface is beset with minute spines, though these are so small as to be indicated only under oil immersion magnification and under favourable conditions of intra-vitam staining. Ordinary methods recommended to show spines, *e.g.*, the use of picric acid and menthol, were ineffective. There was no indication of the fine protoplasmic hairs described by some writers for related cercariae. Caudal pockets are not present.

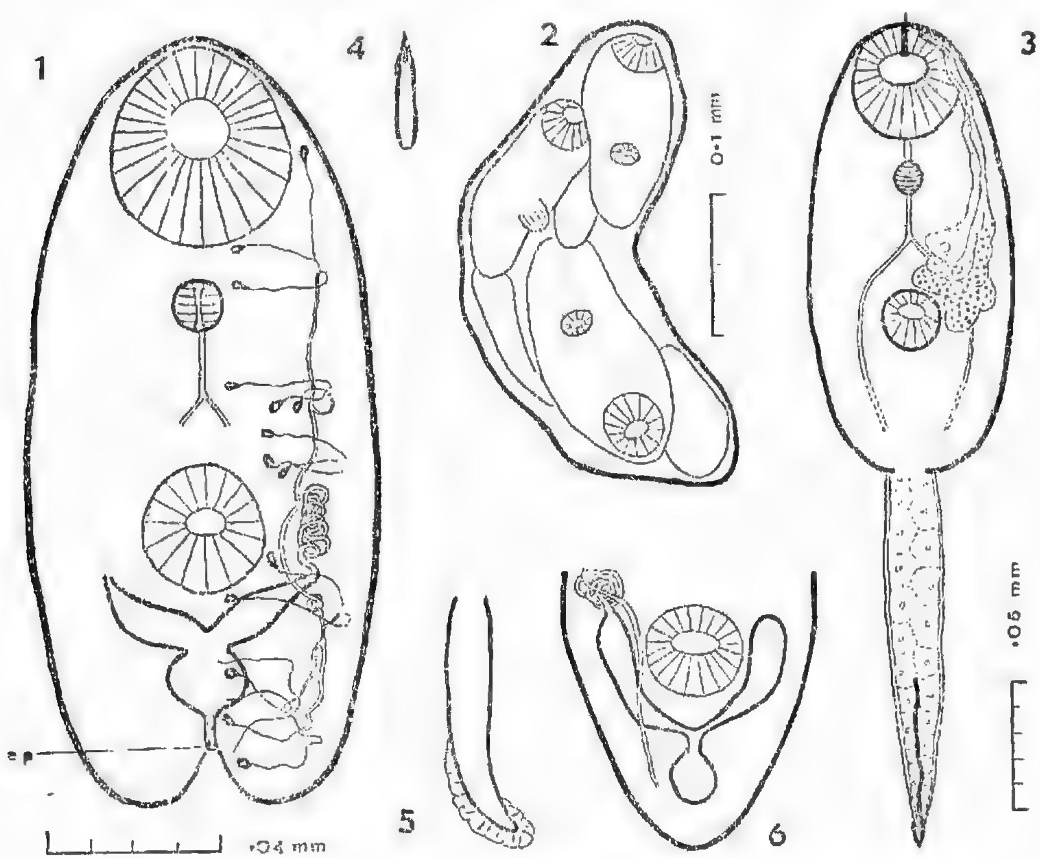

Fig. 1: body of cercaria, outlines from camera lucida drawing—details of excretory system from living specimens. Fig. 2: sporocyst. Fig. 3: cercaria, gland cells and alimentary system. Figs. 4, 5, 6: sketches. 4, stylet, 5, tail in dorso-ventral view. 6, excretory cornua in more extended position.

Reference to lettering: ep = excretory pore.

On either side of the body there is a group of gland cells extending from the bifurcation of the oesophagus almost to the level of the posterior border of the acetabulum. It is impossible to determine the number accurately, but there are from 3 to 5 (perhaps more) pairs. Specimens stained with nile blue sulphate following neutral red show two pairs anteriorly and medially which are finely granular but uncoloured, while the remaining gland cells take on a dirty purple colour; these and their ducts, however, tend to contract into an indeterminate mass. In unstained specimens the nuclei of the glands appear clear and are slightly tinged with pink. Throughout the body there are a number of other cells, which are presumably cystogenous, and under extreme coverslip pressure when the nuclei become evident it is not possible to distinguish such nuclei from those of the gland cells in the same region.

There is a short pre-pharynx, a quite circular pharynx and a very narrow oesophagus which bifurcates some distance anteriorly to the acetabulum. The angle of bifurcation is characteristically acute (figs. 1, 3); the crura are very narrow, and in living specimens are not seen beyond the level of the posterior border of the acetabulum, and rarely as far as its anterior border. Staining rendered them slightly more obvious, and in a few of the best preparations they could be seen to extend almost to the end of the body, ending level with the insertion of the tail. Krull (1933) when describing the cercaria of *Haematoloechus complexus*, indicated very narrow intestinal crura and noted that they were very difficult to see, even in the most favourable specimens.

The excretory bladder is Y-shaped; the arms of the Y terminating normally below the level of the anterior border of the acetabulum, but in some specimens (notably in those which had been swimming in a solution of basic fuchsin in normal saline) the arms were well above this region. There is, of course, a considerable margin of difference between the levels reached in the expanded and contracted positions of the bladder. The main excretory tubes are attached at the anterior tips of the arms. The flame cell formula is apparently $2[(3+3+3)+(3+3+3)]$. This is extremely difficult to determine, and for a long time we thought that there were only two groups each of three flame cells, attached to the anterior collecting tubule. When the third group from the anterior end was seen its point of origin from the collecting tubules could not be determined, and we are assuming that it is attached to the anterior tubule, as seems most likely. Again, the point of bifurcation of the anterior and posterior collecting tubules has not been seen definitely, though we feel satisfied that it is on a level just behind the anterior border of the acetabulum in a position where the convolutions of the main excretory tubule rendered any closer elucidation impossible. In the posterior groups not all the flame cells have been seen; the last two groups however are clearly indicated by the capillaries. In the first of the posterior groups only two of the elements have been seen, but we have no doubt that a third is present. The excretory pore opens at the base of the tail by a crescentic slit on the ventral surface. There is no caudal excretory tube as shown by Sewell for several xiphidiocercariae. In stained, fixed specimens the genital rudiment shows as an irregular undifferentiated mass dorsal to the acetabulum, and of about the same size.

Experimental Infections

We have not been able to obtain the cyst stage, though a number of different animals have been used for experimental infections. Negative results were obtained with *Daphnia* sp.; Dytiscid beetle larvae; dragon-fly larvae, *Aeschna brevistyla* and *Austrolestes analis;* the yabbie, *Cherax destructor;* mosquito larvae; leeches (*Glossiphonia* spp.); the molluscs, *Amerianna* spp. and the host species, *Planorbis isingi;* as well as with tadpoles and the fish, *Gambusia affinis*.

Cercaria of all frog lung flukes of which the life-history is known encyst in larval insects, the majority in dragon-fly larvae. In some species there is a considerable degree of specificity for the second intermediate host. Krull (1931) found that cercariae of *Haematoloechus medioplexus* and *H. parviplexus* encysted in two species of *Sympetrum* but did not infect closely related dragon-flies. On the other hand, he (1933) thought it probable that many species of dragon-flies could serve as hosts for *H. complexus*. Ingles (1933) suggested that the presence of the infection of *Ostiolum oxyorchis* in frogs collected from ponds and its absence from frogs of the same species collected from small streams was due to the habits of the intermediate host since most of the natural infections of *O. oxyorchis* occurred in the pond-inhabiting dragon-fly, *Sympetrum illotum*. Such a specificity may well explain the fact that *C. beckwithae* has been found only in a pond and not in the swamps, and also our failure to obtain its metacercaria in the only two species of dragon-fly larvae which were available to us for experiment, and which had been obtained from the swamps. Krull (1932) reported that the metacercaria of *Pneumobites longiplexus* whose adult stage occurs in *Rana* sp., was found in cysts or free in the body cavity of damsel flies, *Lestes* sp. We have not found metacercariae in numerous dragon-fly larvae (*Aeschna brevistyla*) collected from swamps along the Lower Murray.

The Sporocyst

The sporocysts are inconspicuous, and cannot be discerned as finite bodies when the snail is dissected after death. Numbers of cercariae are found in the liver; these apparently migrate from the sporocyst soon after the death of the host, leaving the sporocyst as an empty sac. Staining of some of the dissected liver material gave one good preparation of a sporocyst, a small body containing (and more or less filled by) three or four cercariae (fig. 2). If we had had sufficient material to sacrifice a living snail, the sporocysts would probably have been more obvious.

Affinities

C. beckwithae belongs to the Cercariae Ornatae, a group defined by Lühe (1909) as "distome cercariae with a stylet, in which the slender tail is furnished with a fin fold." Since 1914, when Cort described *C. hemilophura* and included it provisionally in the "Ornatae," workers have stressed the fact that the group is probably an unnatural one.

Sewell (1922) created the "Prima" subgroup, and Faust (1924, table II) in his "synoptic flame-cell formulary for digenetic trematodes" placed *C. hemilophura* Cort 1914 and *C. trifurcata* together in the "Hemilophura group," as having a flame cell formula of $2[(3+3)+(3+3+3)]$. It may be noted that Faust (1924) included *Cercaria prima* with *C. indica LIII* Sewell in the "Daswan" group, and thus denied the importance of the fin fold in the classification of cercariae, since *C. indica LIII* has not this feature.

In 1929 McCoy, who did further work on the excretory system of *C. hemilophura* and ascertained the formula to be $2[(3+3+3)+(3+3+3)]$, found it necessary to remove this cercaria from the group, though he did not create one to contain it.

In 1936, E. L. Miller divided the Cercariae Ornatae into four subgroups, using the flame cell formula as the differentiating feature:—

I. Sewell's Prima group, with an excretory formula $2 \times 6 \times 1$ (*i.e.*, $2[(3)+(3)]$).

II. Hemilophura (sic) group, containing only *C. trifurcata* Faust 1919; formula $2[(3+3)+(3+3+3)]$.

III. A third subgroup (formula $2[(3+3+3)+(3+3+3)]$) containing *C. hemilophura* Cort 1914 and *C. mesotyphla* E. L. Miller 1935. To this can now be added *Cercaria merchanti* Rankin 1939 (the larva of *Haematoloechus* sp.), *C. herberi* McMullen 1938 (quoted in Zool. Rec. 1938 Vermes, p. 94, as *C. herberi*) and *C. beckwithae*.

IV. Subgroup four—*Cercaria racemosa* Faust 1917, the excretory formula of which was not worked out, but was "obviously quite different from other forms of this group" (Miller).

McCoy stated that "the exact location of the flame cells in *C. hemilophura* varied greatly in different individuals, probably depending upon the way in which the animal was compressed. The second flame cell group from the anterior end was the most difficult to locate, and without careful study of abundant material might be entirely overlooked." These remarks apply also to *C. beckwithae*, excepting that it was the third group from the anterior end which might have been overlooked. One wonders whether further study of *C. trifurcata* might not disclose another group of flame cells, and thus place the cercaria in Miller's subgroup III. McMullen in 1937 discussed the taxonomy of the family Plagiorchiidae Lühe and related trematodes, and used knowledge of the larval and developmental stages to supplement classification of the adults, stating that the exclusive use of adult characters for identification left much to be desired. On the other hand, classification of cercariae on their larval characters, without a knowledge of the life histories, could be only tentative. As to the importance of a fin fold on the tail, he cited the genera *Alloglossidium* and *Macroderoides* "which are evidently closely related," yet while the cercaria of *Macroderoides typicus* has a fin fold, that of *Alloglossidium corti* has none (the only two life histories which were known for these genera); again, all cercariae of frog lung flukes and related trematodes with the exception of that of *Haplometra cylindracea* have a fin fold on the tail. He concluded, therefore, that the possession of a fin fold on the tail (and other such larval modifications) were of little more than specific value in the Xiphidiocercariae. This confirmed the opinion held by most previous workers that the group Cercariae Ornatae was an unnatural one.

From the point of view of description of cercariae, however, the fin fold does provide a valuable means of separation from, or comparison with, previously described forms.

It is evident that *C. beckwithae* resembles most closely the cercariae of *Haematoloechus* spp., as indicated by McMullen (1937) in his composite diagram of *Haematoloechus* and *Ostiolum* species. (*Ostiolum* is now given by Dawes, 1946, as a synonym of *Haematoloechus*). Among the characteristics of these cercariae of the frog lung flukes McMullen cites "a large oral sucker, four pairs of stylet glands" (though in the figure five pairs are shown, and *C. herberi* which McMullen described in 1938, has six pairs), "and a Y-shaped excretory bladder which goes through extensive development in the maturation of the adult"; and (as mentioned previously) "all have a fin fold on the tail with the exception of *Haplometra cylindracea*." It would seem that to this description should be added "main excretory tubes attached to the tips of the arms of the bladder," though this feature has not been indicated clearly in all of the descriptions. For *C. herberi*, McMullen stated that the origin of the main collecting tubule did not agree with that given by Ingles (for *Ostiolum oxyorchis*), *i.e.*, lateral to the arms of the bladder, and that though it was possible that the tubules did arise laterally in *O. oxyorchis*, the same was at first believed to be true of *C. herberi*, because the loop of the main tubule crossed the arm of the bladder and the rest of the tubule was difficult to see. As is shown in our figure, this is also the condition in *C. beckwithae*. Ingles' figure of the excretory system in the metacercaria is somewhat unconvincing in that the anterior and posterior collecting tubules appear to arise independently from the arms of the bladder, and we suggest that the origin of the main tubules should be similar to that in *C. herberi* and our cercaria.

Although the life histories of several frog lung flukes have been described (Ingles, 1933; Krull, 1931, 1933), in none of these has the anatomy of the cercariae been dealt with in complete detail. So far as the descriptions go we can only say that none of them resembles *C. beckwithae* as closely as do *C. merchanti* and *C. herberi*. It is of interest that the sporocysts of our species appear to conform to the type found in *Haematoloechus* spp.—*i.e.*, they are small and contain few cercariae, whilst in *C. hemilophura* and *C. mesotyphla* the sporocysts are elongated.

Cercaria merchanti was shown by Rankin (1939) to be the larval stage of a species of *Haematoloechus*, but pending further study he deferred the specific description. The general appearance of the alimentary canal, excretory system, arrangement of gland cells, and fin fold of the tail in *C. merchanti* is similar to these structures in *C. beckwithae*, but the stylet of *C. merchanti* measures 40μ, the sucker ratio of the two forms is different, and *C. merchanti* has "fine protoplasmic hairs" on the body, a feature which is lacking in our cercaria. Comparison of *C. beckwithae* with *C. herberi* shows that the length of the stylets is the same, the general sizes of body and tail seem to be comparable (although one is diffident about placing too much stress on measurements of cercariae made by different workers and under different conditions) and the general appearance of the alimentary systems is similar. However, the two cercariae differ in the ratio of the suckers, probably in the extent of the fin fold of the tail (said to start at about the middle of the ventral surface for *C. herberi*, and at the distal third for *C. beckwithae*) and the cuticular spines of *C. herberi* are evidently more obvious.

McMullen stated that *C. herberi* was similar to cercariae of genera belonging to the Haplometridae McMullen 1937. This family included the Haplometrinae Pratt and the Prosthogoniminae Lühe, the genera of which, as far as known, were parasitic in the lungs of Amphibia and the reproductive tracts of birds respectively. Dawes, however, included the genus *Macrodera* (from lung sacs of snakes) in the Haplometrinae, and placed both subfamilies in the Plagiorchiidae. The only life history of a member of the Prosthogoniminae to which we have a reference is that of *Prosthogonimus macrorchis* Macy 1934. Macy did not describe the cercaria in detail, but stated that there was no fin fold on the tail and that the excretory formula of the metacercaria was $2[(2+2+2)+(2+2+2)]$. If this formula is correct, then it seems that the Prosthogoniminae can scarcely be included in the Plagiorchiidae.

We regard *Cercaria beckwithae* as the larval stage of *Haematoloechus*, a parasite of the lungs of frogs. Only one species, *H. australis* (S. J. Johnston 1912), described originally as *Pneumonoeces australis*, is known to occur in Australian frogs, *Hyla and Limnodynastes*, and has been identified by us in material belonging to these genera from New South Wales, Victoria and South Australia.

Cercaria tetradenoidea nom. nov.

In 1945 Johnston and Beckwith described a furcocercaria, *C. tetradena*. As the name had previously been given by Miller (1935, 252) for a member of the Cercariae Armatae group, we suggest the renaming of our cercaria as *C. tetradenoidea*.

Summary

1. A new xiphidiocercaria, *C. beckwithae*, with a fin fold on the tail is described from *Planorbis isingi*.
2. This was found at Tailem Bend, South Australia, in a rock pool in a private garden. Over a period of three months it was found in 16 of 403 snails, but has not been obtained from natural sites on the River Murray.
3. The cyst stage has not been found.

4. The cercaria is considered to be the larval form of a frog lung fluke, *Haematoloechus* (Plagiorchiidae, Haplometrinae).
5. A discussion is given of the classification of the group "Cercariae Ornatae" defined by Lühe, and later divided into sub-groups by several workers, the latest being Miller (1936).
6. Brooks' observation (1943) regarding the uniformity of dimensions of stylets of various species is supported. Such measurements are unaltered by formalin.
7. An addition to McMullen's list of characteristics of cercariae of frog lung flukes is suggested; namely, that the main excretory tubes enter the arms of the bladder at the tips.
8. *C. tetradenoidea* nom. nov. for *C. tetradena* Johnston and Beckwith 1945 nec Miller 1935.

We desire to acknowledge our indebtedness to Messrs. G. G., Fred, and Bryce Jaensch of Tailem Bend. The work was financed through the Commonwealth Research Grant to the University of Adelaide. The species is named for a former colleague in our work, Miss A. C. Beckwith, now Mrs. J. Hardy. Type material has been deposited in the South Australian Museum.

Literature

Brooks, F. G. 1943 Jour. Parasit., **29**, 330-339

Cort, W. W. 1914 Jour. Parasit., **1**, 65-84

Dawes, B. 1946 The Trematoda, 644 pp.

Faust, E. C. 1917 Jour. Parasit., **3**, 105-123

Faust, E. C. 1919 Biol. Bull., **36**, 322-339

Faust, E. C. 1924 Amer. Jour. Hyg., **4**, 241-300

Ingles, L. G. 1933 Univ. Calif. Publ. Zool., **39**, 135-162

Johnston, S. J. 1912 Proc. Linn. Soc., N.S.W., **37**, 285-362

Johnston, T. H., and Beckwith, A. C. 1945 Trans. Roy. Soc. S. Aust., **69**, 229-242

Krull, W. H. 1931 Trans. Amer. Micr. Soc., **50**, 215-277

Krull, W. H. 1932 Zool. Anz., **99**, 231-239

Krull, W. H. 1933 Zeit. f. Parasitenk., **6**, (2), 192-206

Leigh, W. H. 1937 Science, N. S., **86**, 423

McCoy, O. R. 1929 Jour. Parasit., **15**, 199-208

McMullen, D. B. 1937 Jour. Parasit., **23**, 244-258

McMullen, D. B. 1938 Livr. Jub. Prof. Lauro Travassos, 299-306

Macy, R. W. 1934 Univ. Minn. Agric. Exp. Sta. Tech. Bull., **98**, 7-71

Miller, E. L. 1935 Jour. Parasit., **21**, 244-254

Miller, E. L. 1936 Ill. Biol. Monogr., **14**, (2), 125 pp.

Rankin, J. S. 1939 Jour. Parasit., **25**, 309-328

Sewell, R. B. S. 1922 Ind. Jour. Med. Res., **10**, (Suppl. No.), 370 pp.

THE PETROLOGICAL NATURE OF SOME ROCKS FROM THE MANN, TOMPKINSON AND AYRES RANGES OF CENTRAL AUSTRALIA

BY E. G. ROBINSON

Summary

The rocks herein described were collected by Herbert Basedow, when a member of the Government Far North-West Prospecting Expedition of 1903. He first published an account of the geology of the country traversed (Basedow, 1905) and late (Basedow, 1915) the daily journal of the Expedition. In his geological report the rocks collected were dealt with on general lines only and many deserved fuller treatment.

THE PETROLOGICAL NATURE OF SOME ROCKS FROM THE MANN, TOMPKINSON AND AYRES RANGES OF CENTRAL AUSTRALIA

By E. G. Robinson *

[Read 21 July 1949]

The rocks herein described were collected by Herbert Basedow, when a member of the Government Far North-West Prospecting Expedition of 1903. He first published an account of the geology of the country traversed (Basedow, 1905) and later (Basedow, 1915) the daily journal of the Expedition. In his geological report the rocks collected were dealt with on general lines only and many deserved fuller treatment.

Basedow's specimens, what remained of them when he died, are now housed in the Geological Museum of the University of Adelaide, and because of the unusual nature of some of them. their further investigation by present-day petrological methods was suggested by Professor Mawson. Accordingly, the more significant of them, but not including any from the Musgrave and Everard Ranges, were selected and are dealt with herein. The omission of any examples from the Musgrave and Everard Ranges is consequent on Allan Wilson's (1947) recent detailed work in that area superseding earlier investigations.

ROCKS FROM THE TOMPKINSON RANGES

Referring to the Tompkinson Ranges, Basedow (1905, page 73) states—"Generally speaking, their dominant features are . . . . igneous intrusions within crystalline gneisses. In the case of the Tompkinson Ranges, the intrusive rock consists largely of gabbro, accompanied by diorite dykes. The Mount Davies chain includes, among others, a large intrusion of granular olivine-gabbro, varying in colour from dirty green, through shades of green

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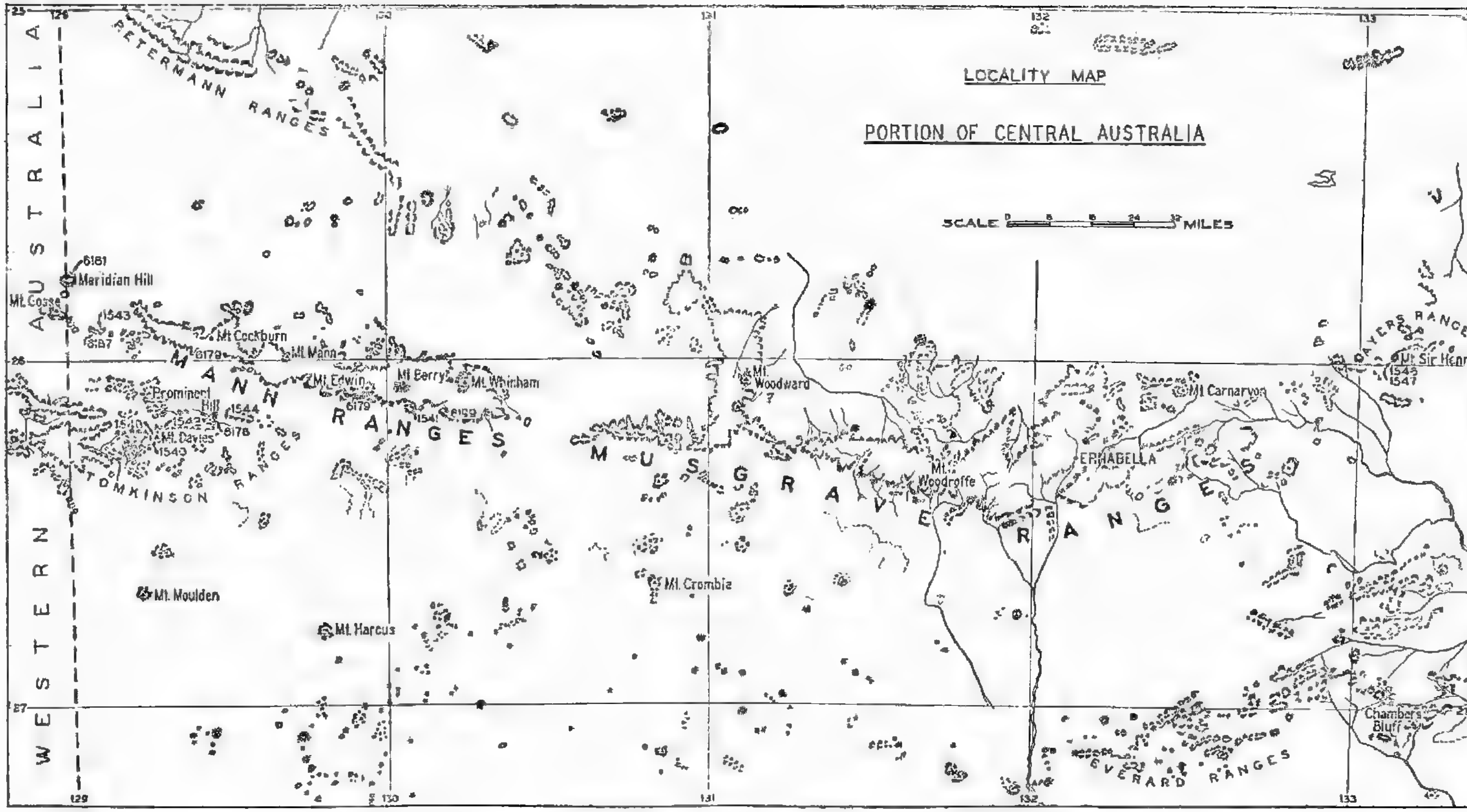

Locality Map with Rock Locations indicated by Catalogue Numbers.

to faint blue. In the last case the predominance of plagioclase feldspar, and the presence of only a small amount of olivine have produced the bluish tint. The intrusion trends east and west as a massive, rugged chain, flanked by less conspicuous diorite dykes. The latter, though individually smaller, are very numerous."

"North of Mount Davies, outcrops of hypersthene-bearing granulite which trend slightly east of north, present splendid examples of spherulitic weathering. The rock is compact and granular, with little or no evidence of foliation on freshly fractured surface, though it is apparent on weathered faces. The rock has a peculiar olive-green, waxy appearance."

Red garnet (almandine) schists are a feature of the north-eastern area about Gosse's Pile and Prominent Hill.

Skirting the foot of Mt. Davies on the north side is a mineralised outcrop striking W. 20°S. and extending westerly for some miles. This ferruginous and gossaneous outcrop includes chalcedonic and semi-opaline varieties of quartz, some of which are bright green due to chromium staining.

OLIVINE AUGITE-BYTOWNITE-GABBRO (1540). Collected from Mount Davies adjacent to Camp 28, Tomkinson Range.

In the hand specimen this rock is dark grey and of an even-grained, saccharoidal texture. It consists of highly weathered olivine, grey-green pyroxene and light grey feldspar, the latter being the most plentiful.

Microscopically examined it exhibits a holocrystalline, allotriomorphic, granular texture. The average size of the grains in section is of the order of 1·25 mm. to 1·5 mm.

Bytownite is by far the most abundant mineral present, comprising about two-thirds of the rock. It is clear and usually cracked. The grains exhibit albite, Carlsbad and pericline twinning. It is biaxial negative, with 2V about 83°, extinction angle in the symmetrical zone is 52°. These properties confirm the mineral as bytownite with about 80% of the anorthite molecule.

Augite is the next in order of abundance. It is light grey-brown, only faintly pleochroic and occurs as anhedral grains averaging about 1 mm. in length. It has the following optical characters: biaxial positive, $2V = 46°$, $Z \wedge c = 34°$. R.I. in sodium light is $\gamma = 1{\cdot}702$. These characters indicate an approximate composition of Wo35 En55 Fe15 corresponding to a typical augite. To a very limited extent the diallagic 100 cleavage is shown. Many of these monoclinic pyroxene individuals have a selvage of hypersthene, which is generally of darker colour than the augite.

Next to augite in abundance is *olivine*, which occurs as greatly cracked, very pale pink individuals. Alteration especially along the cracks has developed iron staining and some tiny grains of iron oxide. In many instances marginal alteration has given rise to antigorite. It is biaxial-positive with $2V = 89°$, corresponding to a magnesium-rich chrysolite. In some cases the olivine has borders of hypersthene.

Hypersthene occurs to a limited degree as separate individuals but more so associated, as already mentioned, with the augite and to a lesser degree with the olivine. It is faintly pleochroic: $X =$ pale grey, $Y = Z =$ pale grey-brown; biaxial negative, 2V is 88° and $c = Z$. These properties suggest an enstatite-rich hypersthene with about 20% of the ferrosilite molecule.

Accessory minerals are rare, consisting of a few grains of magnetite and some apatite.

HYPERSTHENITE (1548): from the west side of Mount Davies, Tompkinson Range.

This is a dark grey-brown, holocrystalline, even, granular rock.

In microscope slide the texture is observed to be holocrystalline, allotriomorphic granular with a grain-size ranging from 2 to 5 mm. It consists entirely of hypersthene except for a few small grains of magnetite.

The *hypersthene* occurs as pale greyish-brown cracked, anhedral grains. It is weakly pleochroic: X = faint pink, Y = pale greyish-brown, Z = pale greenish-brown. Other optical properties may be summarized as follows: $2V = 88^\circ$, R.I. (sodium light) $\alpha = 1{\cdot}673$, $\gamma = 1{\cdot}682$. According to Larsen and Berman these optical characters correspond to a hypersthene which has an Mg: Fe ratio of approximately 6: 1.

The two prismatic cleavages are well developed. The orientation is length slow. While generally straight, strain has in some cases developed an undulose extinction. In some areas the larger hypersthene individuals are roughly rounded and set in fine granular interstitial hypersthene, apparently the result of crushing.

Black iron-ore in tiny grains is distributed mainly around the borders of the hypersthene: some, translucent in brown colours, are evidently *chromite*. Others appear to be *magnetite*. Analysis of this rock was made with the result as stated on page —.

CHEMICAL ANALYSES

Rock Number	1548	6199
SiO_2	54·35	47·77
TiO_2	0·22	0·12
Al_2O_3	3·85	4·87
Fe_2O_3	1·85	1·42
FeO	7·08	3·21
MnO	0·22	0·66
MgO	28·23	23·27
CaO	2·48	16·50
Na_2O	0·73	0·37
K_2O	0·14	0·02
H_2O+	0·32	0·58
H_2O-	0·15	0·21
P_2O_5	—	0·01
Cr_2O_3	0·68	0·79
Total	100·30	99·80

NORMS

Rock Number	1548	6199
Orthoclase	0·556	nil
Albite	6·288	1·31
Anorthite	6·950	11·68
Nepheline	—	0·99
Diopside	4·168	55·16
Hypersthene	73·468	—
Olivine	4·252	26·46
Magnetite	2·784	2·09
Ilmenite	0·456	0·30
Chromite	0·896	1·12
Water +	0·320	0·58
Water —	0·150	0·21
Total	100·298	99·80

CRUSHED CHARNOCKITE (1542) from north of the Mount Davies Camp (31), which was located 3 miles north of Mount Davies, Tompkinson Ranges.

An even, fine-grained, dark brownish-grey rock which in the field is reported to exhibit splendid spheroidal weathering. Feldspar and quartz are the more obvious minerals.

It is holocrystalline, allotriomorphic granular, with slightly uneven grainsize. In the microslide can be observed larger grains of microperthite and quartz which average about 1·6 mm. in diameter with a maximum of about 3·5 mm., are distributed through an even-grained granular association of feldspar, quartz and hypersthene with an average grainsize of about 0·5 mm.

Microcline microperthite is by far the most abundant mineral, constituting approximately two-thirds of the rock. It occurs as both large and small individuals. The microcline base and the exsolution albite, which is developed on a fairly coarse scale, are usually clear and unaltered but exhibit undulose extinction.

Oligoclase is present in very small amount in the form of small clear grains most of which exhibit albite twinning.

Quartz is much less abundant than feldspar. It occurs as anhedral individuals often cracked and exhibiting undulose extinction, sometimes to a marked degree.

Hypersthene is nearly as abundant as the quartz. It occurs as very irregular grains which tend to form aggregations, frequently associated with magnetite and apatite. The colour is pale brown. Pleochroism noticeable with X = pinkish-brown, Y = yellow-brown, Z = green. Biaxial negative with a fairly high 2V. A very small amount of non-pleochroic, pale green *diopside* is present.

Magnetite is plentiful, generally associated with the hypersthene.

Apatite is very common, both associated with the magnetite and hypersthene as well as in the form of anhedral and subhedral grains dispersed throughout the rock. A few grains of zircon appear in the slide.

GARNET-MAGNETITE-OMPHACITE-GRANULITE (6178). Collected on 20 May 1903 near camp 30, adjacent to Prominent Hill, North Tompkinson Ranges.

A heavy, dark rock of an even, granular texture. The obvious constituents are a dark ferro-magnesian mineral, red-brown garnet, magnetite and a little greyish white feldspar. The light-coloured streaks of granular feldspar traversing the dark body of the rock appear to have developed under directed stress.

In thin section it is observed to be granoblastic and noticeably even-grained for a rock of this type.

The predominant mineral is a *diallagic pyroxene* which occurs in granoblastic individuals with an average grain size of 1·3 mm., and a maximum ranging to 3·5 mm.; Schiller structure is strikingly developed. Colour, very pale green, weakly pleochroic from a faint flesh colour to faint green. A few basal sections show cleavages at 90°, also an additional rough parting parallel to the 100. Its optical character is negative, with a moderate to high 2V. A few individuals exhibit faint polysynthetic twinning. These characters suggest a diallagic pyroxene close to omphacite.

Granular pink garnet is the next most abundant mineral, occuring as individuals similar in size to those of the pyroxene.

Magnetite is abundant and plays an important role in the make up of this rock. *Hercynite,* a green spinel, occurs to a notable degree included in some of the larger magnetites. Some of these spinels measure up to 0·4 mm. in length; they are a bright clear green. Another noticeable feature associated with the magnetite is the presence of clear yellow pleochroic *anthophyllite* which occurs only as a peripheral band on some of the grains of magnetite. *Apatite,* usually in association with magnetite is present as an accessory mineral.

Feldspar, which plays a minor role, exhibits undulose extinction indicating the effects of stress. Optical measurements determine it to be andesine of composition about $Ab_{64}An_{36}$.

Porphyroblastic Hornblende - Garnet - Mica - Oligoclase - Quartz - Schist. (1544). Collected near Prominent Hill, Camp 30, North-Eastern Tompkinson Ranges.

In the hand-specimen this rock is a dark grey-brown schist, for the most part finely granular but with larger porphyritic crystals of hornblende and red-brown garnet. The hornblende porphyroblasts reach 10 mm. in length and the garnet to 8 mm. diameter. Banding and schistosity are notable features.

In thin-section the rock is seen to be schistose, with large porphyroblasts of green *hornblende*, pink *garnet* and *zircon* set in a fine even-grained base with average grain-size 0·1 mm., composed mainly of quartz and oligoclase.

Orientated flakes of *biotite*, pleochroic yellow to green are distributed through a granular base of clear *quartz* and *oligoclase* (An_{29}). Yellowish-green *hornblende* and pink *garnet* are well represented both as porphyroblasts and fine flakes through the quartzo-feldspathic base.

Faintly pleochroic *sphene* is in notable quantity both in fine grains and as larger individuals. Other minor accessories are *apatite*, *zircon* and tiny *magnetite* and a yellow mineral conforming to *allanite*, faintly pleochroic in pale yellow to pale brown.

ROCKS FROM THE MANN RANGES

Basedow (1905, p. 65) states, these Ranges "extend as a more or less compact chain in a westerly direction . . . . a distance of some eighty miles . . . . The western portion of the Mann Ranges, of no great width at this end, consists almost wholly of igneous rock exposures. In the centre, the core of the igneous intrusion is flanked on either side, namely the northern and southern boundaries, by complexes of green schist and gneissic quartzite; whereas on the eastern limits of the Ranges, by far the widest portion, the main intrusion lies hidden beneath the metamorphic series, into which it was injected, to appear once more at the surface to the eastward in the Musgrave Ranges"

Of igneous rocks "An intrusion of granite has been by far the greatest, it continuing uninterruptedly as a backbone of the whole Range, to disappear under superincumbent gneisses on the east, and occurring as isolated outliers for a considerable distance to the west. The character of the rock varies, from a true granite (in portion porphyritic) to various metapyrigen gneisses."

At the western extremity of the Range, where there is a salt pan depression in the surface of the gneisses, erosion has developed yardangs on a notable scale along the outcrop.

Crushed Leuco-Granite (6181). Collected 4 June 1903 from the main intrusion at Meridian Hill, Western Mann Range.

This rock is holocrystalline inequigranular. The larger individuals are grey feldspars usually seen to be embedded in finer material consisting essentially of granular feldspar and quartz.

Microperthite is the most abundant mineral, occurring as large individuals. The orthoclase host is generally clear but cracked, displaying undulose extinction. Apart from normal exsolution spindles which characterise the perthite, inclusions of oligoclase are numerous.

Oligoclase (25% An) occurs usually as aggregations of small grains but larger individuals are not uncommon.

Quartz is plentiful usually in granular aggregates, apparently the crushed remains of former large individuals.

Garnet as tiny rounded grains, usually in aggregations, occur sparingly in the crush mosaics. In such locations also, hornblende in very small quantity and occasional flakes of *biotite* are met with. *Magnetite*, though small in quantity but in comparatively large grains, at times with encrusting *sphene*, is a feature of this rock. Small grains of *zircon* are to be noted.

In thin section it exhibits many similarities in both texture and mineral composition to specimen (1543), and so may be assumed to be a leucocratic phase of it. However, the effects of stress are more marked in this rock, while the quantity of ferromagnesian minerals present is appreciably less.

Sheared Hornblendic Garnetiferous Gneissic Granite (6187). Collected 6 June 1903, just north-east of Camp 41; about 10 miles south-east by north of Mount Gosse, Mann Ranges.

This is a coarse holocrystalline rock with a mottled appearance, due to the ramifications of finer grained, darker aggregates ramifying through it. The most obvious constituent is greyish-white feldspar in large individuals up to 3 cms. in diameter.

Microscopically examined the rock is observed to be holocrystalline and dominantly constituted of closely packed large feldspars embedded in tracts of fine, granular aggregates of feldspar, quartz and ferromagnesians.

Orthoclase forms large phenocrysts and perthitic intergrowths are common. It is also present as a constituent with quartz and plagioclase of the fine granular aggregates surrounding the larger feldspars. The large feldspars are bent and otherwise distorted by stress.

Basic Oligoclase (about An_{30}) is present both as large individuals somewhat less in size than the orthoclase and as constituents of finer-grained (0·1 mm.) granoblastic aggregates.

One of the most interesting features of this rock is the presence of aggregations of garnet, hornblende, magnetite, sphene, apatite and biotite, in association with greater or less quantities of granular quartz and plagioclase. These aggregates result from granulation and recrystallization under stress.

The garnets are small rounded light pink grains, present as tightly packed aggregations or strung out like tiny beads. Associated therewith is green *hornblende* and some *clino-pyroxene*.

Brown biotite occurs in very small amount. *Zircon, sphene, magnetite* and *apatite* are also present as accessories.

Stressed and Crushed Granite (1543). From the Mann Ranges at about 2 miles east of Camp 41 and 11 miles south-east by north from Mount Gosse. Collected 6 June 1903.

A coarse textured, somewhat crushed and recrystallised granitoid rock, composed mainly of large grey feldspars up to 2 cms. in length and smaller quartz grains.

In micro-slide the large feldspars are seen to be greatly cracked and slightly cloudy with marked undulose extinction. They are *microcline* as they give an off-centred obtuse bisectric figure on sections parallel to the 010 face; contained in them are perthitic intergrowths of acid plagioclase. Irregular borders with embayment are very prevalent, with fillings of crushed and recrystallized quartz and feldspar.

Of the smaller dimensioned constituents, *quartz* showing marked strain effects is dominant. A small amount of basic *oligoclase* can be recognised. Still less abundant is *hornblende* pleochroic in green and yellow. Occasional granular aggregates of garnet usually strung out in linear arrangement is a feature of special note. Finally, there are present occasional flakes of *biotite* and grains of *apatite* and *zircon*.

MYLONIZED GRANITIC GNEISS (6182). Described by Basedow as a compact, gneissic band in granite about 2 miles west of Hector's Pass, Mann Ranges.

A very fine, and even grained, compact, light-coloured rock with sheer lamellations clearly marked.

In thin section the rock is seen to be an excellent example of mylonization, crushing having been very regular and complete, resulting in granular lamellae, ranging from 0·1 to 1·0 mm. thick. Lamellae, constituted essentially of quartz grains, alternate fairly regularly with others dominantly of feldspar.

The feldspathic bands, which on the average exceed the quartz bands in thickness, are chiefly *orthoclase* but are usually so fine-grained and show the effects of crushing to such a high degree that their exact composition is in doubt. Clouding of the orthoclase appears to be due to the development of sericite. Larger augen with associated mortar structure occur in the feldspathic bands. These are usually perthitic. In these cracked and highly strained lenticles there is present, in addition to orthoclase, some *oligoclase* (26% An), showing albite and pericline twinning.

The bands constituted of *quartz* grains are readily distinguished, for the granules, though strained, are always quite clear.

The lamellar structure of the rock is further emphasised by strings of tiny *garnets* and some grains of *magnetite* and *sphene,* also grains and elongated crystals of *zircon;* these are usually associated with the feldspathic bands and lenticles. A little *biotite* as very tiny flakes is met with in certain of the garnetiferous strings. The average size of the grains of garnet is about 0·03 mm.

This rock has evidently resulted from the mylonization and apparently represents a sheer zone in the granite.

DIOPSIDE PERIDOTITE (6199). Collected near Camp 27, about 6 miles south of Mount Whinham, Mann Ranges. A holocrystalline, granular rock of fairly coarse grain; the latter about 4 mm. diameter.

In microscope slide it is seen to be holocrystalline, allotriomorphic granular, and is composed essentially of two minerals. The more prevalent of these is *diopside* which occurs as anhedral, clear to pale grey-brown individuals showing cleavages (86°) and cracking to a marked degree. Some sections are so oriented as to show a faint pleochroism from a faint flesh colour to very light green. Both normal and polysynthetic twinning are exhibited. Some of its optical properties are: D.R. fairly high, biaxial positive, $2V = 58°$(R.I. in sodium light is $\alpha = 1{\cdot}676$ and $\gamma = 1{\cdot}702$. These characters indicate a diopside with about 10% of the hedenbergite molecule.

The other abundant mineral, *olivine,* contrasts strongly with the diopside, as it is more extensively cracked and is clearer, though it has a much higher degree of secondary iron staining. It occurs in anhedral individuals which are barely half as abundant as the diopside. Its optical properties are as follows: biaxial positive, $2V = 88°$, R.I. in sodium light is $\alpha = 1{\cdot}651$ and $\gamma — 1{\cdot}688$. It is thus indicated that it has a composition of Mg : Fe = 88 : 12 approximately.

Grains of magnetite and chromite are to be observable in the slides but are rare.

So this is a *Peridotite* consisting of diopside (10% hedenbergite) and olivine (Mg : Fe = 88; 12) in the ratio of about 2 : 1. This rather striking rock was subjected to chemical analysis with the result tabulated on page 32.

DIOPSIDITE (6197). An even-grained, green holocrystalline rock almost monomineralic, for in the hand specimen only *diopside* is visible. There are slightly pleochroic biaxial positive, $2V = 58°$, R.I. (sodium light) $\alpha = 1{\cdot}677$, $\gamma = 1{\cdot}703$.

Labradorite distributed interstitially occurs in very small amount. Grains of magnetite are very rare.

This rock appears to be related to (6199) from the vicinity of Camp (27), but is labelled "Camp 28, Mann Ranges," this is immediately south-east of Mount Edwin.

SHEARED GARNET-ANDESINE-AMPHIBOLITE (6179). Collected 11 June 1903 near Camp 51, Mount Cockburn, Mann Ranges. This would appear to be from the "Diorite Dyke" reported by Basedow (1915), half-a-mile from the Camp.

It is a dark, dense, fine-grained rock which under the microscope exhibits a roughly banded structure, richer and poorer in amphibole, and seen to have suffered considerable chloritization and retrograde changes.

Amphibole, pleochroic in light brown to green is the most abundan mineral. *Garnet* in cracked and rounded grains is next, but *andesine* (33% An) closely approaches it in quantity. *Magnetite* is present both as tiny grains in aggregations and strung out along shear lines.

Through the rock run bands, sometimes well defined, sometimes tenuous, which have the appearance and character of pseudo-tachylite.

CHARNOCKITIC TONALITE (1541). Collected 16 June 1903 near Camp 56 to the south-east of Mount Berry, Mann Ranges.

In the hand specimen this rock presents a greasy appearance and is observed to be holocrystalline, coarse, granular, with feldspar as the dominant mineral.

In microscope slide the texture is holocrystalline, allotriomorphic granular. Andesine is by far the most abundant mineral, and with it is associated a little microcline, quartz, hypersthene, etc.

This rock consists chiefly of *andesine* which has the following optical properties: biaxial positive, $2V = 86°$, maximum extinction angle in the symmetrical zone of 20°, R.I. (sodium light) $\alpha = 1\cdot552$, $\gamma = 1\cdot560$. These characters indicate an andesine of composition about 40% An. It occurs as anhedral individuals showing marked undulose extinction due to strain. Crushed areas are to be observed along the borders of many individuals, and here occur some myrmekitic quartz intergrowths. The albite twin lammelae are usually fine and pericline twinning is often superimposed resulting in a superficial resemblance to microcline. However, a little *microcline* is recognisable. *Orthoclase* is present in very small amount, some of it is antiperthite in the plagioclase.

Quartz, clear and cracked with undulose extinction, is present in small amounts, mainly playing an almost interstitial role. It also occurs as inclusions in the feldspar and as recrystallised mosaics.

Next in abundance to andesine is *hypersthene*, which usually appears as rounded grains whose colour is frequently masked by change products and schiller inclusions. The clearer individuals are grey and pleochroic in faint green and pink. Cloudy grey-green alteration products, possibly antigorite are associated with it. This hypersthene is biaxial negative, with 2V of about 82°, pointing to the possibility of about 20% of the ferrosilite molecule in its composition.

A green *diopsidic pyroxene* is present in very small quantity: biaxial positive, $2V = 60°$. Notable amounts of granular *magnetite* are usually associated with the hypersthene. *Apatite* is present in rounded grains.

A fuller examination with chemical analysis may show this rock better classified as a charnockitic trondhjemite.

ROCKS FROM AYRES RANGES

A group of hills more or less disconnected. The highest point, though 2,200 feet above sea-level, stands only 300 feet above the surrounding sea of scrubby, red sand plains.

Basedow (1905, p. 77) states, referring to the higher hills of the Ranges: "All these prominences have been determined by igneous intrusions. The more northerly ones consist of granite and the southern ridge of diorite dykes. Lying between these masses, disconnected rounded hills of metamorphic rocks appear."

APLITIC GRANODIORITE (1547): Mount Sir Henry, Ayres Range. This rock is probably a phase of (1546).

This rock is light grey-brown with an even-grained granitic texture. It is composed largely of buff-coloured feldspars and grey opalescent quartz. The lack of ferromagnesian minerals is noticeable. In some respects it appears to be not a normal igneous rock. The silica percentage is too high to be considered as an aplitic tonalite.

In this section the texture is holocrystalline inequigranular consisting essentially of anhedral individuals of feldspar and quartz. The average grainsize if about 1·5 mm., whilst some feldspars reach 4 mm. and quartz over 5 mm. in length. Quartz and plagioclase are present in approximately equal amounts.

The *Quartz* is generally clear with inclusions arranged in strings. Cracking and undulose extinction are evidenced. The larger individuals have highly irregular shapes. Vermicular quartz, frequently associated with the plagioclase in the form of myrmekite is plentiful.

Andesine in anhedral individuals is generally cracked but clear. Untwinned individuals are frequent but are easily distinguished from the potash feldspars by their optically positive character and their R.I. In the untwinned individuals the maximum extinction angle measured in the symmetrical zone is 20°, corresponding to a composition of 40% An. Some of these twinned members are optically negative, corresponding to a more albitic plagioclase.

Several examples of *antiperthite* were noted; these have andesine as the host and exsolution spindles of clear orthoclase.

Microcline is present in the form of small anhedral individuals which are generally clearer and less cracked than the andesine. The microcline generally occurs in those areas of the rock which show the greatest strain effects and in such places it tends towards an intersticial role: with it is associated some myrmekite.

Occasional grains of *magnetite* are present, and associated with it are a few small flakes of highly altered biotite.

The effects of strain are evident throughout in cracking and undulose extinction, as well as small areas that appear to have experienced a minor degree of crushing.

HORNBLENDE-GRANODIORITE (1546): Mount Sir Henry, Ayres Range.

A light brown, even-grained, granular granitic rock. It is composed of quartz, buff-coloured feldspar and dark green to black ferromagnesian granules dispersed evenly throughout the rock.

In thin section the texture is holocrystalline, granular with boundaries highly irregular. The average grain-size is in the order of 3 mm., although in extreme cases individuals reach 9 mm. in length.

Andesine (about An_{32}) in cracked and cloudy individuals, is by far the most abundant mineral present and constitutes the major portion of the rock. Plagioclase also occurs in myrmekitic intergrowths with quartz.

Microcline with perthitic intergrowths is a lesser feature. Antiperthite is also present.

Quartz is next mineral in order of abundance but plays only a minor role, tending to become interstitial.

Hornblende appears in notable amount as irregular grains. It is pleochroic: X = light brown; Y = green-brown; Z = grass-green. Biaxial negative, with moderate optical axial angle, $Z \wedge c = 20°$.

Magnetite is plentiful and with it often embedded or adhering to it are grains of *zircon* and *apatite*. Crusts of *sphene* adhere to some of the magnetite. *Apatite* is also met with plentifully elsewhere in the slide.

REFERENCES

BASEDOW, HERBERT 1905 Geological Report of the Country traversed by the South Australian Government North-West Prospecting Expedition, 1903. Trans. Roy. Soc. S. Aust., **29**, 57-102

BASEDOW, HERBERT 1915 Journal of the Government North-West Expedition of 1903. Trans. Roy. Geog. Soc. Aust., S. Aust. Branch, **15**, 57-242

WILSON, ALLAN F. 1947 The Charnockitic and Associated Rocks of North-western South Australia. Trans. Roy. Soc. S. Aust., **71**, 195-210

THRUST STRUCTURES OF THE WITCHELINA AREA, SOUTH AUSTRALIA

BY REG C. SPRIGG

Summary

Upper Precambrian (Adelaide System) sediments near the north-western margins of the Flinders geosyncline have been deformed very differently from the rest of the folded geosyncline. The tens of thousands of feet of sediments concerned locally are dominantly slates and limestones, but they include a massive quartzite, 6,000 feet thick, which has exerted a major influence in the local tectonics.

THRUST STRUCTURES OF THE WITCHELINA AREA, SOUTH AUSTRALIA

By Reg. C. Sprigg

[Read 21 July 1949]

ABSTRACT

Upper Precambrian (Adelaide System) sediments near the north-western margin of the Flinders geosyncline have been deformed very differently from the rest of the folded geosyncline. The tens of thousands of feet of sediments concerned locally are dominantly slates and limestones, but they include a massive quartzite, 6,000 feet thick, which has exerted a major influence in the local tectonics.

Great faulted sheets of the quartzite with overlying sediments have moved differentially to the south-east, resulting in large scale high- and low-angle thrust faulting. The major faults have followed obvious zones of weakness such as steep regional fold axes, or the junctions of the massive quartzite with its enclosing relatively incompetent sediments; in one case horizontal translation is measured in miles. There are no signs of "lubrication" horizons along any of the thrusts and generally the faults are loci of intense brecciation. One fault zone is intruded by doleritic plugs.

It is suggested that the thrusts constitute an example of tectonic sliding on the old continental platform induced by a rapidly rising continental foreland at the time of geosynclinal collapse.

INTRODUCTION

A group of remarkable regional thrust structures was recently discovered near Witchelina Station in the north-western Flinders Ranges of South Australia in younger Precambrian or Adelaide System sediments (fig. 1). These sediments constitute the lower portion of the Flinders geosyncline and locally they have been folded in a manner which differs greatly from that of the main body of the sediments to the south and east. Instead of the simple folding along east-west or north-south axes with complementary cross-warping and normal faulting, typical of the central portion of the geosyncline, there has been a great development of thrust faults, frequently with large horizontal displacement.

Before discussing some of these aberrant structures, the broader geotectonic pattern of the whole of the Flinders geosyncline will be outlined briefly.

THE GEOSYNCLINAL SETTING

The Flinders geosyncline which exceeds 500 miles in length (longitudinally) and 200 miles in width, borders the eastern margin of the older Precambrian shield of Australia (fig. 1). During its growth it probably had direct connections with the MacDonnell geocyncline of Central Australia, although its developments in that direction are now obscured by younger deposits. The central deeper portion of the Flinders geosyncline now constitutes the so-called "shatter belt" of South Australia.

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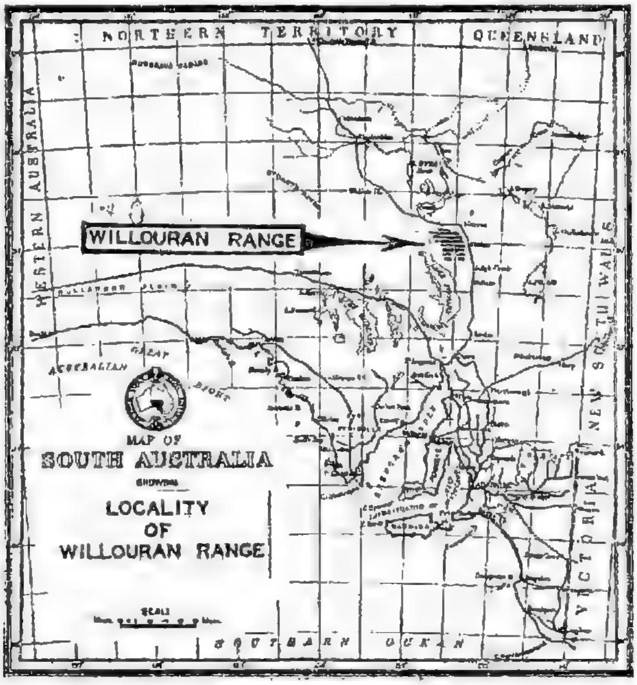
* Geological Survey of South Australia.

During geosynclinal evolution, sedimentation was practically continuous throughout the Upper Precambrian and most or all of the Cambrian period. Significant sedimentary overlap occurred to the east of the basin during the deposition of the Sturtian tillites, and subsequently to the west, with the onset of Cambrian time. Altogether a maximum of more than 40,000 feet of sediments was deposited, including two stratigraphically widely separated quartzites each of which in the north attained 6,000 feet or more in thickness.



Classification of the Flinders Geosyncline within the systems of either Kay (1947) or of Dapples, Krumbein and Sloss (1948) is difficult. In many respects it has much in common with the Miogeosyncline of Kay. For example, sinking progressed extremely regularly with continued deposition, and volcanic activity was generally very restricted. Sedimentary facies typical of the rapidly sinking linear geosynclines (eugeosynclinal or island arc types) were notably absent. Lithologically the sediments indicate unusually prolonged environmental stability during the period of deposition. Quartzites are remarkably well sorted and reworked in spite of occasional abnormal thickness; greywacks, or even sub-greywacks, occur infrequently or are absent. Shales grade from true claystones to siltstones; limestones are frequently thick. Reddish and greenish colours reflect oscillating shoreline conditions over wide areas.

Geosynclinal sedimentation closed in post-Cambrian times (?Early Caledonian), following the "collapse" of the vast accumulation of sediments.

Within the central meridional portion of the geosyncline, folding developed with major axes essentially north-south or east-west, and while the longitudinal set were most strongly developed in the south, the latitudinal set dominated in the north. In the neighbourhood of Wilpena Station the two-fold influences had approximately equal intensity with the result that large centripital fold structures were produced. Particularly fine examples of these are the Wilpena Pound (or basin) and the Bibliando dome, which have been described by Sir Douglas Mawson (1940).

Away from the central region the cross folding becomes less strongly developed, so that towards the north or south the major (almost isoclinal) folds show only gentle reverse of pitch along their major axes. In this way, in plan, a particular formation may outcrop as a narrow elongated ellipse perhaps 20 miles long, but only 2 or 3 miles wide.

Faults occur sparingly through the sediments and they are generally of the steep normal or reverse type with variable vertical throw, but without significant horizontal displacement. One normal fault in the Copley (or north) district has a stratigraphical throw of about 40,000 feet. In the south the faults usually trend meridionally in sympathy with the major axes of folding, but in the north while the local fold influence is still important, the pattern of faulting is less regular.

The Adelaide System sediments are relatively unaltered except along the eastern extensions of the geosyncline where intense metamorphism accompanied granitization and/or granite intrusion. This igneous activity modified or accentuated folding locally in most instances. In the more northerly areas doleritic plugs are intruded along a number of the larger fault zones.

In relation to the foregoing generalised geotectonic pattern, the thrust structures of the Witchelina province (which forms the north-western extension of the geosyncline) can only be described as erratic.

THRUST STRUCTURES OF THE WITCHELINA AREA

The fold and fault structures of this province are still inadequately known, but sufficient evidence is available to indicate that they are largely the outcome of regional thrusting. The local patterns of deformation have obviously been strongly influenced by a massive thick quartzite enclosed in relatively very incompetent slates and limestones (folded map). The quartzite belongs near the base of the Adelaide System, but here it is underlain by some thousands of feet of slate carrying minor horizons of sandstone quartzite.

Where thrust faulting can be recognised, the main criteria indicating horizontal movement are the enormous drag structures evident in plan in sediments which are steeply dipping. In cases where the thrust faults cross the strike of sediments, stratigraphical evidence also supports this interpretation. In general, translation was to the south-east.

Brecciation is extensive along the thrust planes, and there is no evidence of significant subaqueous slumping within the area. Hence it is thought that the development of the thrusts was late or post-geosynclinal, which is borne out by the absence, so far as is known, of unconformities within the overlying portions of the sedimentary system.

In view of this, the great horizontal translation inferred may be an example of tectonic sliding. On this interpretation, during the foundering of the Flinders geosyncline, the rising foreland to the west would have tilted marginal sediments appreciably towards the deeper portions of the basin, and under locally favourable circumstances sliding would have commenced. If the sediments had been water-soaked and unconsolidated, slumping would have dominated but this was not so, the sediments behaved as if they were consolidated. Consequently in the sliding mass, where variations in sedimentary competencies were great, excessive stresses accumulated locally, eventually to cause failure along zones of weakness producing thrust nappes along large faults with vertical shears. If this is correct, the Witchelina quartzite provided a local control while the assumed zones of weakness included (a) axes of developing or pre-existing regional folds, and (b) contacts between competent and incompetent beds. Pre-existing normal faults may also have aided failure locally.

The thrusting was generally to the south-east, but there are several additional regional faults of undetermined significance. These are usually accompanied by wide crush zones and some drag folding.

Minor fold structures of the region can usually be correlated closely with thrust movements and are therefore probably contemporaneous. The Mount Nor-west *regional* fold on the other hand was in existence or developing at the time of thrust faulting.

THE WITCHELINA THRUST STRUCTURE

(Fig. 2, and pl. ii, fig. 1)

The massive Witchelina quartzite outcrops extensively to the north of Witchelina Station homestead. From a point approximately 17 miles north of the homestead where it is truncated abruptly by a cross fault, the formation strikes uniformly south and displays conformable relations with its enveloping slates and limestones. The sediments dip east at a consistently high angle.

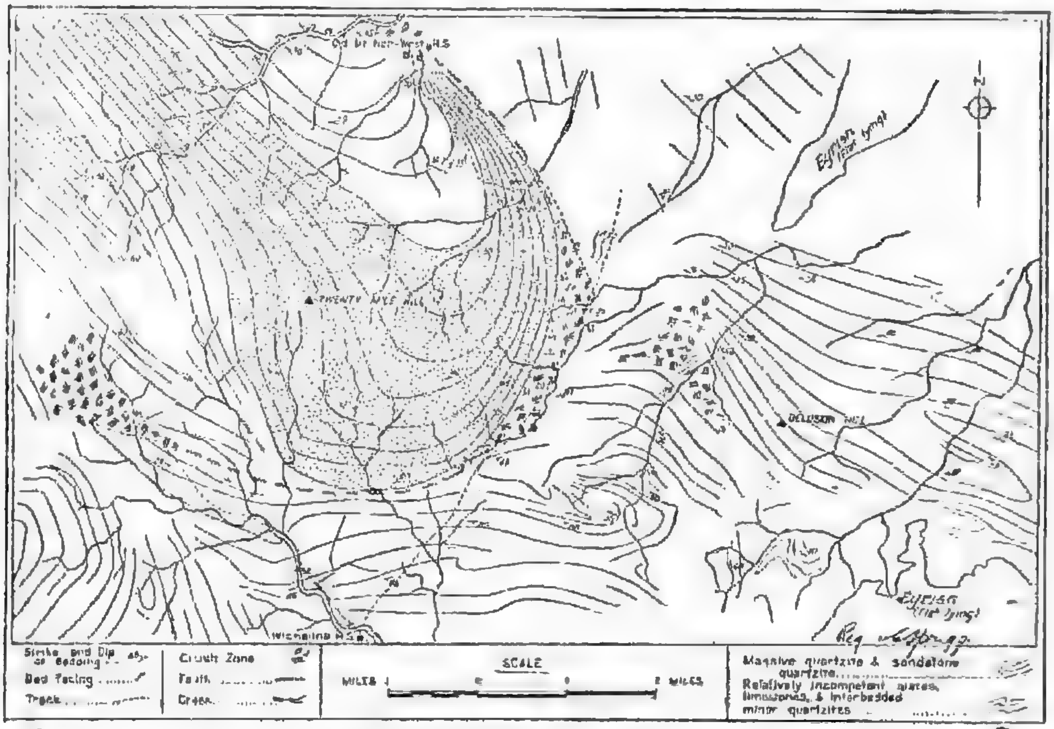


Fig. 2 The Witchelina Overthrust.

Within four miles of the homestead the quartzite flattens and spreads in outcrop and at the same time swings eastward and then back on itself until almost paralleling its original strike. In being deflected in this manner, the formation thins out rapidly, and unduly sharply for normal sedimentary lensing, until it cuts out in a mass of large white quartz reefs in a highly shattered zone. In shearing out, the quartzite apparently preserved its coarser bedding structure, so that on aerial photographs particular horizons within the formation can be traced almost to the point of cut-out. At the nose of the induced fold, the quartzite resumes its steep dip even though underlying beds have been faulted, broken and brecciated in a manner suggesting low angle overthrust faulting to the south-south-east.

The crush zone in the sole of this assumed thrust includes "erratic" blocks, some of them quite extensive, of dolomites, shales and quartzites, and extends for at least two or three miles transversely to the assumed direction of movement. The zone abounds with crush breccias, minor drag folds and quartz reefs, and from the angular nature of the brecciation there can be little doubt that the rock was consolidated at the time of movement The zone of maximum disturbance is usually less than half of one mile in width, but faults and crush zones extending into the sole of the thrust are probably complementary

THE MOUNT NOR-WEST SINISTRAL TEAR FAULT

(Fig. 3, and pl. iii, fig. 1 and 2)

Sediments in the vicinity of Mount Nor-west have been deformed into a steep regional anticline with a north-west and south-east-trending axis. The lowest formation exposed alnog the axis is the Witchelina quartzite which is overlain by the dolomite and magnesite series of the lower Adelaide system.

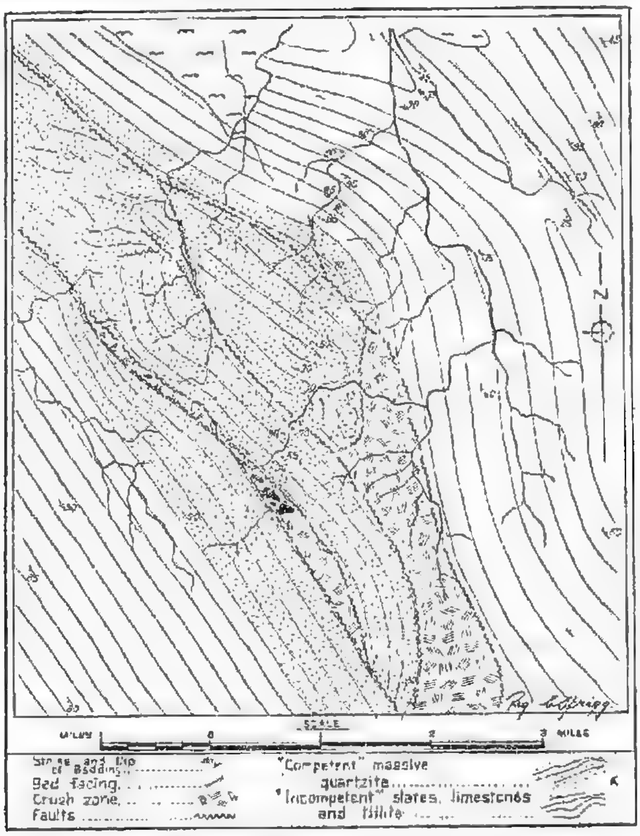


Fig. 3 The Mt. Norwest Sinistral Fault.

This regional fold axis became the locus of large-scale regional faulting, and whereas the south-west limb of the fold is relatively undisturbed and stands vertically, the quartzite in the complementary limb evidences tremendous thrusting with relative movement to the south-east. Directly north of the Mount the northern limb of the quartzite was caught up on the great shear movement, and as it appears in plan, the quartzite standing on edge was "overfolded," and secondarily thrust-faulted.

Where these various faults have been studied in the field they are obviously very steep, and in support of this, the regional "axial" fault strikes almost perfectly straight for 30 miles even though topographic relief frequently varies several hundred feet quite rapidly. The fault instead of being "overthrust" in type is therefore more correctly labelled "sinstral."

Adjacent to Mount Nor-west, the quartzite in the north limb of the fold is missing over a distance of several miles and at first sight has the appearance of having been sheared or faulted-out locally. However, this is not so, and the discontinuity is caused by a considerable degree of "dragging under" in the "overfold" structure which is not reflected very markedly in the overlying finer-grained sediments. Such selective overfolding of the quartzite has resulted in a great mashing of sediments bordering its upper face, particularly "overlying" the advancing aspect of the "lower" quartzite *nappe*.

Along the major regional fault, crushing and brecciation has been most severe where opposing limbs of quartzite are in contact. Large masses of quartzite have been "quarried" into the broken zone, and in one locality the fault has become a locus of dolerite intrusion. A cluster of four plugs occurs to the north of Mount Nor-west, the largest measuring some hundreds of yards in diameter.

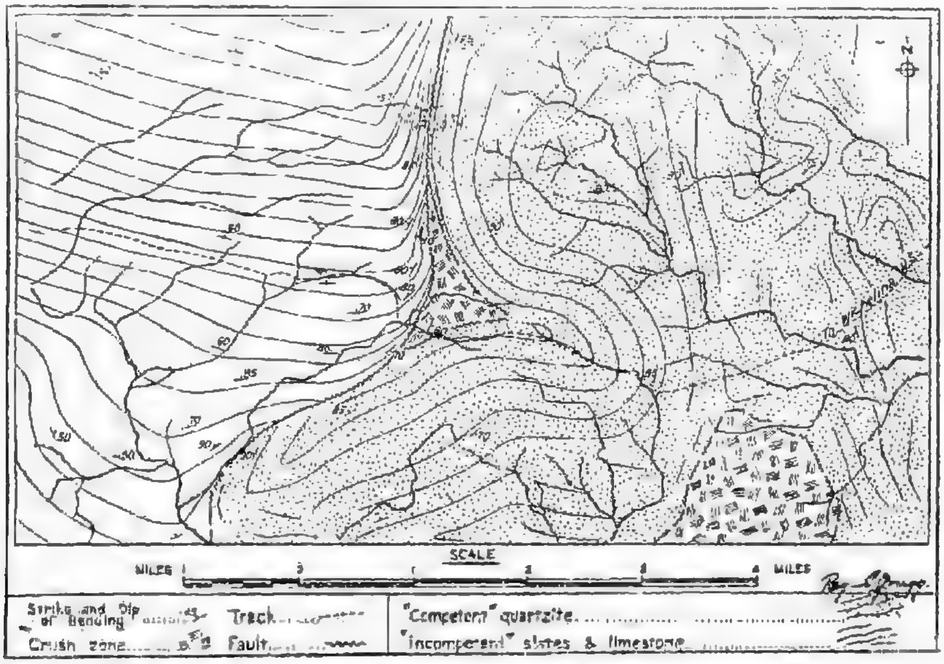


Fig. 4 The South Hill Dextral Fault and Drag Structures.

THE SOUTH HILL DEXTRAL TEAR FAULT AND DRAG STRUCTURE

(Fig. 4, and pl. ii, fig. 2)

Several miles south-west of Witchelina Station, in a zone of tremendous crushing, the Mount Nor-west sinistral fault splits off another steep shear to the north-east. Unlike the foregoing fault, this South Hill shear is dextral. On its western side a relatively incompetent magnesite series, which dips steeply to the north, is preserved in its entirety, while the massive Witchelina quartzite lies on its eastern aspect.

From the west, the magnesite series is almost undisturbed in its strike until within about half-a-mile of the fault, from where the beds become dragged and severely attenuated. The drag has been consistently to the north and the various formations have been successively sheared off in that direction.

East of the fault, the Witchelina quartzite stands vertically, and in spite of its relative "competency" has been contorted into a pronounced drag fold. The quartzite did not fracture into individual blocks, but folded perfectly in parallel manner with no thinning on the limbs of folds. As yet the attitude of the quartzite has not been determined satisfactorily but evidence suggests that "face up" is away from the shear.

The South Hill fault itself is a narrow zone of very intense mashing, rarely exceeding a score or more yards in width, which includes a wide range of breccia types. The shatter zone also extends into the core of the South Hill drag fold which consists of resistant masses of broken and mineralized slates and dolomites. No igneous bodies were encountered cutting either of these broken zones, but silicification was well developed about many centres.

SUMMARY AND TENTATIVE CONCLUSIONS

1 The Witchelina province lies near the margin of the ancient Flinders geosyncline adjacent to the older Precambrian shield of Australia.

2 It displays structural features which can be observed nowhere else in this upper Precambrian and Cambrian geosyncline.

2 The local sediments are lower members of the Adelaide System which locally instance a remarkable vertical change in competency from slates, through a massive (6,000 foot) quartzite, into more slates with limestones.

4 The relative competencies of the sedimentary members exercised a controlling influence in the development of local structural patterns.

5 The sediments have been folded and faulted extensively.

6 Regional folding, in part at least, preceded thrust faulting.

7 Thrust faulting is late or post-sediment consolidation, as brecciation predominates along the fault zones and evidence of significant subaqueous slumping is absent. The absence of unconformities above the thrusts also supports this view.

8 Thrust faults in some cases followed obvious lines of weakness, such as the axis of a steep regional anticline and the contact between competent and incompetent formations.

9 At least three of the regional thrust faults have large horizontal components, and relative movement has been to the south or south-east, apparently away from the inferred rising foreland of the old continental shield.

(a) North of Witchelina, the Witchelina quartzite and its associated magnesite series have over-ridden lower sedimentary members to the south.

(b) The Mount Nor-west and South Hill faults appear to be complementary, enclosing a central block moving relatively to the south. The two faults lie almost at right angles and are respectively sinistral and dextral.

10 Additional regional faults are known, but their field relations have not yet been determined satisfactorily.

11 No "lubrication" horizons have been met in association with any of the thrust faults.

12 The thrust structures described may constitute a case of tectonic sliding, and on present indications two major controls in deformation would appear to be:

(a) Situation near the margin of the old geosyncline. In this position a rising continental foreland accompanying geosynclinal collapse would increase sedimentary dip towards the centre of the basin and finally initiate tectonic sliding.

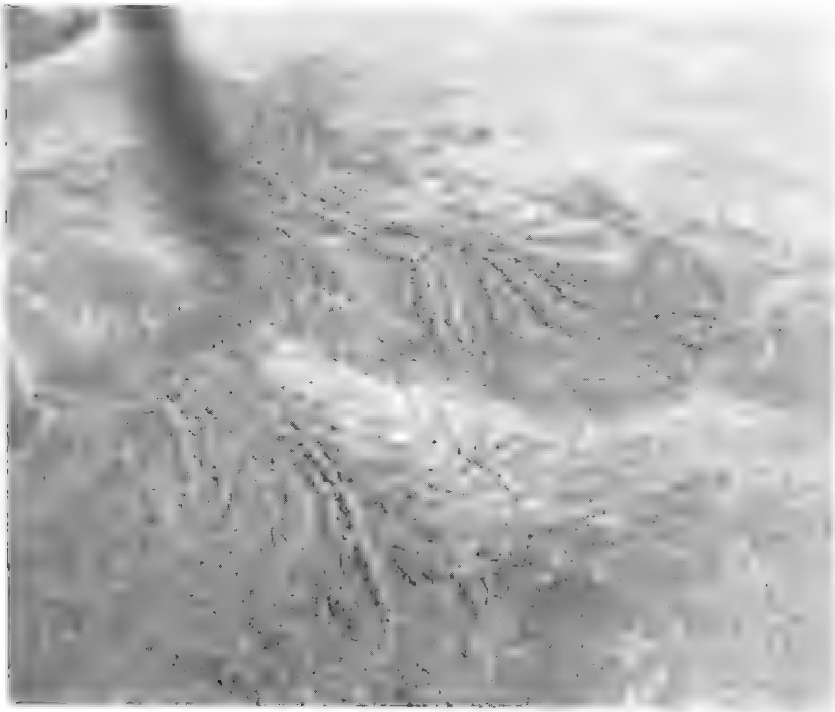


Fig. 1 The Witchelina Thrust Structure
Photo looking north towards the Lake Eyre Plains.
R.A.A.F. photo No. 53, run 337 LOB.
Lat. approx 30° S. Long. 138° 00′ E.
Scale in foreground, approx. 45 chains to the inch.

Fig. 2 The South Hill Drag Structure.
Vertical photo from 20,000 feet R.A.A.F. photo, No. 51, run 337.
Lat. 30° 05′ S. Long. 137° 55′ E.

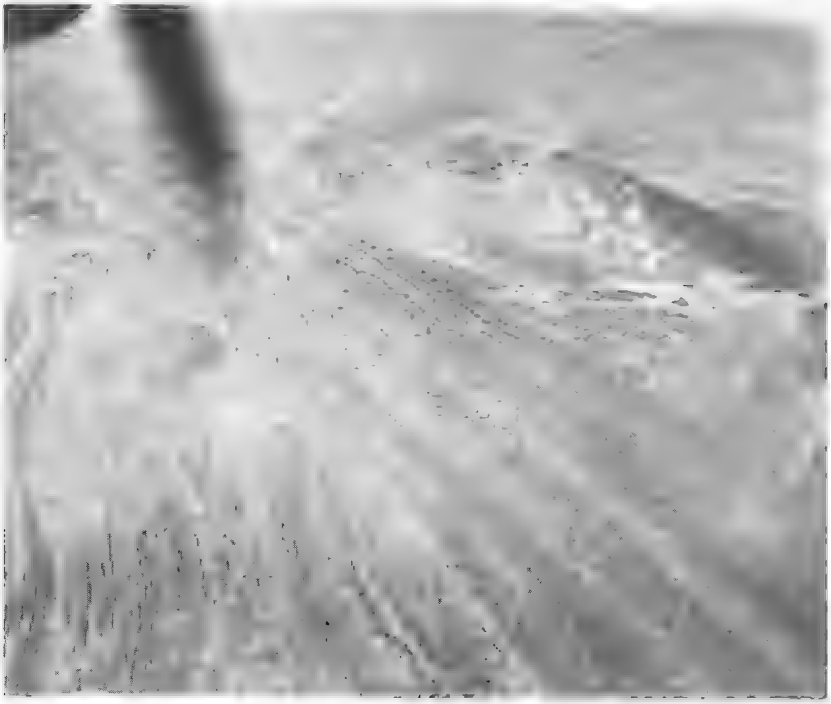
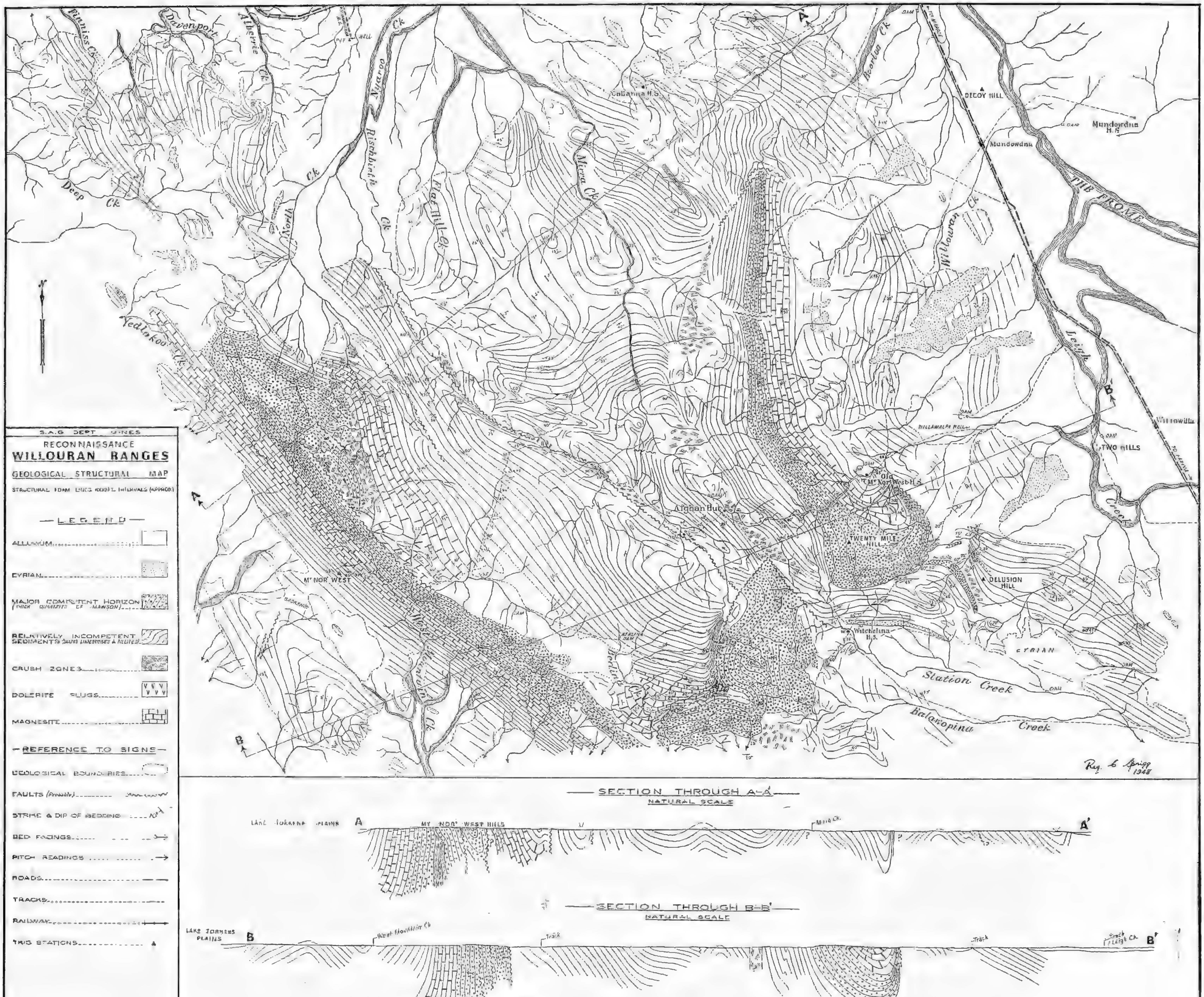


Fig. 1 Mt. Norwest Fault, showing truncated limb of quartzite in foreground.
Photo looking south to Lake Torrens.
R.A.A.F. photo No. 68, run 336 L.O.B. Lat. approx. 30° [illegible] Long. 137° [illegible]

Fig. 2. The Mt. Norwest Fault. Dark patches in centre foreground are doleritic plugs intruding fault crush zone.
R.A.A.F. vertical photo No. 68, run 330.


S.A.G. DEPT MINES
RECONNAISSANCE
WILLOURAN RANGES
GEOLOGICAL STRUCTURAL MAP
— LEGEND —
ALLUVIUM
CYRIAN
MAJOR COMPETENT HORIZON
RELATIVELY INCOMPETENT SEDIMENTS
CRUSH ZONES
DOLERITE PLUGS
MAGNESITE
— REFERENCE TO SIGNS —
GEOLOGICAL BOUNDARIES
FAULTS (Probable)
STRIKE & DIP OF BEDDING
BED FACINGS
PITCH READINGS
ROADS
TRACKS
RAILWAY
TRIG STATIONS
— NOTES —
Geology by R.C. Sprigg
Base Map compiled from trimetrogon
Photographs flown by R.A.A.F.
Finniss Ck
Davenport Ck
Alberrie Ck
Nguroo Ck
Deep Ck
North Ck
Rischbieth Ck
Flat Hill Ck
Mirra Ck
Callanna H.S.
Koorloo Ck
DECOY HILL
Mundowdna H.S.
Mundowdna
THE FROME
Willouran Ck
Leigh Creek
Yednakoo Ck
Mt Nor' West
Afghan Hut
Old Mt Nor' West H.S.
TWENTY MILE HILL
DELUSION HILL
Witchelina H.S.
Willawalpa Hill
TWO HILLS
Witrowilla
West Mountain Ck
Station Creek
Balacopina Creek
Reg. C. Sprigg 1948
SECTION THROUGH A-A'
NATURAL SCALE
LAKE TORRENS PLAINS
A
MT NOR' WEST HILLS
Mirra Ck
A'
SECTION THROUGH B-B'
NATURAL SCALE
LAKE TORRENS PLAINS
B
West Mountain Ck
Track
Track
Track Leigh Ck
B'
SCALE
MILES 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 MILES

(b) The presence of a major competent formation, 6,000 feet thick, low in the sedimentary sequence, which during sliding concentrated stresses locally, to bring about severe local deformation.

REFERENCES

MAWSON, D. 1942 The Structural Characters of the Flinders Ranges. Trans. Roy. Soc. S. Aust., **66**, (2)

DAPPLES, E. C., KRUMBEIN, W. C., and SLOSS, L. L. 1948 Tectonic Control of Lithologic Associations. Bull. A.A.P.G., **32**, No. 12

KAY, M. 1947 Synclinal Nomenclature and the Craton. Bull. A.A.P.G., **32**, No. 7

THE NULLARBOR CAVE SYSTEMS

BY J. M. THOMSON

Summary

The writer has organised five trips to the Nullarbor Plains (1932, 1934, 1935, 1939 and 1947) in order to study the vast cave system there.

THE NULLARBOR CAVES SYSTEM

By J. M. Thomson

[Read 21 July 1949]

The writer has organised five trips to the Nullarbor Plains (1932, 1934, 1935, 1939, and 1947) in order to study the vast cave system there.

The present paper details some of the results of the last expedition carried out in February 1947.

Surveys by J. M. Thomson, Master Mariner, and F. E. Ellis (Licensed Surveyor). Geological Data by D. King.

Caves on the Nullarbor may be classed in two distinct types—Shallow and Deep.

Shallow caves may be again subdivided into four distinct classes according to the nature of the entrances.

(a) Those having a narrow cleft or fissure-like opening. These are usually only as deep as the upper hard crust, 60 to 70 feet, and consist for the most part of various short passages, never more than a few feet wide. They nearly always contain some dead stalagmites and stalactites.

Examples—Plate v, fig. 1: One (unnamed), ¾ mile north-west of White Wells Station. One, 3·7 miles north of Disappointment Cave. Murrioodna Cave (pl. v, fig. 2).

(b) Caves and passages leading off from the bottom and sides of Blow Holes. These are seldom more than 100 feet in length or deeper than 40 to 60 feet. They nearly always contain some dead stalactites and stalagmites.

Example—Ivy Cave (see pl. v, fig. 4). Koomooloobooka Cave. Bildoolja Cave. The Catacombs (pl. iv, fig. 1).

(c) Bottleneck Caves (Blow-hole entrance).
These are always found in stony outcrops and invariably have several stunted quandong trees growing around the entrance and have been named from the fact that the interior is similar in shape to the interior of a bottle. At the base of the opening is always found the heap of mullock which once formed the roof at this part. This heap of mullock is never found at the base of normal blow-holes. I have never found bottleneck caves to contain stalactites or stalagmites. They mostly consist of the one chamber only and rarely have passages leading off but often have many small pipes a few inches in diameter leading into them at varying heights. They are generally about 40 feet deep.

Examples—Cave; one mile south of No. 3 Murrawadginic Cave. One; ½ mile north-west of No. 1 Diprose Cave.

(d) Small sink-hole entrances, *i.e.*, with sink-holes 60 to 70 feet across and 10 to 30 feet deep, and generally having long passages leading down from the bottom of the sink hole and usually deepening to between 50 and 60 feet.

Examples—Diprose Caves. Disappointment Caves (pl. iv, fig. 3). Creek Tank Caves. Murrawidginie Caves.

DEEP CAVES

These have large sink-hole entrances, *i.e.*, sink-holes from 200 to 400 feet across, and as deep as the hard upper crust of the limestone, 60 to 80 feet. These large sink-holes are only found in the sparsely-timbered belt bordering the Nullarbor and have never yet been found actually on the Plain itself, probably because of the greater thickness of the limestone nearer the coast.

These all penetrate the hard surface crust and invariably lead down through huge passages to the water table, approximately 300 to 340 feet, some containing large lakes of water. These, from their enormous size, are the most spectacular of the Nullarbor Caves.

Examples—Koonalda (pl. iv, fig. 2), Warbla. Weebubbie (pl. vi, fig. 2).

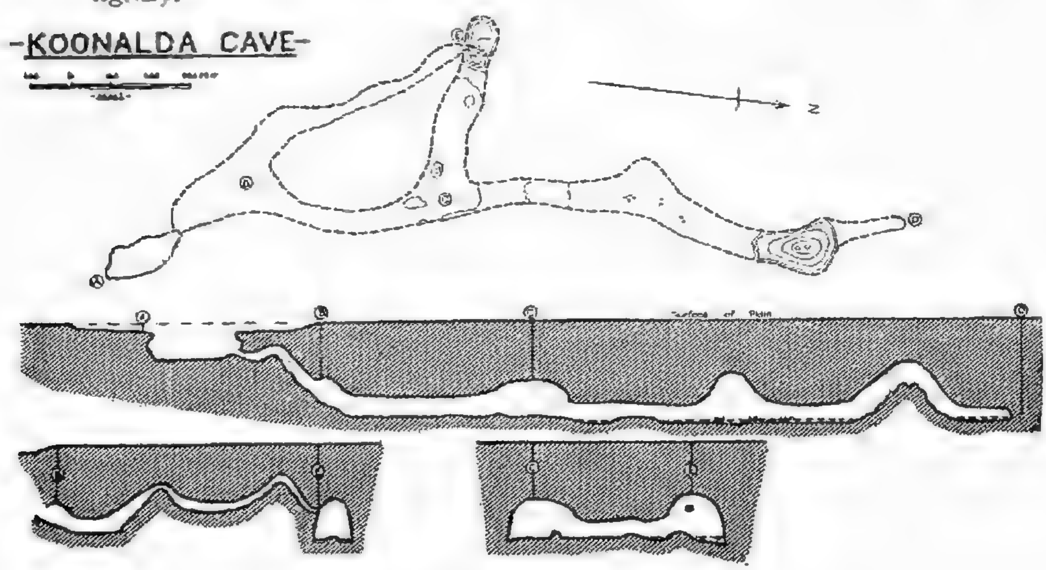


Fig. 1 Plan of Koonalda Cave

A Description of Koonalda as an Example of a Deep Cave

Main Sink-hole (pl. iv, fig. 2)

210 feet long by 80 feet wide and 90 feet deep at its deepest part (pl. iv, fig. 2).

This sink-hole A has steep sides with overhanging lips from the north-west through west to the north-east portions the edge is slightly tilted, allowing reasonable access with a Jacob's ladder.

At the bottom of the sink-hole and at the north-west corner an opening leads down to the lower chambers. After a descent to 200 feet a huge chamber, B (fi. 1), with domed roof is reached. This cavern is 280 feet long and 120 feet wide with the roof 100 feet high. Long underground passages lead from the northern and western ends of this chamber, the northern one 1,650 feet long with the roof an average height of 50 feet and approximately 60 feet wide.

At 500 feet, C, a small pool of water 5 feet deep and extending 150 feet blocks the passage; then an "isthmus" 110 feet across, followed by a lake 475 feet long and 5 feet deep with an average width of 90 feet.

Analysis of this water shows salinity 372 grains to the gallon total salts. This corresponds to a good sheep water. The relatively good quality of this water is probably influenced by recent heavy rains.

At the far end of this lake a huge fall again forms an "isthmus" 210 feet long in the form of a conical island, at its highest peak 85 feet above water level. This "isthmus" is also a fall from the roof and above it the roof is dome shaped, rising almost to ground level.

Past this "isthmus" is a further lake 180 feet long and 40 feet wide (depth unknown, but it appears to be very deep).

Scattered along the centre and largest lake are huge boulders, fallen from the roof, whose tops jut out above the water surface and could be very dangerous to the canoeist.

480 feet along the main northern passage, near C, a passage forks off to the westward for 370 feet, ending in a lake of water 60 feet by 70 feet and about 10 feet deep at its farthest point. Analysis of this water showed salinity 493 grains per gallon total salts, and the previous remarks may be applied to its freshness. The average width of this passage is 90 feet and the roof 40 feet high. Over the lake the roof rises and domes to 110 feet above water level.

The north-west passage commences at the north-west corner of the main chamber, B, at a point near the roof and continues on for 640 feet. It is slightly undulating, the highest points being roughly 250 feet apart. This passage is roughly 30 feet high and between 40 and 50 feet wide. At the last high peak a steep slope of 45 degrees drops down to a narrow cat-walk barely a foot high which proceeds through the limestone for 20 feet, ending at a narrow ledge 5 feet wide and 20 feet long.

In 1935 when we first discovered this passageway our lights would not illuminate the far side of this further cavern, but on dropping stones we found they landed in water approximately 100 feet down (E). In January 1947, when we thoroughly surveyed this cave, we discovered that the north-western passage ended in the domed roof at the end of the western passage, commencing at (C), and that it is exactly 90 feet above water level in the end of the western passage.

This small ledge cannot be seen from ground level at the end of the western passage.

There is a possibility that further passages lead off from the main chamber, B, in a south-westerly direction as this is indicated by the depressions above ground, but considerable removal of earth and boulders would be necessary before entrance could be obtained.

Particularly in the western passage and at about 20 feet above floor level several horizons of large nodular flints ornament the walls.

A Description of the Catacombs, typical of the Shallow Caves

Latitude 31 degrees 8′ south; longitude 130 degrees 36′ east, approximately. Discovered by Jones in 1880 and only partly explored.

Entrance to the Catacombs is in a stony outcrop (pl. iv, fig. 1) scattered with small quandong trees, the actual entrance being a blow-hole about 3 feet in diameter and 25 feet deep. The sink-hole or depression surrounding this blow hole is 70 feet long by 35 feet wide but only 10 feet deep.

After descending the blow hole a main north-west south-east passage 240 feet long by 50 feet wide is reached. The roof of this chamber is supported by a pillar 30 feet by 20 feet (it is not a Great Mite). This was described by Jones, but it appears that a very recent and quite heavy fall from the roof has blocked a considerable part of this passage which Jones penetrated.

85 feet from the entrance hole and in an easterly direction a cross passage is reached; position C, fig. 2, running north-east and south-west. From C, we penetrated to D, a total distance of 150 feet. This passage is 10 feet wide with the roof 5 to 6 feet high and reaches a point 60 feet below ground level and continues on. Branching off from this main passage, as is also the case from the centre chamber B, are innumerable passages and cat-walks leading off in all directions.

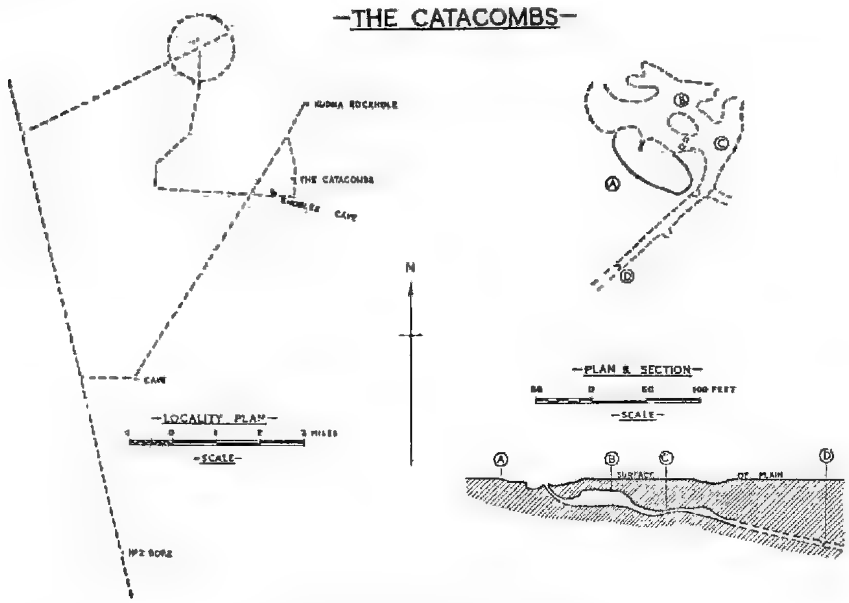


Fig. 2 Plan of the Catacombs

Time would not permit further exploration in this cave, but we found slight evidence of drip stones, etc., and I believe a thorough exploration of this cave might well be warranted.

$1\frac{3}{4}$ miles north-east of the Catacombs is Kudna Rock-hole (see pl. v, fig. 2). It is really two holes capable of holding about 70 gallons of water. This was found and named by Delisser in 1876. Jones also watered here in 1880.

$\frac{1}{2}$ mile south-west of the Catacombs we discovered and named Knowles Cave, which is a kidney-shaped sink-hole 1,000 feet long running north-west and south-east. It is 100 feet deep at the north-western end and 80 feet deep at the south-eastern end. There are no branch passages from these deeper caverns.

GEOLOGICAL NOTES ON THE NULLARBOR CAVERNOUS LIMESTONE

BY D. KING

Summary

In the first portion of this paper the nature and environment of the Nullarbor caverns are discussed and theories put forward to explain their formation. The immense deep-seated chambers are attributed to solution of the the limestone in the zone of rock saturation below the surface of the water table, i.e., Phreatic conditions. The more numerous shallow caves, blow holes and minor sinks are related to the dual effects of solution and corrosion by precipitated surface waters making their way down to the water table – Vadose conditions. It is suggested that the caverns were for the greater part formed during the pluvial Pleistocene when the water table stood at a higher level.

GEOLOGICAL NOTES ON THE NULLARBOR CAVERNOUS LIMESTONE

By D. King*

ABSTRACT

In the first portion of this paper the nature and environment of the Nullarbor caverns are discussed and theories put forward to explain their formation. The immense deep-seated chambers are attributed to solution of the limestone in the zone of rock saturation below the surface of the water table, i.e., Phreatic conditions. The more numerous shallow caves, blow holes and minor sinks are related to the dual effects of solution and corrosion by precipitated surface waters making their way down to the water table—Vadose conditions. It is suggested that the caverns were for the greater part formed during the pluvial Pleistocene when the water table stood at a higher level.

In the stratigraphical portion of the paper, a considerable thickness of Upper Cretaceous bryozoal limestone is reported.

THE ORIGIN OF THE NULLARBOR CAVES

The fact that not one creek or watercourse of any consequence is met within the whole 30,000 square miles of the Nullarbor Plain proper, reveals that the drainage of the meagre rainfall of the area is completely restricted to underground waterways. The abundance and large dimensions of the caves suggest that they were developed during a highly pluvial period, and although no direct evidence of their age was found, it is considered that they were for the greater part hollowed out during the Pleistocene, when Australia experienced a notably wet climate. Relics of an ancient river system, in the form of a string of saline lagoons linked by partially sand-drifted depressions, occur in the Pidinga region on the eastern fringe of the plain, and present evidence of former high rainfall conditions.

Precipitated surface waters, making their way downward through the limestone as vadose streams, created both erosional and solutional passages in the rock, ornamented with dripstones. At the water table, and below, solution alone was responsible for the formation of immense horizontal caverns devoid of dripstones.

The discussion of the origin of the caves thus resolves itself into two categories.

Caverns of Phreatic Origin

The large deep-seated caverns such as Koonalda, Weebabbie, Abrakurrie and Warbla, are confined to near the coast where the limestone is of greater thickness. The sinkholes of these range in depth from 60 to 100 feet. At the base of these sinks there are commonly found lateral passages, firstly with a down gradient and of cramped dimensions, but which gradually open out into immense rounded chambers, with little or no gradient, and continue as such for many hundreds of yards. The chambers meander, with gently rounded bends, but have a dominant north-south trend. In some cases there are off shoots from the main caverns. The caverns end abruptly as an enlarged rounded amphitheatre.

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* Department of Mines, South Australia.

At a depth of 300 feet the water table is reached and below this "underground lakes" of perfectly clear water extend for great distances, interrupted by islands of material fallen from the roof.

The lower chalk horizon of the limestone (see stratigraphic notes) is extensively eaten out into such chambers. The possibility of access to them is only exceptional, necessitating the collapse of the overlying silicified "hard crust", and incomplete blocking of the chambers. The writer's interpretation of the structure of this type of cavern is illustrated in the accompanying sketch. (Fig. 3).

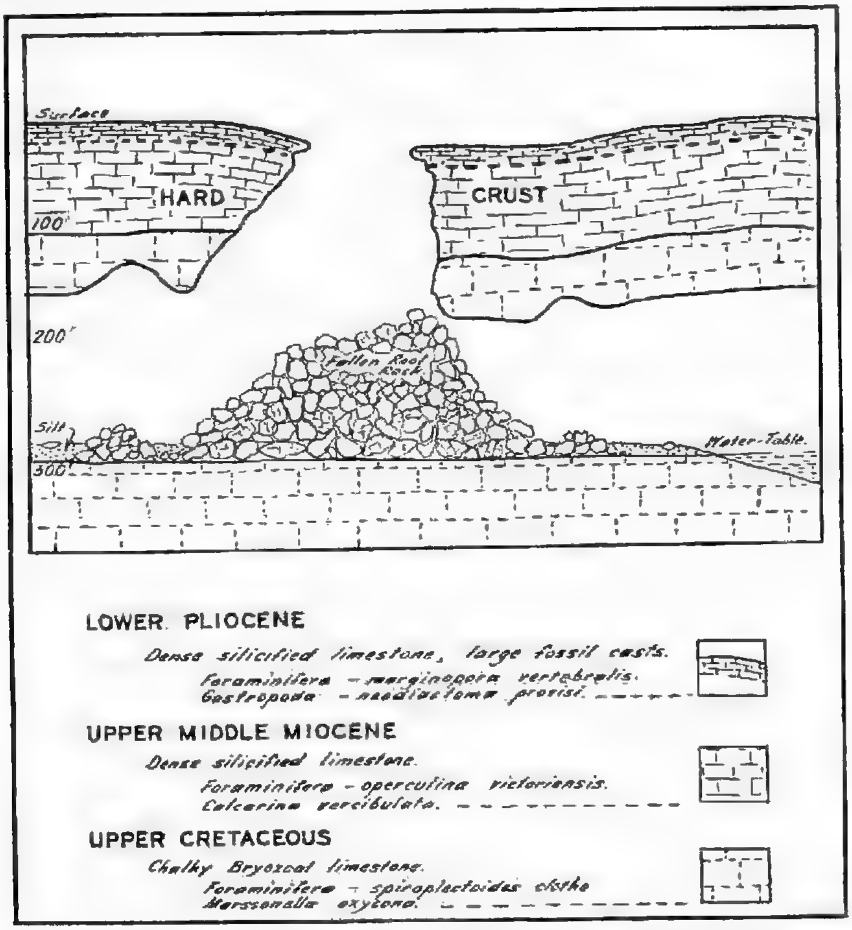

Fig 3 Sketch section showing a typical sinkhole entrance to a Nullarbor cavern, and the stratigraphical succession.

From evidence outlined below, the writer contends that these caverns were produced and enlarged under completely phreatic conditions by solution effects along major joint planes, the underground water being supplemented by vadose streams. The periodic addition of carbonated rain water from above would greatly enhance the susceptibility of the limestone to solution, the carbon dioxide bringing about the formation of the much more soluble calcium bi-carbonate. Assuming an annual rainfall of 20 inches at the time of formation of the caves, the amount of water which fell in the course of a year on one square mile of the plain would alone be capable of dissolving some 350 cubic feet or more of rock as calcium carbonate, or even more as bi carbonate.

The concentration of the solvent activity in localised places, such as along joint planes, made possible the formation of the very large caverns. As circulation in the phreatic zone is confined to lateral drainage, which does not extend far below the water table, it may be assumed that solutional effects on such a great scale as observed would only be possible just below the water table. A. C. Swinnerton (3) has demonstrated that solution in the upper part of the water table is quantitatively adequate to perform the task demanded.

The data on which the phreatic origin of the caves is based may be summarised as follow:—

(a) The cavern floors show little or no gradient. This is well illustrated in the section of Koonalda cave. (fig. 1), neglecting the material that has fallen from the roof.

(b) The caverns have rounded cross-sections and, in general, there is no line of demarcation of roof and wall. The smooth and undulating surfaces of both roof and walls are diagnostic of solution effects. (See pl. vi, fig. 2.)

(c) The occurrence of calcite crystals and calcite encrustations on the walls and ceilings, in contrast to the absence of dripstones, has an important significance. Under wholly phreatic conditions, the absence of air would eliminate the possibility of the formation of dripstones, whereas the saturated condition of the water which must occur in deep-seated more or less stagnant "circulation", would bring about precipitation of crystalline mineral matter while the rock material was actually being dissolved.

(d) The general direction of the caverns (north-south) corresponds with the direction of water table drainage.

(e) The ends of the caverns are as sudden at their commencement as sink-holes (pl. vi, fig. 1), and are rounded out perfectly in continuity with the roofs and walls. Such a phenomenon is not in accordance with the habits of vadose streams.

The porosity of the chalky cavernous limestone, calculated to be 26%, and the fall of material from the roof, would aid solutional effects in enlarging the caverns by exposing a larger surface area to attack.

At this stage a quotation from the thesis of W. M. Davis (2) would not be out of place. He says, "It is proposed . . . that large caverns are ordinarily excavated by ground water solution during an epoch when the body of limestone in which they occur lies below the water table of its district, and the change from this epoch of solutional excavation to the following epoch of depositional replenishment takes place when the water table sinks below the cavern level in consequence of regional elevation or other effective cause . . .".

The question arises, "What then has caused the draining of the Nullarbor caves?". There is no definite evidence that the plain is rising or has risen although there are indications in this direction. Inhabitants of Eucla say that the sea has receded gradually during the last generation but no scientific work has been done to verify this. The explanation of the drying out of the caves is more likely to be connected with the relative levels of the water table under changing climatic conditions. In consequence of a change from the pluvial Pleistocene to the arid present, it follows that the water table would stand at a much lower level today. The simultaneous draining of the caves and the change to arid conditions would also account for the absence of dripstones in these deep chambers. The collapse of the roofs with the production of sink-holes (fig 3) may have been prompted by the draining off of the water, which previously would have acted as a means of support.

The common occurrence in the ceilings of perfectly developed domes by a partial collapse of the rock material seems to be a natural means of resisting further collapse. Most domes are smooth and merge gently into the roof proper. This suggests that the rock fell during or at the decline of the phreatic phase of the cavern's history. Enlargement of the caverns is probably going on to a minor degree at the present time, the bottom of some being below the water table, where water accumulates as underground lakes. The extent of solution under present conditions is discussed in a later section.

Caverns of Vadose Origin

The origin of the numerous shallow underground passages, caves, swallow-holes and blowholes, in contrast to the large deep-seated caverns, appears to have been dependent on corrosional and solutional effects of surface waters making their way down to the water table. The erosive action of the water would be enhanced by suspended silty material carried in from the surface. The walls and roofs are angular and irregular and, in general, they have a fairly steep gradient. The blowholes are often vertical. The occurrence of dripstones in these shallower caves is evidence that they were formed by vadose waters. The writer contends that the dripstones are mainly relics of the high rainfall period (Pleistocene?) existing when the caverns were formed. In some localised parts of the passages, at the intersection of joints and along planes of weakness afforded by the bedding, more active erosion has taken place and larger openings have been developed. This is well illustrated in the narrow passageways of the Catacombs which occasionally open up into large chambers (fig 2.).

WATER ANALYSES

Samples of water from the surface of pools in Koonalda Cave, forwarded to the S.A.G. Department of Mines, were analysed by T. W. Dalwood of the School of Mines Assay Department. The results are recorded below.

Locality	Koonalda Cave Western Passage	Koonalda Cave Northern Passage	Muddaugana Bore Water Cut 198 ft.
Ions and Radicles (grains per gall.)			
Chlorine, Cl	264·95	201·60	749·43
Sulphuric acid, SO_4	46·54	30·70	145·31
Carbonic acid, CO_3	3·15	4·20	4·50
Nitric acid, NO_3	trace	trace	—
Sodium, Na } Potassium, K }	145·70	110·80	414·21
Calcium, Ca	16·74	12·37	46·95
Magnesium, Mg	16·72	12·52	47·15
Silica, SiO_2	-	-	1·90
Total saline matter (grains per gall.)	493·80	372·19	1,409·45
Total saline matter (ounces per gall.)	1·13	0·85	3·22

Assumed Composition of Salts (grains per gall.)

Calcium carbonate	5·25	7·00	7·50
Calcium sulphate	49·66	32·51	149·43
Calcium chloride	-	-	—
Magnesium carbonate	-	-	—
Magnesium sulphate	14·41	9·73	49·79
Magnesium chloride	54·16	41·32	147·21
Sodium carbonate	-	-	—
Sodium sulphate	-	-	—
Sodium chloride	370·32	281·63	1,053·62
Sodium nitrate	trace	trace	—
Silica	-	-	1·90

The low lime content may be partly explained by the fact that the samples were taken after local heavy rains, and sufficient time may not have elapsed for appreciable solution of the limestone to have taken place. Nevertheless, samples from bores on the Nullarbor Plain have shown a similar low figure for lime. The analysis of water from the chalk horizon in Muddaugana Bore quoted by Ward (4) has been listed for comparison.

The conclusion is reached that under the existing arid conditions, a sufficient influx of carbonated surface waters essential for the large scale solution of the limestone is lacking, and consequently, the excavation of the caverns at the present time is restricted to almost negligible proportions.

CAVE EARTHS

The floors of the caves are covered with a thick layer of red-brown clayey soil, partly residual, and partly washed in from the plain, as well as large heaps of fragmentary limestone fallen from the roof. Other mineral matter is uncommon and the following only occur locally.

Glauber's Salts—Efflorescent crusts of Glauber's Salts occur on the floor of certain passages of Koonalda Cave. The deposits are several feet thick. The lower portions are crystalline but promptly fall into powder on exposure to air.

Bat Guano—A small sinkhole about one mile south east of Koonalda Cave contains abundant bat guano oozing out of fissures in the walls. The material is almost black in colour, moist and sticky where broken, and of an unpleasant odour. The outside surface of the guano is smooth and polished. On drying, it becomes much harder and brittle. The occurrence suggests that it oozed along the fissures and down the walls of the depression at reduced viscosity, in the presence of abundant water. There are considerable amounts of ligneous matter, mainly twigs, included in the guano. A qualitative chemical test showed the presence of phosphate.

Gypsum—Long fibrous crystals of gypsum commonly radiate from the flint nodules in the walls of most of the deeper caves. The mineral was restricted to this occurrence.

Ochre—Nodules of soft powdery red-brown hydrated iron oxide occur in some parts of the limestones. They may represent a leached residual. There are only a few isolated occurrences of the ochre, best seen at Warbla Cave.

Carphosiderite—Minute yellow stains of this mineral are present in the lower horizon of Weebabbie Cave. The carphosiderite was determined by chemical spot tests. (The test was carried out because of its resemblance to carnotite stains).

STRATIGRAPHY

The horizontal undisturbed limestones of the Nullarbor Plain cover more than eighteen thousand (18,000) square miles of South Australian territory, and extend into W.A., north of the Great Australian Bight. The thickness as observed from water boring varies from five hundred to seven hundred feet, the basin becoming shallower inland. They overlie lacustrine sediments, including lignite, and Precambrian granites and gneisses.

An upper "hard crust" of silicified limestone from 40 to 60 feet thick, with abundant casts of fossil shells (pl. vi, fig. 4) abruptly passes down into a soft white chalky horizon which continues down to a depth of at least 300 feet. In the upper horizons (100 to 150 feet) the chalk contains abundant echinoids (*Cassidulus* sp.). At a depth of 150 to 200 feet *Notostrea* are common. Below this there are no large fossils. Thin horizons of nodular flints, elongated horizontally, and with longer axes measuring up to several feet, occur in the chalk at depths of 105, 140, 190 and 220 feet. The chalk has been the most susceptible to solution effects and the collapse of the overlying "hard crust" under gravity has given rise to sink holes.

Samples of the limestones were collected at regular depth intervals. Twenty-six thin sections were prepared by the writer and forwarded to Miss I. Crespin, Commonwealth Palaeontologist, for determination of age relations. Detailed work on zonal foraminifera carried out by Miss Crespin provided most interesting results. Of particular importance is the discovery that the lower chalk is of Upper Cretaceous age.[1] Previously the limestone had been referred to Tertiary times only.

The surface limestones apparently belong to two series, the Lower Pliocene and the Upper Middle Miocene, and can be correlated with parts of the sections of the Adelaide Plains. Miss Crespin believes that the Lower Pliocene limestones represent a deeper water facies of the "Adelaidean" which she is now convinced is Lower Pliocene, (but not Kalimnan) and which extends as far north as North West Cape in Western Australia. The chalky limestones from the caves are Upper Cretaceous, several well-known zonal foraminifera being noted in them. The nearest known Upper Cretaceous deposits are at Gin Gin in Western Australia.

Miss Crespin's correlation is outlined as under: (Report No. 1947/68).

The limestones came from three caves on the Nullarbor Plains, the Koonalda, the Abrakurrie and the Weebabbie, and from the surface crust in the vicinity of the caves. The surface samples are labelled S1, S2 and S3, and were collected from the surface down to a depth of 10 feet.

1. Lower Pliocene ("Adelaidean")—0-10 ft. in thickness.

S1 and S3 are hard, dense, pink to cream-coloured limestones containing foraminifera. *Marginopora vertebralis* is common and is associated with *Sorites marginalis*, *Valvulina* sp., *Flintina triquetra*, *Triloculina tricarinata* and *Discorbis cycloclypeus*, all of which are typical of the Lower Pliocene ("Adelaidean") of South Australia. The common ("Adelaidean") gastropod *Neodiastoma provisi* is also present in S3.

2 Upper Middle Miocene—50-90 ft. in thickness.

Sample S2 is a hard, dense, dark cream-coloured limestone with numerous lighter patches of the calcareous alga *Lithothamnium ramossisimum*. Numerous foraminifera are present in the rock, the commonest forms being *Operculina victoriensis* and *Calcarina vercibulata*. Rarer forms are *Gypsina howchini* and

[1] Later field investigations by the present writer, however, suggest that the chalky limestone is of Middle Miocene age.

Crespinella umbonifera. This assemblage is typically Miocene and has recently been found at the top of the Miocene and immediately underlying the Lower Pliocene in bores in the Adelaide Plains. Present information suggests that this assemblage represents the uppermost portion of the Middle Miocene.

3 Upper Cretaceous—at least 200 ft. in thickness.

The samples from the Koonalda Cave (C5-C9, C11, C13, C16-C19) were collected from the depth of 60 feet down to 300 feet, those from the Abrakurrie Cave (M5, M6, M8) from 150 feet down to 240 feet, and from the Weebabbie Cave (W10, W16) from 100 feet down to 290 feet. Except for C5 from the Koonalda Cave, which is a crystalline limestone of indeterminate age, all samples from the three caves consist of chalky white bryozoal limestones of Upper Cretaceous age. The limestones contain foraminifera and radiolaria, an association which is frequently found in rocks of Cretaceous age in Australia. The Zonal foraminifera recognised are *Spiroplectoides clotho, Marssonella oxycona* and *Globotruncana* sp. Other typical species are *Guembelina globulosa* and *Globigerina cretacea.* Small rotalines are common but are difficult to determine in thin section. The radiolaria all belong to the Spumellarian group.

ACKNOWLEDGMENTS

The writer wishes to express thanks to Captain J. M. Thomson for the invitation to accompany him on the expedition to the Nullarbor Plain, and to Sir Douglas Mawson for the use of facilities at the University of Adelaide for the preparation of rock sections.

REFERENCES

1 Crespin, Miss I 1947 Notes on Samples of Limestones from the Nullarbor Plains, South Australia. Report No. 1947/68—Unpublished (1947)

2 Davis, W. M. 1930 Origin of Limestone Caverns. Bull. Geol. Soc. Amer., **41**

3 Swinnerton, A. C. 1932 Origin of Limestone Caverns. Bull. Geol. Soc. Amer., **43**

4 Ward, L. K. 1946 The Occurrence, Composition, Testing and Utilization of Underground Water in South Australia, and the Search for Further Supplies. Geol. Surv. of S. Aust., Bull. 23

Fig. 1 Catacombs Cave: entrance.

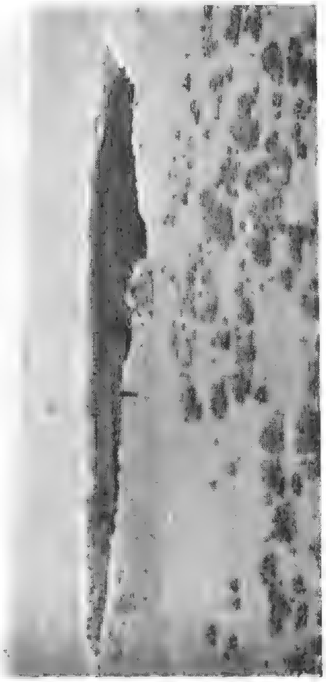

Fig. 2 Koonalda Cave: sinkhole

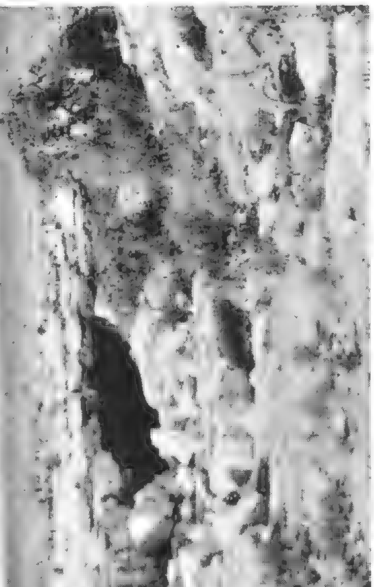

Fig. 3 Disappointment Cave

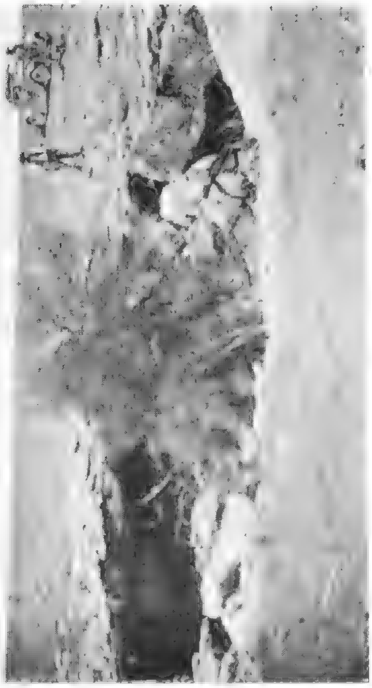

Fig. 4 Dipnose Cave: a smaller sinkhole entrance.

Fig. 1 Narrow cleft entrance.
Murrioodna Cave on Nullarbor Station.

Fig. 2 Kudna Rockhole

Fig. 3 A bottleneck cave on Nullarbor Station.

Fig. 4 Ivy Cave on Nullarbor Station
Descending in a bosun's chair.

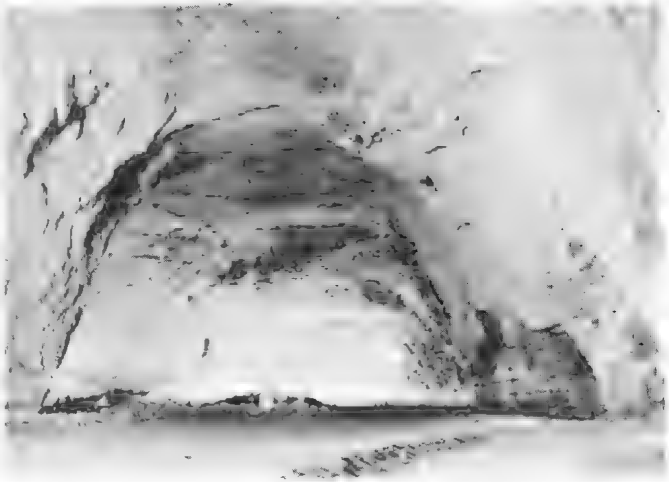

Fig. 1 Abrakurrie Cave, showing abrupt end of the passage.

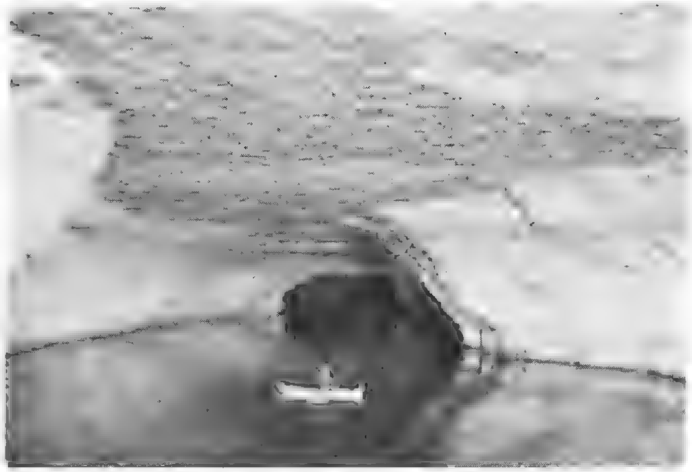

Fig. 2 Weebubbie Lake

Fig. 3 Ivy Cave, showing drip-stones

Fig. 4 Internal casts of Tertiary fossils from the silicified surface limestone, Nullarbor Plain

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AN OLD MANGROVE MUD-FLAT EXPOSED BY WAVE SCOURING AT GLENELG, SOUTH AUSTRALIA

BY BERNARD C. COTTON

Summary

On 17 June 1949 Mr H. M. Cooper drew my attention to an old mangrove mud-flat recently exposed by wave scouring. The site is situated between Broadway and Weewanda Street, Glenelg, and extends for a distance of about a quarter of a mile. At low tide the mangrove flat is exposed from almost the water's edge for a distance of some twenty yards up the beach, and then follows an old quartzite pebble beach some three yards in average width, and then fine sand of the present beach.

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[Read 11 August 1949]

On 17 June 1949 Mr. H. M. Cooper drew my attention to an old mangrove mud-flat recently exposed by wave scouring. The site is situated between Broadway and Weewanda Street, Glenelg, and extends for a distance of about a quarter of a mile. At low tide the mangrove flat is exposed from almost the water's edge for a distance of some twenty yards up the beach, and then follows an old quartzite pebble beach some three yards in average width, and then fine sand of the present beach.

Dead trunks, roots and pneumatophores of the mangrove, *Avicennia officinals* are to be seen in numbers planed off level with the mud surface by gentle tidal action, leaving sections exposed. Numerous dead shells are embedded in the mud in their living position. They are species similar to those found at the Port River mangrove flats today. The bivalves are *Macoma deltoidalis, Macoma modestina, Venerupis crebrelamellata, Venerupis crenata, Soletellina biradiata, Eumarcia fumigata, Notospisula parva, Pholas australasiae* and *Nototeredo edax.* Gastropods are *Bembicium imbricatum, Zeacumantus diemenensis, Austrocochlea zebra, Salinator fragilis, Uber conicum, Phasianella australis.* In addition to these there are reef shells such as *Cleidothaerus albidus, Ostrea sinuata, Brachyodontes erosus, Cominella eburnea, Trichomya hirsuta* and *Melanerita melanotragus.* The reef shells apparently attached to or lived upon the hard sandstone capping, two or three inches thick, found in patches on top of the black mud. Odd samples of the sandstone are covered with young dead "Port Lincoln" oysters of the species mentioned above. Dead specimens of the "shipworm" *Nototeredo edax* are found in practically every mangrove stump examined.

Certain species of mollusca found *in situ* are larger than present-day living specimens. *Bembricium imbricatum* averages over twice the bulk of living examples. *Austrocochlea zebra* is taller and the mussel *Brachyodontes* is consistently slightly larger. Mangrove flats throughout Australia have a similar fauna and show little alteration in different faunal regions, except that produced by lower temperatures. The result is that the large species of the North are missing in the South, and even the species common to all mangrove areas become smaller in cooler waters. Therefore it is logical to expect that the mangrove mud-flat here exposed enjoyed a slightly warmer climate in its day. Mangroves are gradually retreating north in Gulf St. Vincent. Whereas there is every indication from faunal studies that the mangrove lived until a comparatively short time ago on both sides of the present beach sand dune as far south as Port Noarlunga, it has now retreated north to the region of the Outer Harbour mud-flats. Here within the last twenty years silting has killed them over most of the large area which is shortly to be reclaimed for harbour works.

The recently exposed site was rapidly desiccated by tidal action. It was first examined on 17 June. On 19 June it was partly covered by weed (*Posidonia*). By 24 June the pebble reef was mostly covered with sand over its full length, and the sand has already thinly covered a large portion of the mangrove flat.

* South Australian Museum.

By August 15th the scoured area was almost entirely covered with a smooth layer of fine sand like that so typical of Adelaide beaches.

It was ascertained by digging on 3 February 1950 that a minimum average of twenty inches of sand covered this site.

The shells could not remain *in situ* very long when exposed for a week after 17 June. They were already being washed out of the soft black mud. A fisherman, Mr. F. Page, says that a small portion of mangrove flat, about 50 yards long and 20 yards wide, was exposed in front of Weewanda Street in January 1949.

Behind the present sand-dunes, in the area known as New Glenelg, fresh water is struck at about 12 feet in a quartzite pebble bed, which is situated at about the same level as the quartzite bed of the beach. This pebble bed evidently continues almost to the foot of the old red sandhills, which stretch from Somerton to Glenelg in an almost uninterrupted sequence and are exposed near Brighton Road, Sacred Heart College, and at the corner of the College playing fields near Walker's Road. The western edge of the red sand-dunes runs north and south and a little west of Moseley Street. They were merely low ridges about 15 feet in maximum height, but buildings, roads and other influences have now obliterated traces in most areas. In June 1948 scouring took place at Brighton, and the surface sand was removed to a depth of four feet, exposing in places the top of the black mud. The vertebrae and ribs of a whale skeleton were revealed *in situ*. The discovery was reported by Mrs. E. M. Nairn of Brighton. The Director of the South Australian Museum, Mr. H. M. Hale, identified the skeleton, which is in a poor state of preservation, as a whale-bone whale, probably a hump-back. It is possible that the skeleton is contemporary with the mangrove flat. It is suggested that the mangrove flat and quartzite reef may be contemporary with the old red sandhills. It is difficult to decide whether the pebbles are of coastal origin or indicate an old opening of the Sturt River. The occurrence of cross-bedded red sandstone typical of the Adelaide system favours an origin consistent with sea-shore transportation as rocks of this group outcrop in the sea-cliff regions from Marino South. Such rocks do not outcrop in the valley of the River Sturt.

It is interesting to note that a sketch of this area by Colonel Light in about 1836 depicts the beach pretty well as at present, the coastal dunes probably bound with true spinifex (*Spinifex hirsutus*), *Olearia* and other dune vegetation, as they are today. The dunes are 250 yards wide and up to 30 to 50 feet in height, sloping to high water level towards sea. Streets and buildings now cover portion of the inner edge of what is really an unbroken dune ridge.

A test bore shows mangrove mud to be about two feet in thickness followed by glauconitic clay, then sand, but no rock. This suggests that the mangroves flourished for only a comparatively short period.

It may be that the unusual scouring of the beach in this area first commenced when the artificial projection of the Broadway sea-wall was built in 1928. The bottom of this sea-wall is just below high-tide mark. The scouring was strongly accentuated during a heavy sea in April 1948 when H.M.A.S. "Barcoo," survey frigate, was driven ashore at Glenelg North. From then on the scouring continued for about twelve months, exposing the first small portion of mangrove flat in January 1949, mentioned by F. Page.

Mr. A. G. Edquist kindly directed my attention to the sequence of strata exposed in a recently excavated drainage well. Situated on a property in Farrell Street at about 200 yards from high tide mark, the excavation has reached a depth of six feet. The uppermost layer is of black swamp silt which may have been originally dune sand and vegetation, and is about twelve inches in thickness. Next follows a limestone band, six inches thick, apparently contemporary with that of the oyster bed in the mangrove flat.

Beneath this is two feet of yellow sand. Under the sand is about six inches of light coloured mud and sand in which is an abundance of *Coxiella* shells similar to those found in such quantity in the Coorong and around inland salt lakes.

Beneath is the black mud of the mangrove swamp with the cockle *Katelysia* and other marine shells of the mangrove suite.

This sequence, situated in the swale behind the present beach-dunes, presents an interesting contrast to the wave-scoured site on the beach front.

Some years ago a fresh water swamp existed here which accounts for the black swamp-silt resting above the limestone. The fine yellow sand beneath the limestone may be beach dune-sand. The *Coxiella* mud suggests a salt-lake with changing salinity as these molluscs flourish in changing salt concentrations, from water salter than the sea to almost fresh. Beneath this is the mangrove mud-flat.

On 9 February 1950 a similar though smaller site at Henley Beach, just north of the River Torrens outlet, was brought to my notice by Mr. C. V. Fischer. He states that the scouring was first observed about April 1948, with which date the heavy scouring at Glenelg corresponds.

H. M. Cooper intends to describe later some of the native stone implements and other material discovered by him on the site.

Conclusion

The mangrove mud-flat recently exposed by wave-scouring flourished for a short period from, say, one thousand to three thousand years ago when the climate was a little warmer, and may have been contemporary with the old red sand-hills. The mangroves were comparatively quickly exterminated by sand-silting. This process is now proceeding at the Outer Harbour, and has previously killed the mangroves which once grew as far south as Port Noarlunga.

FOSSIL OYSTERS USED FOR ROAD METAL

BY BERNARD C. COTTON

Summary

Deposits of fossil oysters occur in certain areas near the River Murray. The photograph on pl. viii, fig. 2, shows oysters from an excavation made near the Swan Reach – Loxton road about two miles north of Swan Reach. The area so far dug out is about 50 feet in diameter and the sides display a compact mass of oysters, Ostrea sturtiana Tate (? = O. arenicola Tate), 15 feet in thickness and extending to within twelve inches of the surface which is of travertine limestone. The matrix becomes harder at the base, so that excavations have not beeen continued deeper than 15 feet. The oyster bed apparently continues further down. From a superficial examination it seems probable that the deposit may extend for at least three miles inland from the Murray River, the present site being within a hundred yards of the Murray cliffs. It was not observed on the face of the cliffs at this point as they are difficult of access and the normal section may have been covered by earth or sand falls.

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Among the millions of oysters exposed only a few other Pliocene Molluscs were noted. There were two impressions of *Proxichione cognata* Pritchard, a *Mimachlamys antiaustralis* Tate and what may have been a *Milthoidea hora* Cotton. The common Gastropod of the Lower Pliocene (Adelaidean) *Neodiastoma provisi* Tate was not seen during the brief examination. The oysters are being dug out in order to surface about ten miles of the adjacent Swan Reach - Loxton Road and specimens spread on the road directly from the deposit are shown on pl. viii, fig. 2. It will be noticed that the shells vary from the narrow shape of *O. sturtiana* which occurs in "the upper part of the River Murray cliffs from Overland Corner to beyond Blanchetown" (Tate), to the rounder *O. arenicola* Tate described from the "Upper Beds at Aldinga" regarded as Lower Pliocene. A similar variation may be seen in the living *Ostrea sinuata* Lamarck or Port Lincoln Oyster. Another oyster bed of the same age is to be seen at Loxton at and below river level, exposed in the Murray cliffs in the new Engineering and Water Supply pumping station cutting. In this exposure occur *Ostrea sturtiana* Tate, *Plebidonax depressa* Tate, both originally described from the "oyster beds at Nor'-west Bend, River Murray," *Tylospira marwicki* Finlay and *Glycymeris* (*Tucetilla*) *rota* Cotton from the "Adelaidean" and *Uber balteatellum* Tate, and *Anapella variabilis* Tate, both described from the Upper Beds at Halletts Cove and all common species of the Adelaidean and also *Leiopyrga quadricingulata* Tate and *Cucullaea praelonga* Singleton from the Upper Beds of Muddy Creek, all belonging to the Lower Pliocene. There is a large vertebra of a whale amongst the material examined from the Loxton site.

* Palaeontologist, Department of Mines.

Fig. 1
Mangrove-flat looking north, showing the sea-wall projection at Broadway (top right), the sea, mangrove-flat, quartzite pebbles and present sand.

Fig. 2
Mangrove stumps and shells embedded in mud.

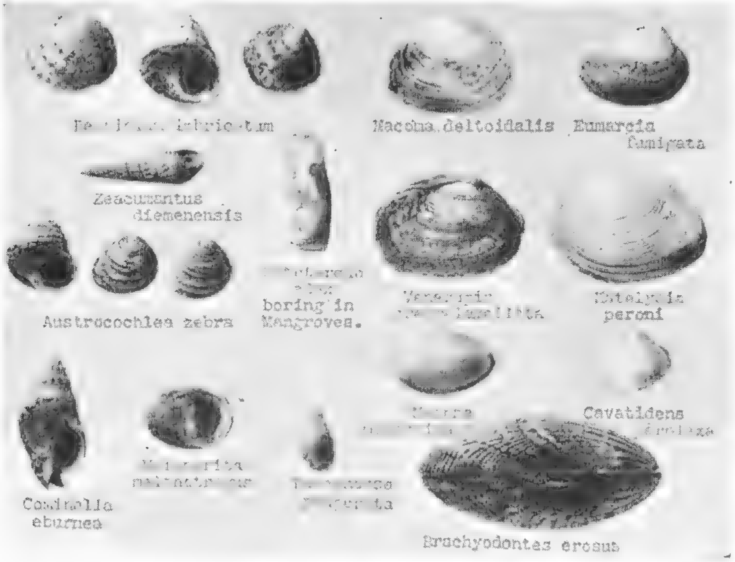

Fig. 1
Suite of shells from mangrove flat.

Fig. 2
Oysters from excavation, spread on road near Swan Reach.

SOME NEMATODES FROM AUSTRALIAN HOSTS, TOGETHER WITH A NOTE ON RHABDITIS ALLGENI

BY T. HARVEY JOHNSTON AND PATRICIA M. MAWSON

Summary

The nematodes examined for this report are recent additions to the helminth collection in the Zoology School of the University of Adelaide. They were, unless otherwise acknowledged, collected by the senior author. Included in the paper are references to some genera and species of Australian nematodes discussed recently by C. C. Kung (1948).

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By T. Harvey Johnston and Patricia M. Mawson*

[Read 11 August 1949]

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Types of the new species are being deposited in the South Australian Museum. We desire to acknowledge assistance in regard to material from Messrs. V. Haggard, Director of the Adelaide Zoological Gardens; G. G. Jaensch and L. Ellis of Tailem Bend; H. M. Cooper of the South Australian Museum; Bruce Shipway of the C.S.I.R.O., Western Australia; M. Blackburn, Fisheries Division, C.S.I.R.O.; as well as Dr. P. O. Flecker and Mr. J. Wyer of the North Queensland Naturalists' Club, Cairns.

The work was carried out in connection with the Commonwealth Research Grant to the University of Adelaide.

LIST OF HOSTS AND PARASITES

Fish

Aracana flavigaster (Gray). *Capillaria* sp., Glenelg, S. Aust.

Pagrosomus auratus Bloch. *Cucullanellus sheardi* J. and M., Outer Harbour, S. Aust.

Ophthalmolepis lineolatus C. and V. *Cucullanellus sheardi* J. and M., Kangaroo Island, S. Aust.

Lovettia sealii (Johnston). *Stomachus marinus* L., Tasmania.

Amphibia

Hyla peroni (Bibron) Tschudi. *Oswaldocruzia limnodynastes* Johnston and Simpson, Strathalbyn, S. Aust. *Physaloptera confusa* J. and M. (larval stage), Tailem Bend, S. Aust.

Limnodynastes tasmaniensis Gunther. *Physaloptera confusa* J. and M., larval stage, Tailem Bend, S. Aust.

Birds

Podiceps cristatus Linn. *Capillaria* sp.; and *Contracaecum podicipitis* n. sp., Tailem Bend, S. Aust.

Anas superciliosa Gmelin. *Tetrameres fissispina* (Dies.), Tailem Bend, S. Aust.

Mammals

Potorous tridactylus (apicalis) Kerr. *Austrostrongylus potoroo* n. sp.; and *Labiostrongylus eugenii* J. and M., King Island, Bass Strait, Tasmania.

Macropus tasmaniensis Le Souef. *Labiostrongylus longispicularis* Wood, Tasmania.

Macropus ocydromus Gould. *Dipetalonema roemeri* (Linst.), South-western Australia.

Macropus agilis Gould. *Labiostrongylus insularis* (J. and M.); *Cloacina digitata* J. and M.; and *Dipetalonema roemeri* (Linst.), all collected by Dr. P. Flecker from Brooklyn Station, Cairns district, North Queensland.

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* University of Adelaide.

Bos TAURUS L. *Onchocerca gibsoni* Clel. and Jnstn., North-eastern S. Aust.

RATTUS NORVEGICUS Erxl. *Trichosomoides crassicauda* Bellingham; *Capillaria hepatica* (Bancr.); *Protospirura muris* Gmelin; and *Syphacia obvelata* (Rud.), Adelaide, S. Aust.

RATTUS RATTUS Linn. *Capillaria hepatica* (Bancr.); *Protospirura muris* and *Syphacia obvelata* (Rud.), Adelaide, S. Aust.

MUS MUSCULUS Linn. *Aspicularis tetraptera* (Nitzsch); *Protospirura muris* (Gmel.); and *Capillaria hepatica* Bancr., Adelaide, S. Aust.

LEPUS CUNICULUS Linn. *Trichostrongylus retortaeformis* (Zed.); *Graphidium strigosum* (Duj.); and *Passalurus ambiguus* (Rud.), from various South Australian localities.

CAPILLARIA spp.

Collections of *Capillaria* spp. were made from two hosts. In both cases the data available were not sufficient to identify the species. As both are new host records for the genus, the available morphological points are noted below:

(1) *Capillaria* sp. from *Podiceps cristatus*, Tailem Bend. One male present, 10·1 mm. in length. Ratio between oesophageal and intestinal regions 1:1·12. Spicule 11 mm. long, sheath not spinose, but spirally striated. Sheath is extruded in the only specimen, and the bursa, if present, was not observed.

(2) *Capillaria* sp. from the cowfish, *Aracana flavigaster*, from Glenelg, S. Aust. Material consists of one whole male and one part, the length of the whole specimen being 6·1 mm., and the ratio of the anterior and posterior parts of the body being 1:0·85. The "bursa" consists of two small lobes posterior to the cloaca. The spicule is ·13 mm. long.

CAPILLARIA HEPATICA (Bancroft)

The characteristic lesions caused by this species, together with its eggs, have been found in *Rattus rattus*, *R. norvegicus*, and *Mus musculus* in the Adelaide district. The parasite had not been recorded previously as occurring in South Australia.

TRICHOSOMOIDES CRASSICAUDA (Bell)

This parasite was found in the bladder of laboratory-bred white rats, *Rattus norvegicus* var. in Adelaide. It has already been recorded by one of us from Eastern Australia.

Austrostrongylus potoroo n. sp. (fig. 1-5)

Numerous coiled reddish to colourless Trichostrongyle worms were taken from the intestine of a rat-kangaroo, *Potorous tridactylus* (*apicalis*), from King Island, Bass Strait. The animal was sent to us by the Adelaide Zoological Gardens. Both male and female worms are 3 to 3·4 mm. in length. The cervical cuticle is dilated and marked with annular striations, the rest of the body cuticle being smooth except for two narrow (lateral) and two wide (dorsal and ventral) longitudinal bands which are transversely striated. These bands become narrower and tend to disappear towards the end in both sexes. The buccal capsule is distinct, the eversible dorsal tooth occupying most of the cavity. Two very small ventral teeth are present. The oesophagus is about ·28 mm. long.

The spicules of the male are ·21-·25 mm. long. The gubernaculum is poorly chitinised. As it proved impossible to obtain a view of the bursa with the lobes spread open, the symmetry of this structure has not been established, but in lateral views right and left lobes appear similar. The form of the rays is shown in fig. 5

The vulva of the female is ·24 mm. anterior to the tip of the tail. Behind this the body narrows rapidly to a finely pointed tail, ·15 mm. in length. The eggs in the vagina are 40μ by 70μ.

The species apparently differs from others of the genus in the form of the dorsal ray, which was constant in all the specimens examined, and in the more backward position of the vulva. The specific name proposed is the native name for this small marsupial.

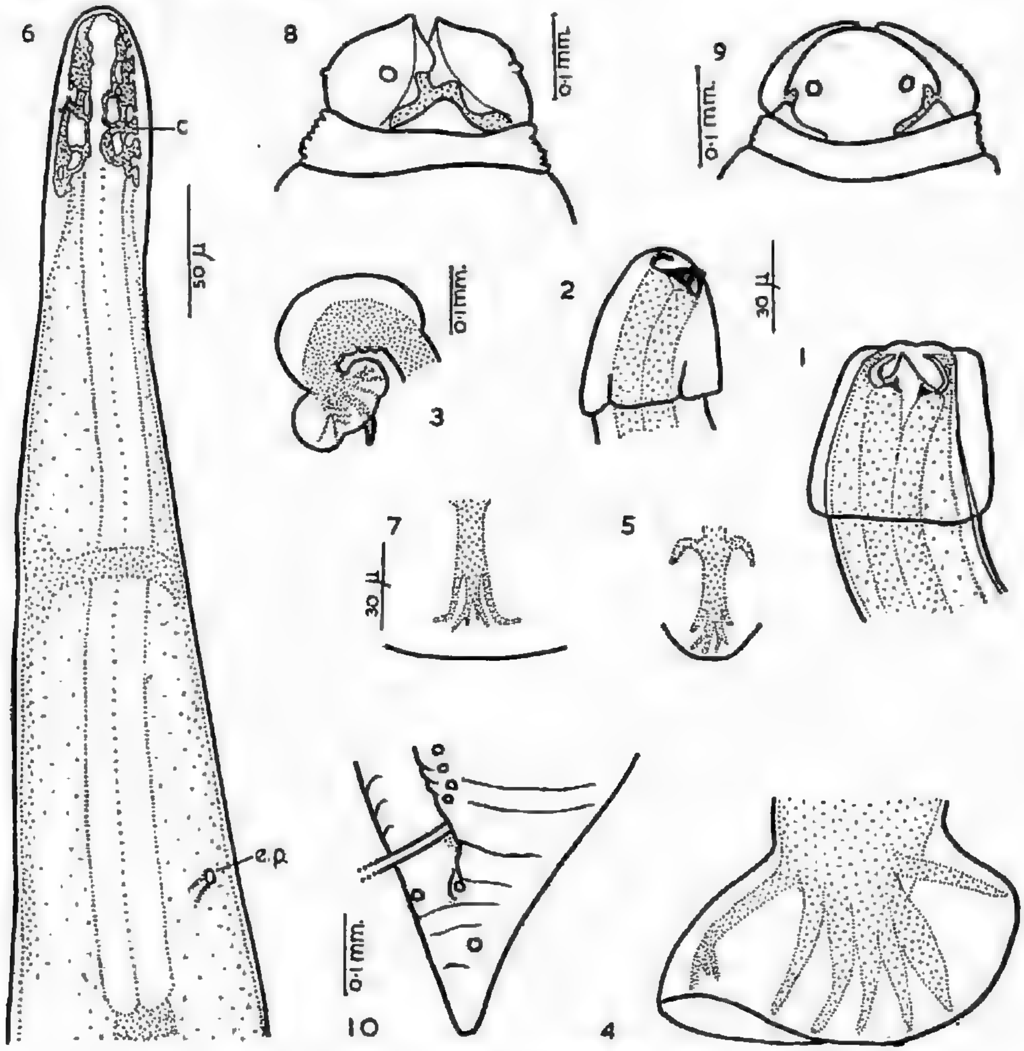

Fig. 1-10

Fig. 1-5, *Austrostrongylus potoroo*—1, anterior end; 2, anterior end with dorsal tooth protruding; 3, posterior end showing expanded cuticle; 4, lateral view of bursa; 5, dorsal ray. Fig. 6-7, *Oswaldocruzia limnodynastes*—6, anterior end; 7, dorsal ray. Fig. 8-10, *Contracaecum podicipitis*—8, and 9, sublateral and dorsal views of head; 10, male tail. Fig. 1 and 2 and 5 drawn to scale beside 2; fig. 4 and 6 to scale beside 6.

OSWALDOCRUZIA LIMNODYNASTES Johnston and Simpson (fig. 6-7)

This species, originally recorded from *Limnodyastes dorsalis* from Adelaide, has now been recognised from *Hyla peroni* from Strathalbyn, collected by Miss L. M. Angel. The material consists of one female, one whole male and one broken male. These agree in general features with the original description, but two minor variations have been noted; firstly the shape of the dorsal ray in which the terminal bifurcation occurs nearer the root, and secondly, chitinisation in the cephalic region. This latter is in the form of a dorsal and a ventral "porose" plate, lying in the inflated cuticle. The structure was seen only in the male specimen; the anterior end of the female is greatly contracted so that observation is in any case difficult. No mention of such chitinisation has been met with in the literature available, although it is probably a development of the "vesicular structure" noted by Morishita (1926, 14) in the inflated cervical cuticle of members of the genus. These two differences occurring as they do in only one specimen, are not considered sufficient evidence to indicate another species. Figures 6 and 7 illustrate these points.

TRICHOSTRONGYLUS RETORTAEFORMIS (Zeder)

Not uncommon in rabbits collected in the vicinity of Adelaide.

GRAPHIDIUM STRIGOSUM (Duj.)

Found occasionally in the stomach of South Australian rabbits.

The genus LABIOSTRONGYLUS Yorke and Maplestone

It has been suggested by Kung (1948, 105) that the genus *Labiostrongylus* Y. and M., 1926, was erroneously synonymised with *Zoniolaimus* Cobb by us (1939, 123). On re-examination of the evidence, we are in agreement with Kung's view.

LABIOSTRONGYLUS EUGENII (J. and M.)

From *Potorous tridactylus*, King Island. Numerous worms were found in the stomach of a rat-kangaroo which reached us by courtesy of the Director of the Adelaide Zoological Gardens. They agree generally with *L. eugenii*, differing slightly in the more forward position of the accessory lobes on the submedian lips.

LABIOSTRONGYLUS INSULARIS (J. and M.)

From the stomachs of the northern wallabies, *Macropus* (*Wallabia*) *agilis* from the Cairns district, North Queensland, collected by Dr. P. Flecker. Previously known only from *M. welsbyi* from Stradbroke Island, Southern Queensland.

CLOACINA DIGITATA J. and M.

From the stomach of *Macropus agilis*, Cairns district, North Queensland, collected by Dr. P. Flecker. Previously known from *M. dorsalis*, Burnett River, Queensland.

The genus ZONIOLAIMUS Cobb 1898

In a recent paper Kung (1948) suggested that three species placed by us under the genus *Buccostrongylus* J. and M. (1939, 140; 139a, 526-7) should be referred more correctly to *Zoniolaimus* Cobb. These species are *B. australis* *B. buccalis*, and *B. labiatus*, of which the first was cited by us as the type species of *Buccostrongylus*. We agree with Kung that the latter genus is therefore synonymous with *Zoniolaimus* Cobb. *Buccostrongylus setifer*, subsequently described by us (1939a, 527), from *Macropus ruficollis* becomes *Zoniolaimus setifer* (J. and M.), but as this name is preoccupied by *Z. setifera* Cobb 1898 (with which it is not conspecific) a new name, *Z. chaetophorus* is proposed for it.

ZONIOLAIMUS LONGISPICULARIS (Wood)

This stout nematode has been identified from material collected from the Forester kangaroo, *Macropus tasmanienus*, near Ross, Tasmania, and sent to us in 1947 by the Tasmanian Museum. We had previously reported it as occurring in that State (J. and M., 1940, 469) but no locality was mentioned. The parasite is known to occur in wallabies or kangaroos in Queensland, New South Wales, Victoria, South Australia, Central Australia, North-western Australia and Tasmania (Johnston and Mawson 1938, 268-9).

Contracaecum podicipitis n. sp. (fig. 8-10)

A small collection of worms from a crested grebe, *Podiceps cristatus,* taken at Tailem Bend, was found to be referable to this large genus of nematodes.

Males and females up to 25 mm. in length were present. The head is shorter than wide. Each lip bears two lateral flanges; in the midlength of each flange is a well-defined indentation (fig. 8, 9). There are no denticles. The interlabia are very short. The oesophagus is 1:4·8 of the body length; the oesophageal appendix and intestinal caecum are 1:3 and 1:1·3 respectively of the length of the oesophagus.

In the male, the spicules are 3·1 mm. long, 1:6·5 of the body length. There are at least 34 pairs of preanal papillae, but only two small postanal pairs were seen (fig. 10).

The presence of very short interlabia is somewhat unusual in the genus *Contracaecum.* In the literature available to us the bird-parasitic species described as having this character are *C. ovale* (Linst.) from *Podiceps cristatus, C. praestriatum* Mönnig from *Podiceps capensis,* and *C. torquatum* Yamaguti from *Larus canus.* The present specimens differ from *C. torquatum* in the absence of labial denticles, and from *C. ovale* and *C. praestriatum* in the shape of the lips and in the greater length of the spicules.

Cucullanellus sheardi J. and M.

This species appears to be common in fish in Australian waters (J. and M. 1944, 64; 1945, 116). It is now recorded from *Ophthalmolepis lineolatus* from Kangaroo Island and *Pagrosomus auratus* from Outer Harbour, both caught by H. M. Cooper.

Tetrameres fissispina (Diesing) (fig. 11-19)

Adult males and females and young worms, agreeing in most features with *Tetrameres fissispina,* were taken from the black duck, *Anas superciliosa,* at Tailem Bend. As this widely spread parasite has not previously been recorded from a native bird in Australia, a description of the present specimens is given here.

There are, as indicated in the more recent descriptions of the species, two trilobed lateral lips, not three lips as in older accounts. The buccal capsule is barrel-shaped in the female, more cylindrical in the male.

The females are from 1·7 mm. to 2·0 mm. in length, and from ·4 to 1·4 mm. in width, according to the number of eggs present. On the female there are no spines except the cervical papillae which are ·22 mm. from the anterior end and lie just in front of the nerve ring in a specimen 2 mm. long. The buccal capsule is 30μ long, and 23μ in internal diameter at its midlength. The tail, ·1 mm. long in a female 1·7 mm. in length, ends in a simple point. The vulva is ·2 mm. in front of the anus. Most of the smaller specimens have been damaged during collection, so the form of the reproductive organs has not been studied. The eggs measure 20μ by 30μ.

The males are from 2·8 to 4·2 mm. in length. Anteriorly the lateral alae may give the appearance of cordons as noted by Wehr (1933). The "long bifid spines" on each side mentioned by some authors (Seurat; Canavan) appear to be, at stated by Wehr (1933) and Hsü (1935), modifications of the lateral alae which in this region are supported by rod-like cuticular thickenings (fig. 11).

The cervical papillae, 1·2 mm. behind the anterior end, are small but distinctly tricuspid, an observation not as far as we know recorded for *T. fissispina.*

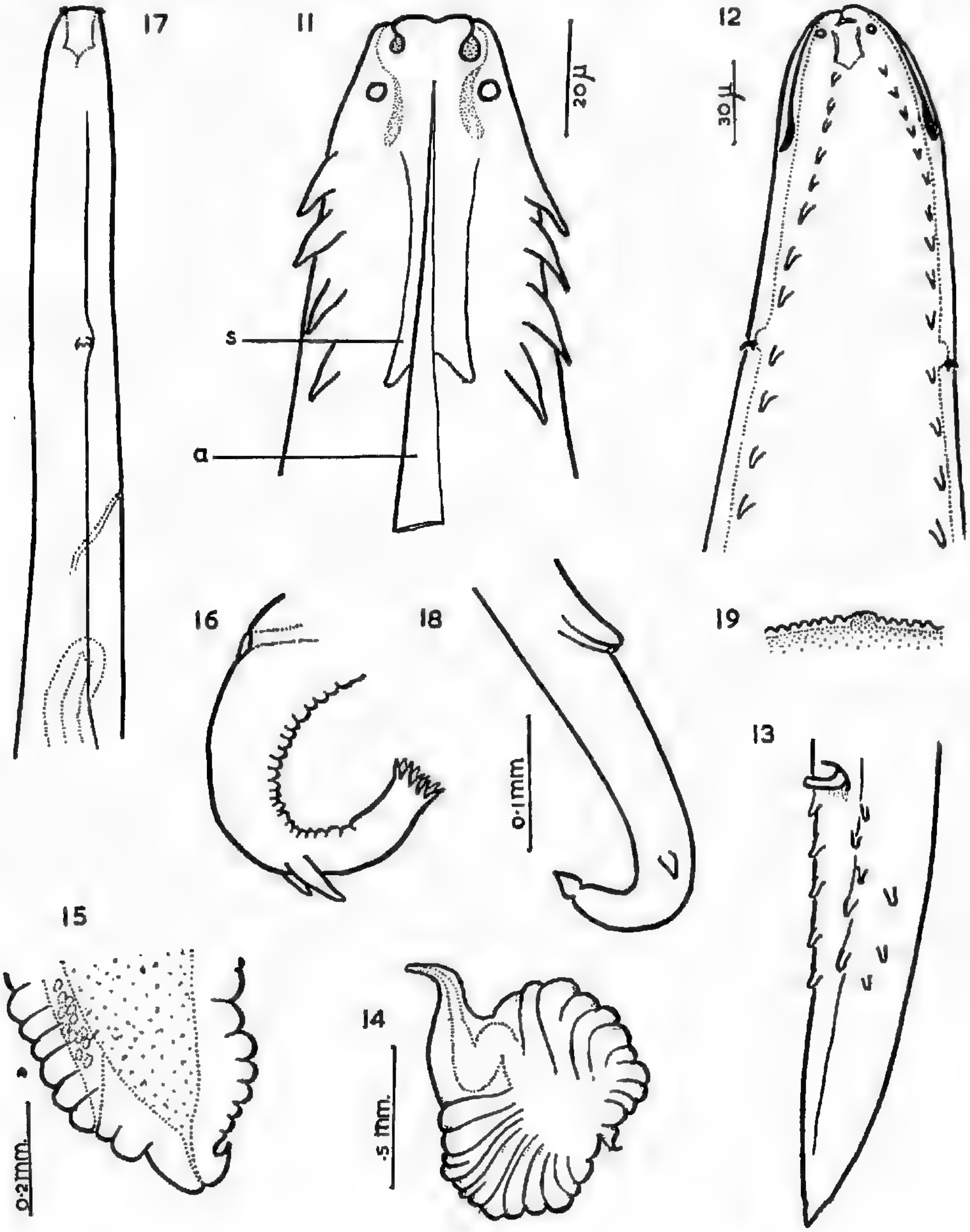

Fig. 11-19

Fig. 11-19, *Tetrameres fissispina*—11 and 12, lateral and ventral views of male; 13, male tail; 14, mature female; 15, tail of young adult female; 16, posterior end of fourth stage larva; 17, anterior end of young fifth stage; 18, posterior end of young fifth stage; 19, lateral ala of young fifth stage worm showing one of the asymmetrical "larval" papillae. Fig. 13, 16, 17, 18 and 19 drawn to scale beside 18.

Fig. 11-19

The body spines commence at the level of the posterior end of the vestibule and are arranged in four sublateral rows. These continue past the midlength of the body, and then become smaller and more sparse. The dorsolateral spines disappear in the hinder part of the body but the ventrolaterals become larger and more numerous, forming two rows of preanal papillae. Postanally there are five pairs of submedian and three pairs of lateral papillae (fig. 13). The tail ends in a small highly cuticularised point. The spicules are ·11 to ·15 mm. and ·3-·45 mm. in length respectively.

Several very young worms, in the early fifth stage, are present. They are from ·95 to 1·4 mm. in length. The cuticle is without annulations or spines except for the large trifid cervical papillae ·1 mm. from the head. The lateral alae are present, though very narrow, and extend from the head to the anus. The tail is ·12 mm. long, and a pair of elongate caudal papillae lie 70μ behind the anus. The tail ends in a pyriform "tail piece" (fig. 18), an exaggerated form of the caudal tip of the adult male. The vestibule is cylindrical, 10μ long and 8μ wide. The excretory pore is about 50μ behind the cervical papillae. As sometimes occurs in young worms, a pair of lateral papillae are present at about a third of the body length from the tail (fig. 19). Three fourth stage larvae are also present. These are easily distinguished from the fifth stage by the form of the caudal extremity which ends bluntly about 80μ behind the anus, the extremity being surrounded by about twelve large spines. The body length is 1·2-1·4 mm., the cervical papillae are hardly distinguishable, and the lateral alae scarcely developed. There is a pair of large caudal papillae, 70μ from the posterior end of the body, that is, in a similar position to those in the young fifth stage, but very much larger. We have referred to these two stages as fifth and fourth respectively, rather than fourth and third, since they were found in the intestine of the definitive host.

Onchocerca gibsoni Cleland and Johnston

Mr. L. Reese. of Miranda Station in the far north-eastern portion of South Australia and adjacent to the Queensland border, informed the senior author that this "nodule worm" parasite occurred in the brisket of locally bred cattle. This is the first record of the occurrence of the parasite in this State, apart from infections in Abattoirs cattle from Queensland.

Physaloptera confusa J. and M.

The larval stage, enclosed in its typical heavily pigmented black cyst has been found in *Limnodynastes tasmaniensis* and *Hyla peroni* from Tailem Bend, South Australia.

Protospirura muris (Gmelin)

From *Rattus norvegicus, R. rattus* and *Mus musculus* in the vicinity of Adelaide. Already reported by one of us as occurring in these hosts in Eastern Australia.

Dipetalonema roemeri (Linst.)

Mr. Bruce Shipway, of the C.S.I.R.O. in Perth, forwarded specimens of this Filariid species from kangaroos, *Macropus ocydromus,* from the south-western region of Western Australia. This grey kangaroo is closely related to *M. major,* which has a very wide distribution in Australia. Mr. Shipway reported finding it in about 60% of the Western Australian kangaroos examined by him. We redescribed it in 1938 (1938, 111-112). We now record it also from *Macropus agilis,* from Brooklyn, Cairns district, North Queensland, collected by Dr. P. Flecker.

Syphacia obvelata (Rud.)

From *Rattus rattus* and *R. norvegicus* from the vicinity of Adelaide. Previously recorded from these host species elsewhere in Australia.

Aspiculuris tetraptera (Nitzsch)

Found occasionally in mice in Adelaide.

Passalurus ambiguus (Rud.)

This oxyurid is seen occasionally in South Australian rabbits. It has not been recorded previously as occurring in this State.

Stomachus marinus (Linn.)

This larval anisakid has been recorded from several Australian marine fish. We now report it from the Tasmanian Whitebait, *Lovettia scalii*, from the Derwent River, the material having been submitted by Mr. Maurice Blackburn of the Fisheries Division of the C.S.I.R.O.

A Note on Rhabditis allgeni Johnston

In 1893 Cobb described *R. australis* from grass roots in New South Wales. Allgen (1932, 192) used the same name for a different nematode from Campbell Island (Subantarctic). Johnston (1938, 151) renamed the latter *R. allgeni*. Allgen, apparently unaware of Johnston's action, has proposed recently (1948) a new name, *R. campbelli*, for his species. *R. campbelli* is thus a synonym of *R. allgeni*, of which *R. australis* Allgen 1938 nec Cobb 1893 is also a synonym.

SUMMARY

1. Known species of nematodes are recorded from additional hosts and localities.
2. *Austrostrongylus potoroo* from a marsupial, *Potorous tridactylus*, from King Island, Bass Strait; and *Contracaecum podicipitis* from the crested grebe, *Podiceps cristatus*, from South Australia, are described as new.
3. *Zoniolaimus setifer* (Johnston and Mawson 1940) nec Cobb 1898 is renamed *Z. chaetophorus*.
4. *Tetrameres fissispina* (Dies.) is described from an Australian duck, *Anas superciliosa*.
5. The free living nematode species, *Rhabditis campbelli* Allgen, from Campbell Island, is a synonym of *R. allgeni* Johnston.

LITERATURE

Allgen, C. 1932 Nyt. Mag. Oslo, B, 1932, 192-194

Allgen, C. 1948 Arkiv f. Zool., **39**, (3), B (2), 1947 (1948), 1-4

Cobb, N. A. 1893 Macleay Memorial Vol. (Linn. Soc. N.S.W.), 252-308

Cobb, N. A. 1898 Agr. Gaz. N.S.W., **9**, 296-321, 491-454

Hsü, H. F. 1935 Z. f. Parasitk., **7**, 578-600

Johnston, T. H. 1938 Trans. Roy. Soc. S. Aust., **62**, 149-167

Johnston, T. H., and Mawson, P. M. 1938 Trans. Roy. Soc. S. Aust., **62**, 107-121

Johnston, T. H., and Mawson, P. M. 1938 Trans. Roy. Soc. S. Aust., **62**, 263-286

Johnston, T. H., and Mawson, P. M. 1939 Trans. Roy. Soc. S. Aust., **63**, 121-148

JOHNSTON, T. H., and MAWSON, P. M. 1939a. Proc. Linn. Soc. N.S.W., **64,** 513-536

JOHNSTON, T. H., and MAWSON, P. M. 1940 Proc. Linn. Soc. N.S.W., **65,** 468-476

JOHNSTON, T. H., and MAWSON, P. M. 1944 Trans. Roy. Soc. S. Aust., **68,** 60-66

JOHNSTON, T. H., and MAWSON, P. M. 1945 Trans. Roy. Soc. S. Aust., **69,** 114-117

JOHNSTON, T. H., and SIMPSON, E. R. 1942 Trans. Roy. Soc. S. Aust., **66,** 172-179

KUNG, C. C. 1948 Jour. Helminthol., 22, 93-108

MORISHITA, K. 1926 Jour. Fac. Sci. Imp. Univ., Tokyo, **1,** (4), 1-32

EARLY CAMBRIAN "JELLYFISHES" OF EDIACARA, SOUTH AUSTRALIA AND MOUNT JOHN, KIMBERLEY DISTRICT, WESTERN AUSTRALIA

BY REG C. SPRIGG

Summary

The richly fossiliferous horizon within the Pound Sandstone, near the base of the Cambrian in South Australia, has provided more new material. With the additional specimens it has been possible to classify several new forms with considerably more reliability. Some very close resemblances with modern genera have been established and the classification of most forms as coelentrates and even as members of either the Hydrozoa or Scyphozoa seems beyond question. One specimen is remarkably similar to the modern Dipleurosoma. A form from an equivalent horizon in the Kimberley or North-West Division of Western Australia collected by Dr A. Wade is also described and included within the Hydrozoa. This latter remarkable form buds daughter medusae at its margin very similarly to the living Niobia dendrotentacula.

EARLY CAMBRIAN "JELLYFISHES" OF EDIACARA, SOUTH AUSTRALIA AND MOUNT JOHN, KIMBERLEY DISTRICT, WESTERN AUSTRALIA

By REG. C. SPRIGG *

[Read 8 September 1949]

ABSTRACT

The richly fossiliferous horizon within the Pound Sandstone, near the base of the Cambrian in South Australia, has provided more new material. With the additional specimens it has been possible to classify several new forms with considerably more reliability. Some very close resemblances with modern genera have been established and the classification of most forms as coelenterates and even as members of either the Hydrozoa or Scyphozoa seems beyond question. One specimen is remarkably similar to the modern *Dipleurosoma.* A form from an equivalent horizon in the Kimberley or North-West Division of Western Australia collected by Dr. A. Wade is also described and included within the *Hydrozoa.* This latter remarkable form buds daughter medusae at its margin very similarly to the living *Niobia dendrotentacula.*

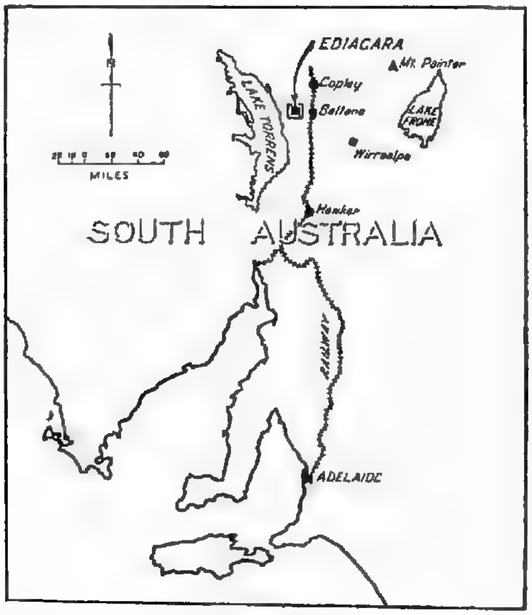

Fig. 1

INTRODUCTION

Since the original discovery and publication of a short report on supposed jellyfish from Ediacara in South Australia, the locality has been visited by Sir D. Mawson and a party of students from the Adelaide University, and again by the writer accompanied by Dr. Curt Teichert. Altogether much new material has been forthcoming, and now nearly 100 fine specimens of (?) pelagic fossils are available from the locality.

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As far as could be ascertained, all the forms collected by the writer came from a single stratigraphic horizon or within a few feet of it. Obviously the particular parting in the fissile quartzites in which the forms occurred is packed with such impressions. The author collected more than 50 specimens in less than three hours, indicating the abundance of the forms. The horizon has been traced for about three miles on the western side of an elongated synclinal basin. Several distinct new forms were discovered, and a form originally described from a single specimen (*Dickinsonia costata*) has proved particularly common. Professor Mawson has indicated that he found evidence of two distinct fossiliferous horizons (personal communication) in the northern extensions of the fossil occurrences.

There can now be no doubt as to the fossils' organic origin, nor can there be any hesitation in placing many of the forms with either the Hydrozoa or Scyphozoa of the Coelenterata. Some forms are referable to Algae, but these will not be described in this paper.

In the previous paper (1947) it was postulated that the environmental associations of the fossils and the local palaeogeography demonstrate tidal flat or at least coastal conditions. This opinion still holds, and practically all forms yet discovered appear to be pelagic; some were obviously free swimming. Such a state of affairs is in keeping with general theories of life at the end of the Precambrian. It has been suggested that most animals were then pelagic, and possibly were only just "discovering" the sea floor preparatory to colonizing it (Hinde 1939).

Whatever the true facts, it does appear fairly definite that with the exception of a few lime-secreting algae, most animals until this time produced few hard parts and then usually chitinous. It is little wonder then that the fossil record below the base of the Cambrian is so devoid of fossils.

The Upper Precambrian has been termed an age of jellyfishes mainly upon evolutionary considerations, but also in view of discoveries from the Cambrian of New York, Sweden, Russia and Bohemia. From consideration of faunal associations of the Cambrian, such assumptions for the immediate Precambrian are quite logical.

There is no need to discuss further the question of the stratigraphical situation of the horizon, as the arguments were summarized in the previous publication and no evidence has been forthcoming since then. The close association with Archaeocyathinae (Pleospongia) leaves little doubt concerning their Lower Cambrian age.

The mode of occurrence and aspects of preservation have also been discussed previously and little need be added here. It should be remembered that Agassiz (1862), in his observations of *Aurelia flavida,* noted that after the spawning period there was a thickening of the tissues by an increased deposition of animal substance. The disc of the animal became thin and almost leathery and more elastic than before. Many marginal appendages of the umbrella and oral region dropped off.

Caster (1945) noted that when *Aurelia* and other medusae were stranded onshore in midsummer, they quickly dried out on the surface. The dehydration of the aqueous jelly brought out in surface relief embedded structures, which in life would be hardly discernible, except by transparency at the exterior. These latter observations are extremely important in considering the present fossil forms.

The stranding of huge numbers of jellyfish high on beaches during strong winds is frequently observed in many parts of the world at the present day. Hence it is not surprising that once favourable conditions for preservation are established large numbers of the forms may become fossilized in a somewhat restricted area. It should be also borne in mind that in Post-Cambrian times with increased number and variety of sea-shore scavengers the possibility of preservation was considerably reduced; sea birds would quickly destroy stranded jellyfish and the chances of fossilization were therefore particularly remote.

Problems of the Classification of the Fossils

In view of Agassiz' and Caster's various observations, classification on the zoological system is obviously hazardous. Where marginal or manubrial appendages are concerned there is need for particular caution, and obviously completely satisfactory relationships will rarely be possible. However, in some cases, manubrial structures, stomachs, gonads, radial and circular canals, and marginal notches are reasonably well defined. In two cases, delicate velar membranes are exquisitely preserved, and in the fossil from Kimberley there is clear evidence of marginal budding. For this reason the modern zoological classification will be followed wherever possible and the system as outlined by Parker and Haswell (1940) will be adhered to with only slight modification. Obviously, detailed classifications of zoologists will be modified slightly to admit even the more completely preserved forms. In many cases diagnostic characters are not present which would allow even a broad classification, while in others, close relationships with other living forms are obvious. The writer has gone so far as to relate one form closely to a modern genus by erecting the subgenous *Protodipleurosoma,* and although the wisdom of this may be questioned, it does serve to illustrate the remarkably faithful preservation of the fossil. Still another form (*Wadeia*) can be related closely to a living genus (*Niobia*) and another placed fairly confidently in a modern family (*e.g., Beltanella* in family Trachylinae). Others can be located with reasonable assurance in modern orders or classes, while still another group are of decidedly uncertain affinities.

Another group of fossils which it may be argued should more correctly be placed with the problemmatica are those thought to represent the oral regions of Rhizostomeae. The striking similarity of patternation of the fossil furrows with the mouth groove system of animals of that highly specialized group is thought to warrant such classification.

Additional complexity is brought about by a possible general tendency to degeneration and simplification over the great geological periods down to the present. Forms which were large and impressive in Cambrian times may now be quite insignificant. This appears to have been the case with both *Beltanella gilesi* and *Protodipleurosoma wardi.* Their assumed modern relatives measure only a fraction of an inch (a few mm.) in diameter and would scarcely be noticed when washed upon a beach. The related fossil forms measured several inches (50-100 mm.) in diameter and were therefore of the order of "modern" scyphozoan medusae.

As only to be expected, it appears almost certain that all modern orders of "jellyfishes" were represented by the beginning of the Cambrian. There were probably other orders that have since become extinct or which were intermediate between and ancestral to two or more modern orders. With such possibilities, classification of the fossil forms must be tentative to some extent and dependent upon the discovery of new and more completely preserved material.

Tentative Classification and Description of the Fossils

All forms described in the present paper appear to be most satisfactorily placed in the phylum Coelenterata and sub-phylum Cnidaria. The Cnidaria include all Coelenterates except the Ctenophores (or Comb-jellies).

The following brief notes which have been extracted from "The Invertebrates—Protozoa through Ctenophora" (Lyman, 1940) will serve to summarise some of the principal features of the subphylum.

The chief feature of the Cnidaria subphylum is the possession of striking radial symmetry. In one group, the Anthozoa, this is modified into biradial or radiobilateral symmetry brought about by elongation of the mouth and other correlated changes.

There is one principal axis of symmetry, namely, the oral-aboral axis, which extends from the mouth to the base, and the organs are arranged concentrically about this axis. The body structures may be definite or indefinite in number, and when definite the number is four or six or multiples thereof. Tentacles are very conspicuous, extensible projections that encircle the oral end in one or more whorls and serve for defence and feeding purposes; they are absent in very few members of the subphylum.

Cnidaria are notable for their di-morphism—the polyp and the medusa—each of which can be derived from the other giving an alternation of generations. The polyp is the sessile form, being vase-shaped and fastened at the aboral end with mouth and tentacles at the free or oral end. The medusa, or free swimming form, contrasts with the polyp in the shortening of the oral-aboral axis, radial expansion and in the excessive formation of mesogloea. The resulting form is a gelatinous bell- or saucer-shaped animal with marginal tentacles. Polyp and medusa occur in several morphological variations, several of which may be found in a single species. In the class hydrozoa, both polypoid and medusoid forms are present; in the scyphozoa, the medusoid is dominant, while the anthozoa are exclusively polypoid. Where a species includes both polypoid and medusoid forms the polyps reproduce exclusively by asexual methods and bud off the medusae or their equivalents which alone are capable of sexual reproduction. In this way there is an alternation of generation—an asexual polypoid generation and a sexual medusoid generation. It is thought probable that the polyp is a persistent form and the medusa the completely evolved coelenterate.

In the Hydrozoa and Scyphozoa all diameters are apolar, that is, any two diameters selected at right angles will be alike. In the Anthozoa, however, the radial symmetry tends to be strongly modified in biradial or bilateral fashion chiefly due to the elongation of the mouth and associated structures. In biradial symmetry the diameters remain apolar, but the long or sagittal axis differs from the transverse axis at right angles to it. Each divides the animal into like halves, as there is no dorsal or ventral surface. In many Anthozoa the sagittal axis is heteropolar with the two ends unlike. Dorsal and ventral surfaces are then definable.

In the fossil forms to be described most have characteristic radial symmetry allying them with the Hydrozoa or Scyphozoa. In a few forms, in particular *Dickinsonia,* there is a strong biradial tendency and the systematic classification of these is more difficult, the more so as the fossils possess so few features of diagnostic value. It has been suggested elsewhere in this paper that the bilateral tendency may indicate the assumption of creeping habit. It is quite possible that this fossil may be representative of a class now extinct.

In attempting to place the various fossils systematically within some system of Zoological classification much must remain tentative. The system given herein is essentially a summary of that of Parker and Haswell (1940) and the placing of the present fossils is indicated as far as possible keeping in mind that in many instances the restricting criteria, as indicated in the keys, have not been observed. In such cases, classification has been made by making use of certain general similarities with modern genera and species.

In this manner it has been found possible to place most of the forms reasonably satisfactorily; a few forms have had to be relegated to Walcott's genus of convenience, *Medusina*. This genus was erected to include all species of fossil medusae whose generic characters were indeterminable. In making use of this genus it is realised that there are arguments for also including some of the forms tentatively placed with the Discomedusae.

Phylum COELENTERATA

Sub-Phylum CNIDARIA

Class HYDROZOA

Order *Hydroidea*—Hydrozoa in which there is a fixed zoophyte stage.

Sub-order *Anthomedusae*. In which the medusae bear the gonads on the manubrium, a.e., *Protoniobia wadea* (cf., modern *Niobia dendrotentacula.*)

Sub-order *Leptomedusae*. In which the gonads occur in relation with the radial canals, *e.g.*, *Protodipleurosoma wardi* (cf. modern *Dipleurosoma*).

Order *Trachylinae*—Hydrozoa with no known fixed zoophyte stage.

Sub-order *Trachymedusae*. Veiled medusae with simple entire bell margin not cleft into lappets. This is a distinguishing feature from the Narcomedusae. Tentacles spring from the margin of the umbrella and the gonads are developed in connection with the radial canals, *e.g.*, *Beltanella gilesi* (cf., modern *Rhopalonema*).

Sub-order *Narcomedusae*—in which tentacles spring from the exumbrella some distance from the margin, and the gonads are developed in connection with the manubrium.

Order *Siphonophora*—Hydrozoa in which the colony usually exhibits extreme polymorphism of its zooids. There may be strong bilateral symmetry.

Class SCYPHOZOA

Order *Lucernaridae* (*Stauromedusae*). Scyphozoa with a conical or vase-shaped umbrella mostly attached to external objects by an exumbrella peduncle. No tentaculocysts.

Order *Coronata*. Scyphozoa with the umbrella divided by a horizontal coronary groove. Four to sixteen tentaculocysts.

Order *Cubomedusae*. Scyphozoa with a four-sided cup-shaped umbrella. Four per-radial tentaculocysts.

Order *Discomedusae* (*Semaeostomeae*). Scyphozoa with flattened saucer-shaped umbrella and not fewer than eight tentaculocysts. The square mouth produced into four long oral arms, *e.g.*, *Ediacaria flindersi*, *Tateana inflata*.

Order *Rhizostomeae*—Scyphozoa having the mouth obliterated by growths across it of the oral arms. Stomach is continued into canals which open by funnel-shaped apertures on the edges of the arms, *e.g.*, *Pseudorhizostomites* and *Pseudorhopilema*.

Medusoid Problematica. Category *Medusina*—Medusae whose generic characters cannot be determined, *e.g.*: *Medusina mawsoni*, *M. asteroides*, *M. filamentis*, *Cyclomedusa davidi*, *C. radiata*, *C. gigantea*, *Madigania annulata*, *Dickinsonia costata*, *D. minima*.

Order HYDROIDEA — Sub-order ANTHOMEDUSAE

Genus Protoniobia Sprigg gen. nov.

Genotype *Protoniobia wadea* Sprigg, gen. et., sp. nov. Lower Cambrian flags; Mount John, Osmond Range, Western Australia.

Genus monotypic, generic characters include the circular form, the close association of the six (?) gonads with the stomach, and the development of medusae by a process of budding from the margin of the form.

Protoniobia wadea, Sprigg gen. et sp. nov.

(Plate ix, fig. 1; and text fig. 2)

Holotype: No. 192, Bureau of Mineral Resources, Canberra, F.C.T. Coll. Dr. A. Wade.

Description—Impression circular, with few prominent annular undulations. Near the centre of the form numerous nodular structures are arranged in a polygonal pattern about a central depressed zone. The nodular structures occur on a slightly wider platform, which in turn is surrounded by a deep circular groove without conspicuous ornamentation. Beyond the latter are annular ridges separated by a second deep groove. This latter groove gives some evidence of secondary sculpturing which may bear relationships to inferred radial canals.

At the margin of the umbrella impression there form sub-circular structures of uneven development which are arranged in an incomplete hexagonal pattern. The bud-like "appendages" have a concentric form within themselves and show an apparent resemblance with the "parent" impression. There are no tentacles present.

Dimension—Maximum diameter of the bell 4·1 mm.; average diameter of (?) gonadial nodes 2·5 mm.; maximum diameter of largest "bud" 1·4 mm.

Discussion and affinities—The specimen is the impression of a medusa. The numerous nodular subcentral nodes are probably gonadial structures, in close association with a circular stomach, and it is just possible that the inner of the two outer annular ridges may be a velar structure.

The circular marginal structures of the form are peculiar features which at first sight may suggest coiled tentacles, and probably prompted the original description of this fossil by Dr. Wade (1924) as a "coiled (?) gephyrean or unsegmented worm." (The impression is not spiral and is almost certainly coelenterate. However, closer inspection of the fossil shows that the marginal structures are essentially circular with annular internal patternation.)

One apparently modern parallel is known to the author, namely the unique *Niobia dendrotentacula* (Mayer 1900) of the Tortugas, Florida. Marginal tentacles of this species develop into medusae by a peculiar process of budding combined with fortuitous growth, and are set free into the water as independent animals similar to the parent medusae.

According to Mayer (1910, pp. 187, 188), *Niobia dendrotenacula* is slightly flatter than a hemisphere and about 4 mm. in diameter. "There are 12 marginal tentacles, one at the foot of each radia-canal and one intermediate between each successive pair of radial canals. These 12 tentacles are arranged in a bilaterally symmetrical manner in accordance with age. The oldest and the youngest tentacles are situated at the ends of the two simple radial-canals and the remaining ten tentacles are arranged in bilateral symmetry in accordance with their various ages, the axis being in the diameter of the two simple radial-canals and the oldest and youngest tentacles. Each half of the margin is thus a reflection of the other. . . ." The order in age of each tentacle is shown in fig. 2 D. "The oldest tentacle is the first to develop into a medusa and be set free, and the others follow in the order of their age until all of the tentacles have been cast off. They are immediately replaced, however, by new tentacles, but after every one of the original 12 tentacles has been developed into a new medusa, the process of forming medusae declines and finally ceases, and then the parent medusa becomes sexually mature. . . ." The gonads occupy four interradial situations in the upper part of the ectodermal wall of the stomach. After the budding medusae have been set free the gonads become mature and the ova are large and project from the interradial surfaces of the stomach. They are finally dehisced into the water."

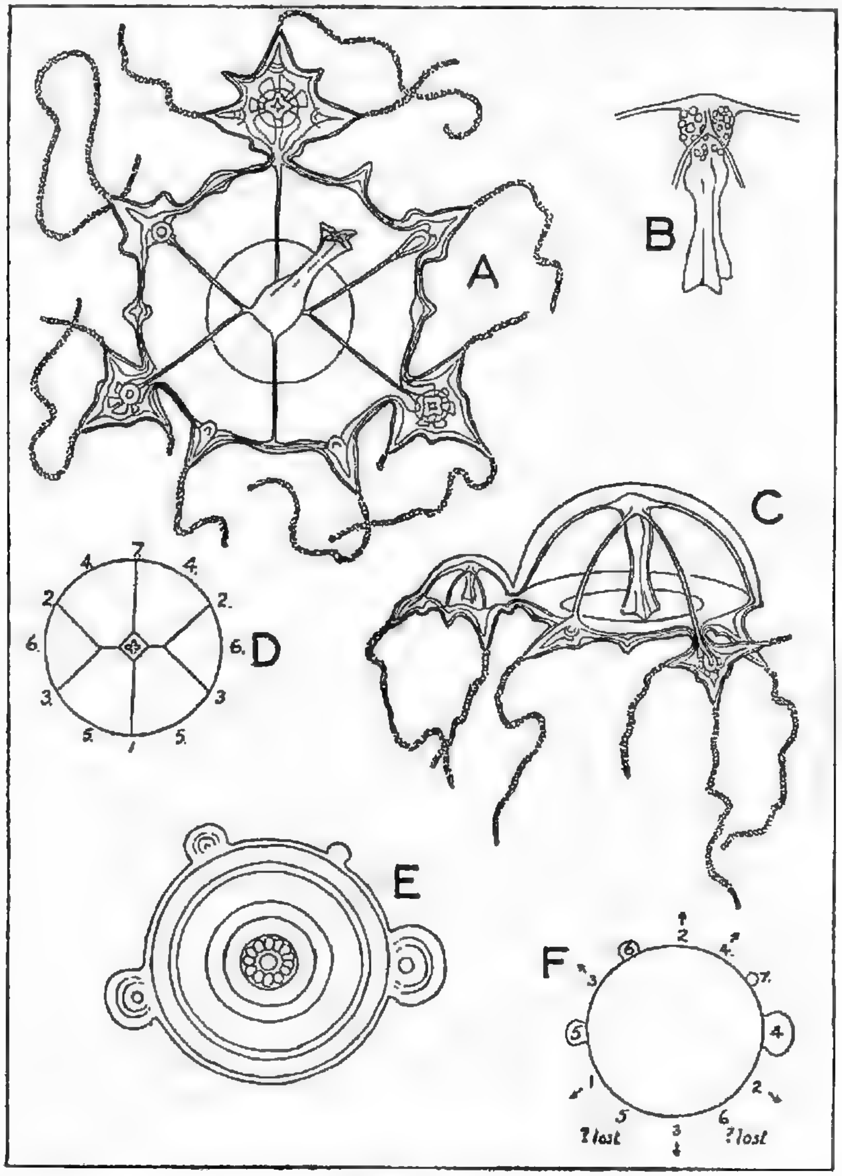

Fig. 2

A—D, *Niobia dendrotentacula:* A, oral view; B, detail of manubrium bearing the gonads; C, side view; D, budding sequence. E and F, *Protonobia wadea:* E, the fossil; F, bud diagram.

In the present fossil there is an obvious unequal development of buds, but with only the one well preserved specimen it is impossible to determine the complete sequence of the animal. Certainly there is a pseudo-hexagonal arrangement of the buds as in the case of *Niobia*, and it is perhaps legitimate to infer a rather similar life history. The two forms may be linearly related and a good case for parallel development of the buds can be made out.

In the fossil form the two adjacent buds on the upper margin (fig. 2 E) are of approximately equal development, while the two diametrically opposed buds are larger and unequally developed. Such an arrangement cannot be matched *exactly* however the form is orientated or in whatever stage of development the fossil was entombed. If, though, the interpretation of the subcentral nodular structures as gonads is correct, then it may be fairly assumed that the form was approaching sexual maturity. In this case it is possible that the animal had reached a stage where the largest bud was in stage 4, the diametrically opposite one in stage 5, and the two smaller ones in stages 6 and 7. The buds in stages 1, 2 and 3 presumably would have been freed.

A second example of *Protoniobia* has been discovered amongst material from Ediacara. The fossil is slightly smaller, its bell being about 20 mm. in diameter. There is evidence of four daughter buds. The example occurs on the same quartzite fragment as fossil No 2010. Its discovery supports the view that the Kimberley fossil was approximately contemporaneous with the Ediacara suite.

Sub-order **LEPTOMEDUSAE** (Haeckel 1866)

The modern Leptomedusae are thought to be descended from the more simply organised Anthomedusae. These medusae are creatures of coasts and are rarely found far out to sea, for they cannot maintain themselves in situations unsuited to the growth of their hydroids.

Subdivision into families in the modern classification is based on the presence or absence of lithocysts and the number of radial canals. The placing of the fossil form in this instance is based on general morphological similarities with a particular living species.

Genus **Protodipleurosoma** Sprigg gen. nov.

Form similar to that of *Dipleurosomo* (Axel Boeck 1866) is observable features, but much larger. *Dipleurosoma* is characterised by three or more main radial canals, some of which give rise to nondichotomous branches. Gonads on the canals adjacent to the manubrium; monosexual.

Protodipleurosoma wardi Sprigg, sp. nov.

(Plate ix, fig. 2, and text-fig. 3)

Holotype: No. 2093, Tate Museum Coll. Adel. Univ. S. Aust. Collected, R. K. Johns.

Description—Impression (bell) circular, flattened. Stomach subcircular constricted unevenly, lobate, radial canals developed irregularly, branched non-dichotomously, only one can be seen reaching the circular canal, but preservation of the velum impression has obscured complete observation. Primary canals are strong and give rise to shorter secondary canals which may not reach the circular canal. Branching occurs near the bases of the primary canals. Ring canal circular, and about 2 mm. in from the margin of the fossil. There are no signs of marginal appendages. The velum is wide and well preserved. Gonads are not present and the example by comparison with related living forms is therefore probably male.

Dimensions—Major diameter of fossil 59 mm.; length of stomach 16 mm.

Discussion and comparisons—The fossil forms are remarkably similar to the living *Dipleurosoma hemisphaericum* (Allman), although the latter is usually only about 10 mm. in diameter. The velum in the fossil species is relatively slightly wider and the stomach relatively larger. Branching of the radial canals and the position of the ring canal agree very closely. Allman (1873), in his description, states that there are three main radial canals with branches; some of the branches enter the ring canal and others terminate blindly. It is noted that the sub-family Berenicinae as described by Mayer (1910) present all radial canals connecting with the circular canal.

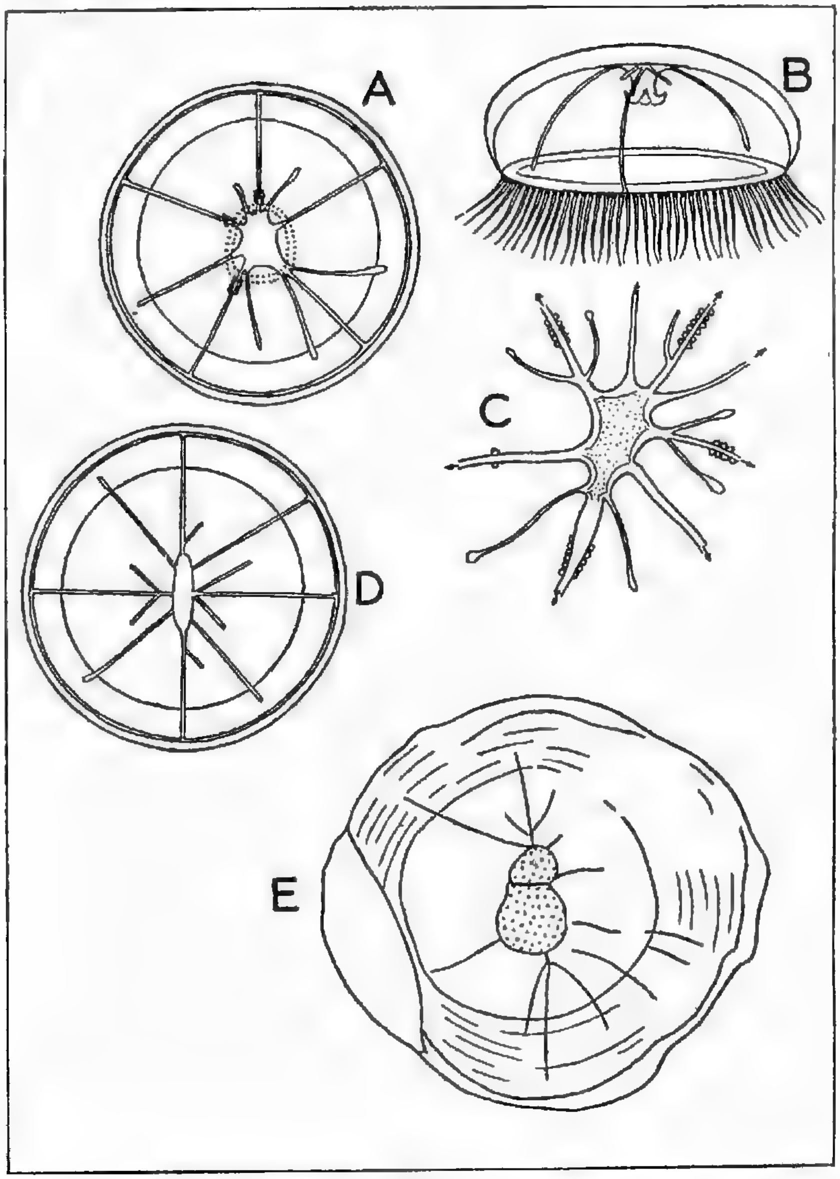

Fig. 3

A—D, details of the living *Dipleurosoma;* E, the fossil *Protodipleurosoma wardi.*

There can be little doubt that this fossil form is closely related to the genus *Dipleurosoma*. In life the fossil form was probably subhemispherical, free swimming, and considerably larger than its assumed modern descendants. It is also assumed that the species experienced an alternation of generation although nothing is known of its hydroid stage.

Order **TRACHYLINAE**

Suborder **TRACHYMEDUSAE** (Haeckel 1866)

Family (?) TRACHYNEMIDAE Gegenbaur 1856

Trachymedusae with eight or more simple radial canals, on some or all of which the gonads are developed.

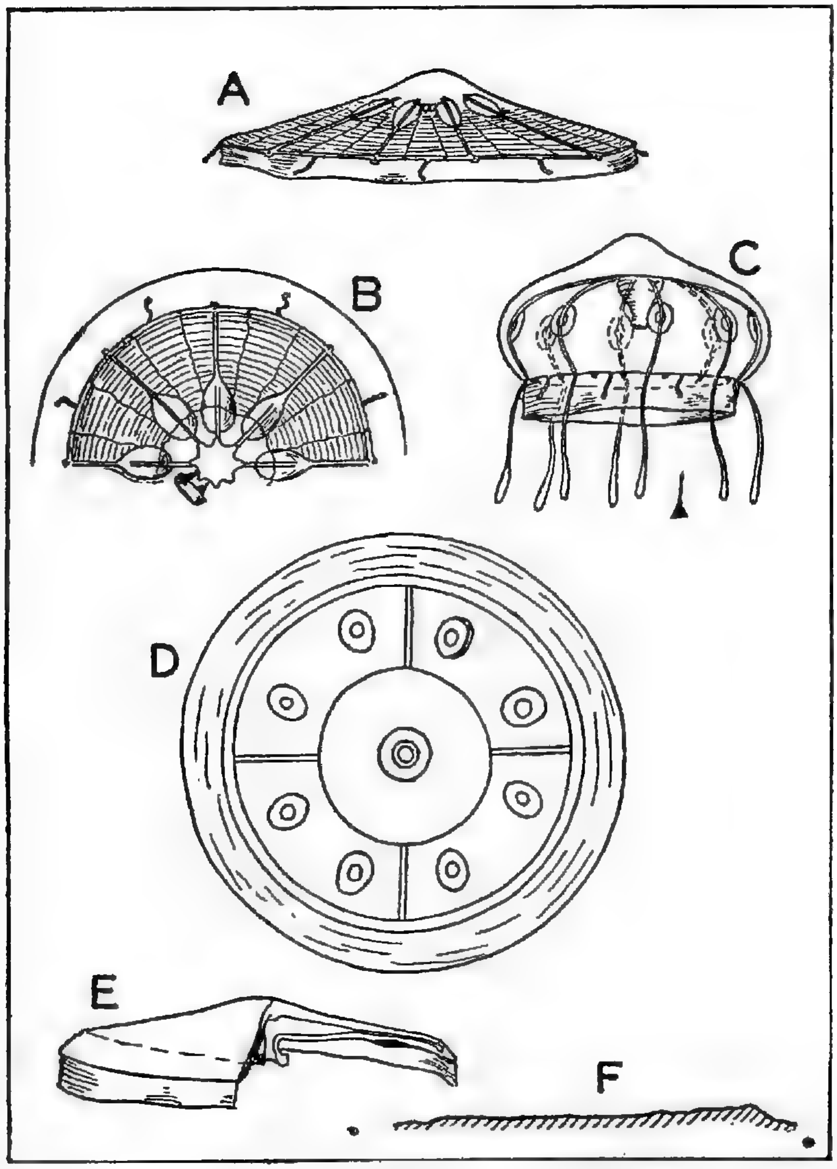

Fig. 4

A. and B, *Rhopalonema striatum;* C, *R. velatum,* side view; *D—F, Beltanella gilesi;* D, aboral view; E, side view with section removed; F, section through fossil.

Genus Beltanella Sprigg 1947

Genotype: *Beltanella gilesi* Sprigg.

Pound Quartzite, Upper Adelaide System (Lower Cambrian), Ediacara, South Australia.

Being monotypic this genus shares the species traits described below. Generic characters include the octagonal arrangement of the circular gonads and their

(?) paired relation about the four radial canals; the presence of a well developed and expanded delicate peripheral umbral structure or velum, and the simple circular oral aperture.

Beltanella gilesi, Sprigg 1947
(Plate x, fig. 1, and text fig. 4)

Holotype: No. 2056, Tate Mus. Coll., Adel. Univ., S. Aust.

Description—Medusa impression circular. Umbrella flat, but falling away sharply near its outer margin. (?) Velum horizontal, depressed approximately 4 mm. in relation to the flat ex-umbrella surface. Umbrella region subdivided into two zones by a faint annular groove as follows:

Inner Zone—Surface smooth, broken only by annular grooves, respectively 5 and 12 mm. in diameter at centre. Centremost area depressed very slightly. The whole zone corresponds with the original stomach.

Outer Zone—Surface dominantly flat, but slopes away steeply near the outer margin of the umbrella. This secondary sloping surface has the form of a highly truncate cone whose apical angle is approximately 80 degrees. Zone is characterised by the presence of circular (?) gonadial structures, approximately 10 mm. in diameter. These regular structures are arranged on either side of the major radial canals in an octagonal pattern centrally within the zone. At least four can be recognised and each has an inner concentric groove 3 to 4 mm. in diameter. Two paired radial grooves (? canals) are diametrically opposed and a third set lies radially at right angles. The grooves pass intermediate between the (?) paired gonadial structures, but do not continue into the inner zone. The ex-umbrella surface is slightly irregular at the edge of the flat raised portion, but below where the conical surface meets the velum, the margin is smooth.

Velum—Structure marginal, obviously thin, well developed; undulose surface depressed; undulations annular in plan.

Dimensions—Maximum diameter of fossil 110 mm., minimum 97; widths along single radii of inner and outer zones and velum respectively 18-20, 21-23 and 10-14 mm.

Discussion—The specimen is the cast of the ex-umbrella surface (ab-oral) of a jellyfish.

The central zone corresponds with the gastrovascular cavity. At its margin it gives (paired) grooves which are interpreted as radial canals. There are no signs of subdivision within the cavity, and no indication of complicated manubrial structures. The simple circular grooves situated centrally may be oral structures, or possibly representative of a collapsed truncate gastric cone of the type which occurs in some jellyfish to aid in the even distribution of food to various parts of the animal's stomach.

The radial grooves of the outer zone are very probably radial canals, although it is not known why they should be paired. There is no sign of branch canals from them, nor is there present any groove suggestive of a circular canal. The circular (?) gonadial structures which are distributed evenly around the centre of this zone may be considered as paired in relation to the supposed radial canals and the central annular grooves of each gonadial structure may mark a genital operculum.

The peripheral velum is remarkably well preserved considering its obvious delicate nature; its contained annular undulations suggest ring muscles. Its expanded position in rest suggests that it swung to and fro within and without the bell cavity as the medusa swam.

Affinities—In the original description this form was placed very tentatively with the Scyphozoa, although it was recognised that many characters were primitive, and indicative of the Hydrozoa. The simple mouth, the presence of a few unbranched radial canals were considered to be Trachylinid (Hydrozoan) characters, while the flattened disc-shaped umbrella, its relatively large size, and the absence of large tentacles were thought to be more characteristic of the Scophozoa.

It is now considered that the presence or absence of marginal appendages in fossil jellyfish can have little significance, and as regards size, diameters of four inches and more are not unknown amongst Trachylinids. A more convincing point concerns the resemblance of the species with the modern *Rhopalonema,* Gengenbaur 1856 (Family Trachynemidae).

Rhopalonema characteristically possesses 8 radial canals, and 8 gonads occur upon restricted portions of these canals. *Beltanella* differs in that although it has 8 gonads lying opposite the central portions of radial canals, these gonads do not appear to be on the canals. Also, evidence of only 4 radial canals can be recognised. Nevertheless, *R. velatum* and *R. striatum* (fig. 4) do show some striking similarities. *R. velatum* possesses rounded gonads situated about half-way between the stomach and bell margin and associated with circular canals which give much the concentric appearance of the gonads in the fossil form. *R. striatum* in general external form approaches the fossil even more closely and is described as having the shape of a Chinese hat. Its velum is very wide and muscular and swings to and fro within and without the bell cavity as the medusa swims. It was noted also that the tentacles of *R. velatum* are very brittle and usually break off very readily. It would appear, therefore, that there is good reason to associate this form fairly closely with *Rhopalonema,* and therefore the order Trachymedusae.

Rhopalonema is distributed throughout the tropical and warm oceans of the world and may live on the surface or at depth.

Order (?) **SEMAEOSTOMEAE** (Discomedusae)

Genus **Ediacaria** Sprigg 1947

Genoytpe Ediacaria flindersi Sprigg 1947

Pound Quartzite, Upper Adelaide Series (Lower Cambrian), Ediacara, South Australia.

Generic characters include the circular form, the bell-like manubrium, the simple circular stomach and association of the (?) gonads with the base of the manubrium. There are 4 and possibly 8 marginal notches.

Ediacaria flindersi Sprigg

(Plate x, fig. 2, and text fig. 5)

Holotype: No. T1, Tate Mus. Coll., Adel. Univ., S. Aust.

Description—Medusa impression circular, radially symmetrical; surface flattened, but with radial and concentric features of low relief. Three concentric zones are clearly distinguishable.

Inner zone—Manubrium bell-like, constricted near its junction centrally with the sub-umbrella surface and expanded distally. It lies over sideways and is compressed laterally. Length 15 mm., and maximum width (flattened) 14 mm. At least three pendant lobate pouches extend 9 to 11 mm. centrifugally from the base of the manubrium. Beyond these pouches the central zone is essentially smooth, although there is an incomplete concentric groove half-way to the zone margin.

Median zone—Surface smooth, somewhat inflated; zone delineated on inner and outer aspects by concentric grooves—one (or two) on the inner margin, and one deeper with associated minor and less regular grooves on the outer. Two well-marked radial grooves are present, while indistinct radial striations are more numerous.

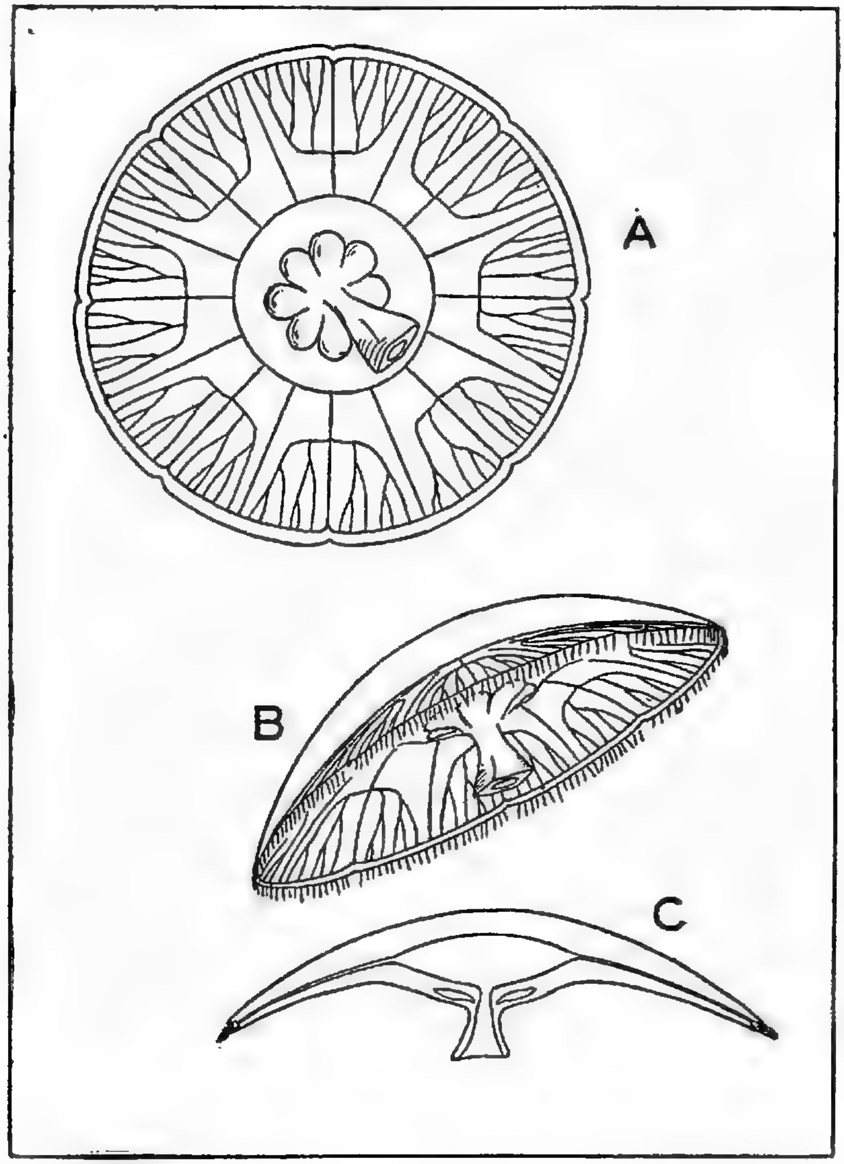

Fig. 5

Ediacaria flindersi, reconstructions; A, oral view; B, side view; C, cross section.

External zone—Surface flattened or only slightly convex in transverse section with minor concentric undulations or flutings and numerous radial grooves or striae. In the annular segment, representing three-fourths of the perimeter, at least 44 separate radial grooves can be recognised. Although somewhat irregular in themselves, they are distributed around the zone relatively evenly. Most diverge centrifugally, but some converge in this direction. The outer margin (perimeter of fossil), is fairly regular (circular), with the exception of one or two doubtful marginal notches. A concentrate groove lies approximately 4 mm. in from the perimeter of the form. The radial striations do not extend beyond the epi-marginal groove.

Dimensions—Largest diameter 114 mm. Respective widths of inner, median and outer zones along greatest radius: 20 mm., 17 mm., and 25 mm.

Discussions and comparisons—The specimen is considered to be the impression of the sub-umbrella surface of a "dried out" jellyfish. Organs adjacent the oral surface of the animal have come to stand out in relief, and the manubrium is preserved clearly. The central zone corresponds with the gastrovascular cavity and the gonads at the base of the manubrium are superimposed on it.

The sub-triangular manubrial structure has been so interpreted in view of its apparent fusion centrally with the sub-umbrella surface, and because no other comparable structures are distributed radially about the centre. The flattened attitude of this manubrium bears a superficial resemblance to the insert lobes of the central discs of Kirklandia (Caster) and Rhizostomites (Haeckel). However, the absence of more of these structures radially about the centre disputes this view. In life the manubrial structure would be suspended vertically from the central region (fig. 5). The shape of the mouth opening cannot be judged, although it was probably simple. On this impression the genus has been classified with the Semaeostomeae and not the Rhizostomeae.

The three pendant pouches extending radially from the base of the manubrium are almost certainly gonads. Judging by their distribution there were probably eight of them originally.

Various concentric flutings, with the exception of that adjacent the margin of the form, are referrable to the circular muscles of the sub-umbrella. The epi-marginal groove is the circular canal. The radial canals do not extend beyond it.

The well marked radial grooves of the median zone are probably radial canals. There is evidence of branching, and although the grooves are sub-parallel they do increase in number centrifugally. The grooves could be merely shrinkage creases, but in any case these would tend to follow such lines of weakness as canal lines.

Two marginal notches can be interpreted; they occur at intervals corresponding with the major radial canals. In each case deeper radial grooves continue to each notch. This would support the view that the notches are regular marginal features, possibly originally enclosing sensory structures. On the other hand, it is noted that in other portions of the fossil where continuous sections of the margin are preserved, other notches are not apparent. The observed notches could be accidental marginal invaginations due to deformation upon burial. There are no indications of marginal tentacles but they probably had dropped off previously.

Ediacaria is probably Scyphozoan. The form was large and obviously had a flattened disc-shaped umbrella and may be referable to either of the orders Semaeostomeae or Rhizostomeae. To decide further to which of these orders the form belongs, a detailed knowledge of the structure of the mouth and oral arms would be necessary. The incomplete preservation of the specimen precludes this. However, it is noticeable that the manubrial structure as interpreted is relatively simple suggesting relationship with the Semaeostomeae.

Comparison with other fossils is exceedingly difficult in view of the absence of many critical features. Closest resemblance is perhaps with *Rhisostomites* and *Semaeostomites* (both Haeckel) of the Upper Jurassic of Solnhofen, Bavaria. In these forms three concentric zones can be inferred but otherwise there is little similarity in available detail of the central disc regions. Ring muscles are well developed in the outer portions of *Rhizostomites* as they are in *Ediacaria*. No obvious ring canal is present in *Rhizostomites* as in *Ediacaria* and *Semaeostomites*, and whereas the margin of *Semaeostomites* is split into 120-128 marginal lobes, such a subdivision is not apparent in the other two forms.

Genus **Tateana** Sprigg gen. nov.

Genotype **Tateana inflata** Sprigg gen. et sp. nov.

Pound Quartzite, Upper Adelaide Series (Lower Cambrian), Ediacara, South Australia.

Generic characters—Circular, slightly inflated medusa with very numerous unbranched radial canals. Well developed submarginal circular canal. Four or eight marginal notches. The genus is distinguished from *Cyclomedusa* (see later) by its more inflated surface and the presence of marginal notches.

Tateana inflata Sprigg, gen. et. sp. nov.

(Plate xi, fig. 1 and 2)

Holotype: No. 2017, Tate Mus. Coll. Adel, Univ., S. Aust.
Hypotype: No. 2018.

Description—Medusa circular, radially symmetrical, surface inflated slightly but with strong narrow radial striations; only very slight annulations can be distinguished.

The central zone (stomach) is simple and circular, representing one-third of the diameter of the complete form. The radial striations lead directly from the central zone to the epimarginal groove or circular canal. They do not appear to branch and number about 100. There is slight evidence of four or more marginal notches.

There is no sign of marginal appendages, manubrial structures or gonads.

Dimensions—Greatest diameter 6·4 mm.

Comparisons—The form has much in common with *Ediacara*, and may prove to be generically identical when more material is available for study. However, in *Ediacara* a tendency to branching in the radial canals has been noted. This is definitely not present in *Tateana*. In its unbranched radial canal system it approaches *Cyclomedusa* (see later under Medusoid problematica) more closely.

The decision to place this species in Semaeostomeae rested on its similarities with *Ediacaria*.

Order **RHIZOSTOMAE** (Cuvier 1799)

Scyphozoa without marginal tentacles and with numerous mouths which are borne on adradial fleshy branched arm-like appendages which arise from the centre of the sub-umbrella. The lips of the numerous mouths are bordered by minute constantly moving tentacles.

All living species are tropical and few extend far into temperate waters. None are known from polar seas. The animals are usually tough and large and therefore are not uncommonly preserved in the fossil state.

Genus RHIZOSTOMITES Haeckel 1866

Genotype RHIZOSTOMITES AMIRANDUS Haeckel 1866

Solnhofen Slates Eichstadt, Bavaria

Generic characters (as defined by Brandt)—Disc as large as 0·4 metre, with 128 marginal lobes, without marginal tentacles; oral trunk rudimentary usually in the form of an oral disc, surrounded by eight arms. Genital cavities, four. Coelenteric central cavity simple, with sphero-quadratic roof. Mouth opening late, perhaps never completely obliterated, cruciform with eight branches.

Pseudorhizostomites howchini, Sprigg sp. nov.

(Plate xii, fig. 1; text fig. 6 F)

Holotype: 2034 Tate Museum, University of Adelaide, South Australia.
Locality: Pound Quartzite, Lower Cambrian, Ediacara, Australia. Coll. by R. Ayliffe.

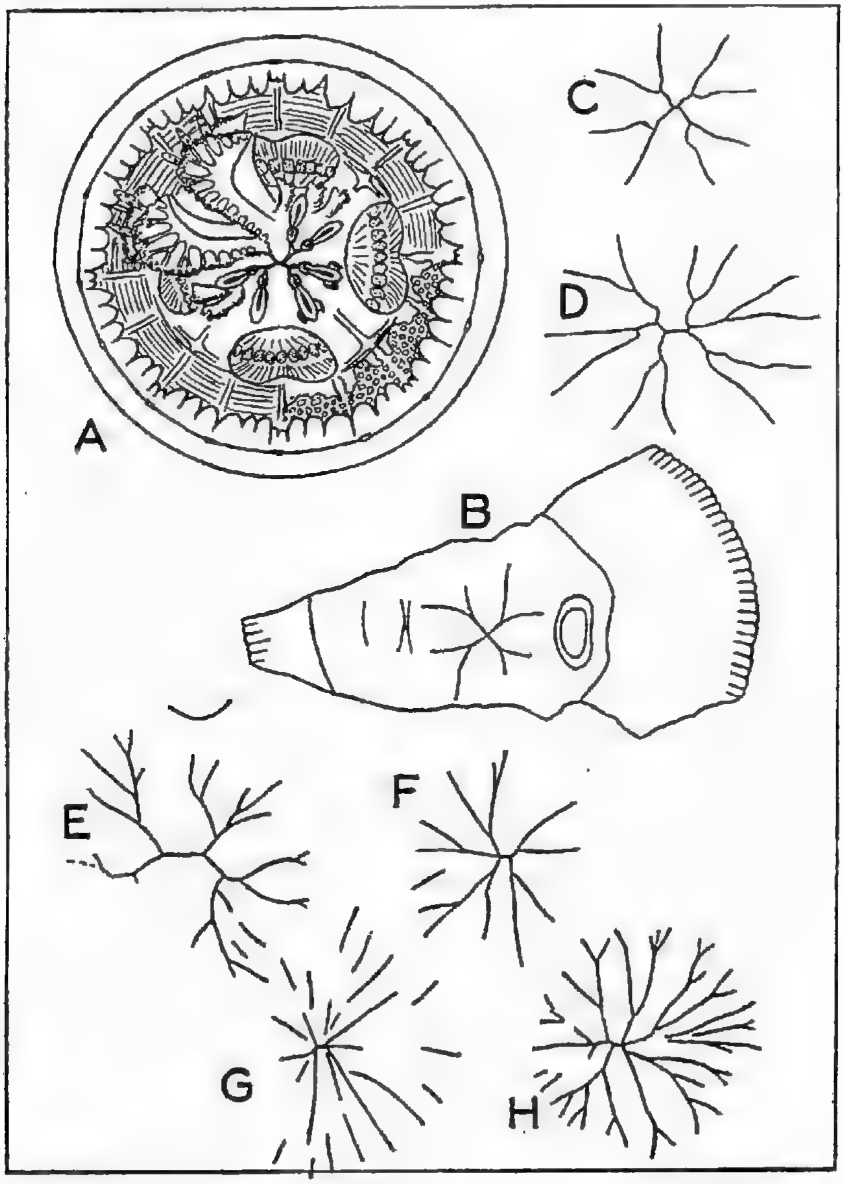

Fig. 6

A, *Rhopilema verrillii* (living); B, *Rhizostomites lithographicus* (Jurassic); C, *R. amirandus* (J.); D, *Hexarhizites insignis* (J.); E, *Pseudorhopilema chapmani*; F, *Pseudorhizostomites*; G and H, *Pseudorhizostomites* sp.

Description—Impression convex, with cruciform radial grooves each branching simply once. The grooves alternatively cut off concave and convex isoscelean areas. There is a slight suggestion of secondary dichotomous branching at the end of one or more of the eight subradial grooves.

Dimensions—Total width of form 30 mm.

Discussions and comparisons—The four areas divided off by the secondarily branched furrows are interpreted to be the basal portion of the four great oral arms, or branches of the gastral trunk which hangs down from the centre of the umbrella cavity of scyphozoans. The grooves are the lines of fusion formed during the coalescence of lips of the primitive central mouth of the juvenile form. In this way the primitive central mouth has been obliterated in Rhizostomeae, but numerous other mouth-openings remain in the gutter-like grooves which extend down the ventral sides of the mouth arms.

Specimen No. T116 (pl. xii, fig. 3 B; text fig. 6 G) may also be referrable to this genus, although the number of primary grooves is somewhat excessive, and the dichotomous branching is essentially restricted to the immediate mid-field. In specimen 2043 (pl. xii, fig. 3 A; text fig. 6 H), on the other hand, dichotomous branching is very pronounced. In view of the problemmatic nature of these fossils there has been no attempt to make specific subdivisions.

Genus **Pseudorhopilema** Sprigg gen. nov.

Pseudorhopilema chapmani Sprigg, gen. et. sp. nov.

Pound Quartzite, Upper Adelaide Series (Lower Cambrian), Ediacara, South Australia.

As the form is known only from the very limited detail of its central field, generic characters tentatively will be taken to include the inferred presence of eight oral arms and associated paired (?) scapulets.

Pseudorhopilema chapmani Sprigg, gen. et. sp. nov.

(Plate xii, fig. 2; text fig. 6 E)

Holotype: No. 2036, Tate Mus. Coll., Adel. Univ., Coll. P. Healy.

Description—Midfield slightly convex with a central groove or furrow giving rise to a system of dichotomously branched primary, secondary and perhaps tertiary grooves.

Dimensions—Length of median furrow 7 mm. Width of central disc., as indicated by extension of scapulets, 50 mm.

Comparisons—The form bears definite relations with the restricted central portion of the well known Jurassic forms (fig. 6) *Rhizostomites amirandus* and *R. lithographicus* (both Haekel 1866). Obvious differences concern the strong development of a central furrow and of the presence of tertiary dichotomously branched furrows. *R. lithographicus* approaches the newly described form more closely in that it has a small single central groove which imparts a minor tendency towards bilateral symmetry as against the simple cruciform character of *R. amirandus*.

Assuming that the form was typical of modern and fossil Rhizostomae, there would have been eight oral arms. But the form has 16 tertiarily branched dichotomous grooves, and these are thought to correspond with the canals or ducts of scapulets which normally arise from the sides and near the bases of each of the oral arms.

A more complete comparison in so far as this is possible is with the living form *Rhopilema verrillii* (Haekel). In this form both the strong central furrow and the scapulae are present (fig. 6 A), and in a general sense the restricted detail in the two cases is very similar.

MEDUSOID PROBLEMATICA

Category Medusina Walcott 1898

Walcott erected this Category (calling it a genus) to include all species of fossil medusae whose generic characters cannot be determined. It is now suggested that the idea of "genus" be dissociated from the term and for *Medusina* to be considered as a category of convenience for such medusoid forms. This would provide for the development of some broader classification within the category and enable the use of new "generic" names additional to *Medusina*. Apparent relationships could be made more obvious in this way.

Medusina mawsoni Sprigg, sp. nov.
(Plate xiii, fig. 4; text fig. 7 B)

Holotype: No. T. 39, Tate Mus. Coll., Adel. Univ., S. Aust.
Type Locality: Pound Quartzite, Lower Cambrian, Ediacara, S. Aus.

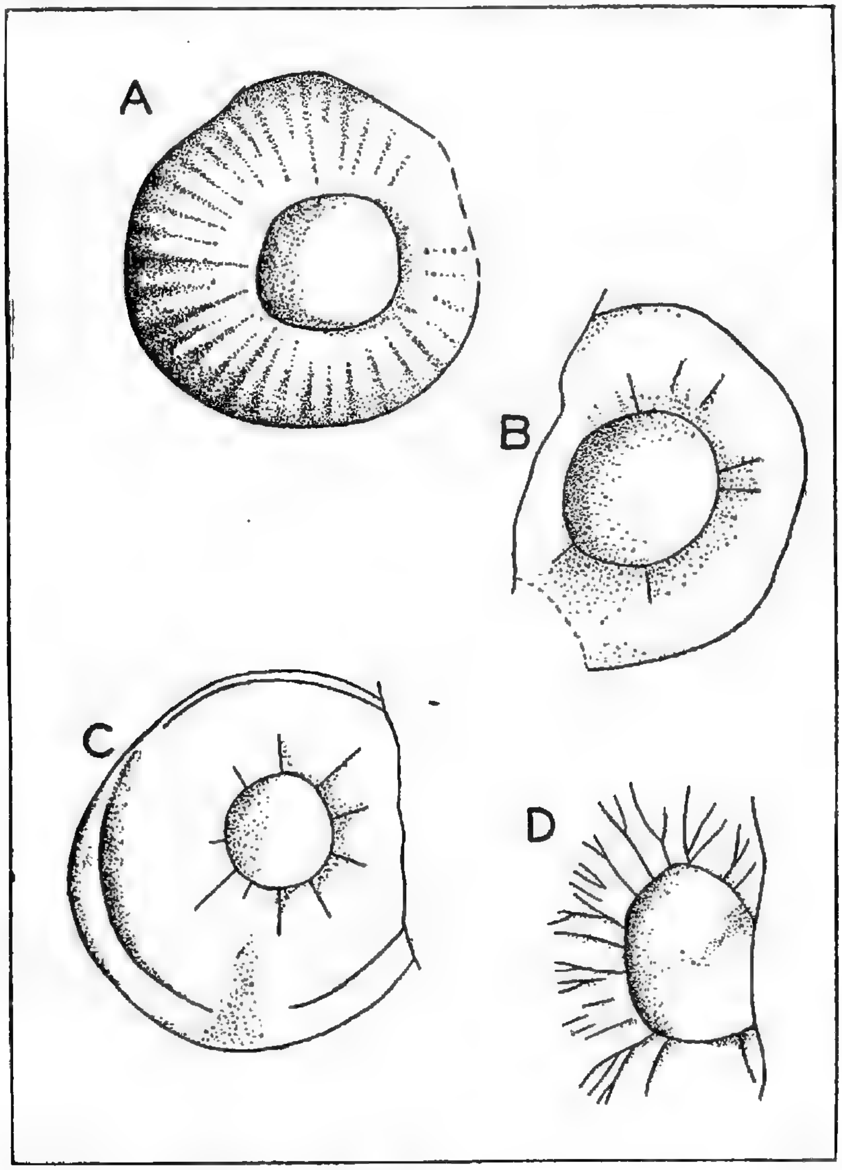

Fig. 7
A, *Medusina radiata* (L. Cambrian, Bohemia);
B, M. mawsoni; C, M. asteroides; D, M. filamentus.

Description—Impression circular, medusoid; central area depressed, circular and convex, occupying between one-third and one-half the full diameter. The outer annular zone is inflated centrally and there is a suggestion of radial ridges within the zone at close intervals. Margin simple, circular. No evidence of marginal appendates.

Discussions and comparisons—The form is obviously the fossil of a medusoid coelenterate. The central depressed area may correspond with a collapsed stomach area, and the indefinite radial structures of the outer zone with radial canals.

The specimen has much in common with Pompeckj's *Medusina radiata?* of the Bohemian Lower Cambrian (fig. 7 A). The radii in the present specimen are faintly and very incompletely preserved and it is impossible to tell whether they are branched as in Pompeckj's specimen. The latter had 75 to 80 radii at the outer margin.

The writer feels that the tentative identification of Pompeckj's specimen with Linnarson's *Medusina* (= *Astylospongia*) *radiata* is unsatisfactory. Pompeckj (1896) notes that it agrees only in a general way and that some differences forbid its direct identification with the original Swedish form. "The string-of-pearls shape of radii, already noted by Linnarsson, cannot be observed, and the number of radii in the Bohemian specimens is less than in Linnarsson's species." The intervals between the radii are larger in Pompeckj's specimen. It is felt, therefore, that *M. Mawsoni* may be synonymous with *M. radiata?* of Pompeckj.

Dimensions—Diameter of complete form 2·7 mm.; diameter of central depressed area 1·7 mm.

Medusina asteroides Sprigg sp. nov.

(Plate xiii, fig. 3; text fig. 7 C)

Holotype: No. 2021, Tate Mus. Coll., Adel. Univ., S. Aust.

Type Locality: Pound Quartzite, Lower Cambrian, Ediacara, Flinders Ranges, South Australia.

Description—Impression circular, slightly inflated, central disc occupying approximately one-quarter of the diameter of the complete form and surrounded by a deep groove. The surrounding zone has an epimarginal groove and is traversed by widely spaced radiating grooves dispersed in an (?) octagonal pattern. Not all radii continue to the epimarginal groove. There are no visible marginal appendages.

Dimensions—Greatest diameter 24 mm.; diameter of the central disc 10 mm.

Dimensions and comparisons—The depressed central area may represent a collapsed stomach; the radial grooves are radial canals and the epimarginal groove corresponds with a circular or ring canal. In view of an absence of restricting critical features, and simple circular form, it is referred to the genus Medusina. It differs from *Medusina radiata* and *M. Mawsoni* in the possession of fewer radii and a relatively small central depressed area.

Medusina filamentus, Sprigg spec. nov.

(Plate xiii, fig. 1; text fig. 7 D)

Holotype: No. T68, Tate Mus. Coll., Adel. Univ., S. Aust.

Type Locality: Pound Quartzite, Lower Cambrian, Ediacara, S. Aust.

Description—Impression ovoid, inflated. Thirty to forty filamentous (?) tentacles are given off at fairly regular intervals around the (complete) margin. The tentacles frequently appear to branch at least once half-way along their respective lengths which are only slightly shorter than the diameter of the fossils.

Affinities—The writer knows of no similar fossil form. Apart from the inflated medusoid form and marginal (?) tentacles restricting features are absent.

Dimensions—Maximum and minimum diameters 22 and 16 mm. respectively. Average length of tentacular processes 10 mm.

Genus **Cyclomedusa** Sprigg

Genotype **Cyclomedusa davidi** Sprigg

Generic characters—Ex-umbrella sculptured by fairly prominent concentric grooves which may or may not extend to the margin, and numerous fine simple unbranched radial striations. The radial striations do not continue into the circular zone which may or may not contain a central nodular structure. The margin is simple and an epimarginal groove is present in well-preserved specimens.

Key to Species

C. davidi - -	prominent annular grooves extend to the margin.
C. radiata - -	outer zone essentially free of annular grooves.
C. gigantea - -	large form, inner and outer zones divided by a deep annular groove. Radial striations extremely numerous.

Cyclomedusa davidi Sprigg

(Plate xiv, fig. 1, 2 and 4; text fig. 8)

Holotype: No. T 5, Tate Mus. Coll. Adel. Univ., S. Aust.

Hypotypes: Nos. 2020, 2040.

Description—Impression circular, flattened, and with concentric undulations. The form exhibits striking radial symmetry and its surface is subdivided by at least seven annular grooves. Central portion raised, distinctly nodular.

The original specimen (T 5) was known to be incomplete. Three zones were recognised, the inner being hemispherical and nodular and 5 mm. in diameter and 1·5 mm. in height. The outer two zones were of lower relief; annular portions within these were traversed alternately by radial striations (? radial canals) or were apparently free of sculpture. The form as preserved indicated a maximum radius of 50 mm. and there appeared to be about 16 radial striations per quadrant.

A newer, better preserved specimen considered to be specifically identical exhibits essentially similar characters, except that it appears that the radial striations are continuous through the various subdivisions of the outer zone. They therefore would continue uninterruptedly from the central (?) stomach region to the margin of the form. A more critical examination of the holotype specimen has indicated a degree of agreement in this respect.

Dimensions—Overall diameter of specimen No. 2020 is 52 mm.

Reproduction—Specimen 2040 at first appearance has the suggestion of a flattened tabulate colonial pleospongian. Dr. Okulitch and others who have seen photos of this specimen have recorded this impression on first viewing it. However, the fossil is more or less identical with accepted specimens of *C. davidi* except for its peculiar constrictions. It is felt that the constriction may be part of an irregular budding process in which the two daughter medusae each possess adult characters. If this is a reliable interpretation, it seems to be another unique method of reproduction amongst jellyfish. It is also remotely possible that the animal may have been damaged and that the irregular form is completely fortuitous. Fission has produced three segments in all, and two differ only slightly in width, while the third is significantly smaller.

A rather parallel but not identical case of reproduction by fission occurs in *Gastroblasta* (Keller). *Gastroblasta raffaelei* (Lang), for example, is slightly elliptical and possesses four manubria. According to Mayer (1910) "the medusa frequently reproduces by fission and the plane of division is at right angles to the long axis of the ellipse and passes between the oldest and next oldest Manubrium.

When about to divide, the oldest lithocyst divides into two and the cleft proceeds inward at this point until the medusa is completely cut into halves, the one being a reflection of the other. Each then develops new radial-canals budding from the ring-canal and growing inward. When the original form has been restored a new fission may take place. This is not a constant process, however, but is subject to much variability, for new radial canals may grow inward from the ring-canal in the regions of the old tentacles, and these new canals may fuse with the old canal-system and develop manubria."

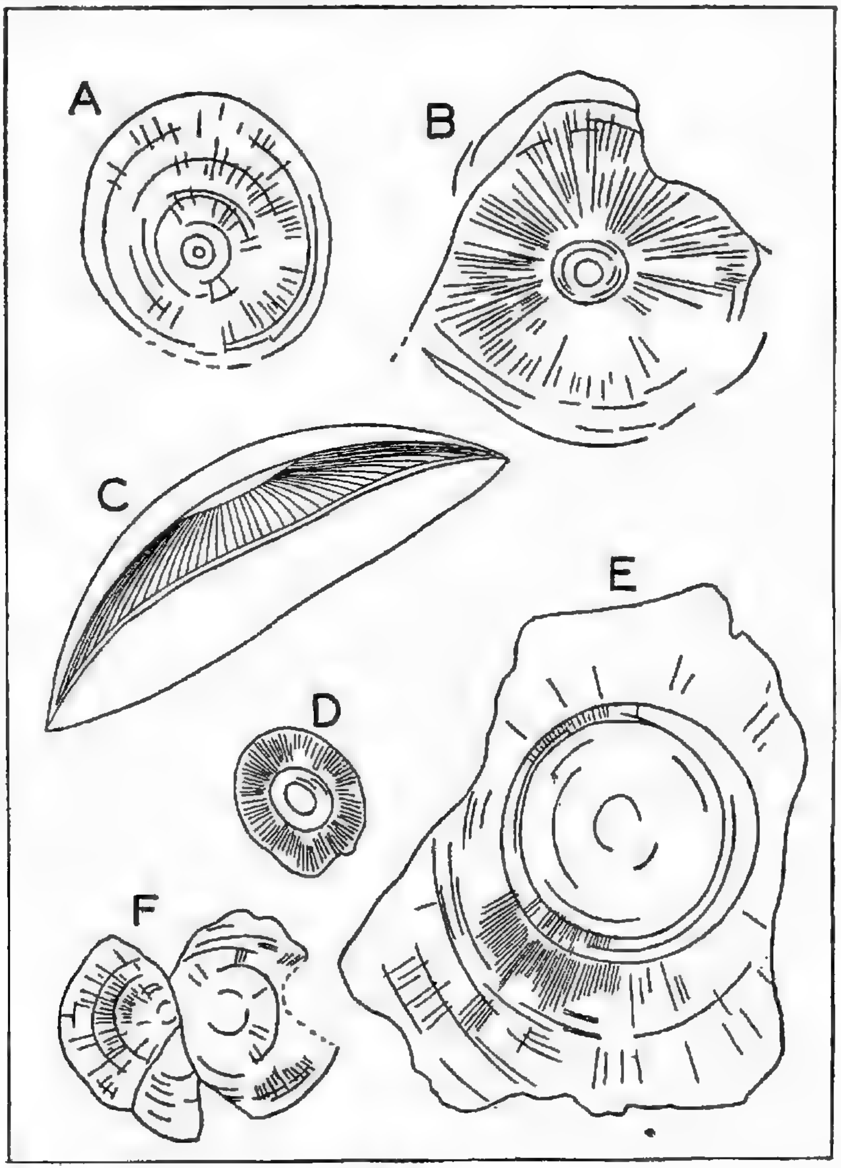

Fig. 8

A, *Cyclomedusa davidi;* B, *C. radiata;* C, reconstruction of *Cyclomedusa;* D, *juvenile form;* E, *C. gigantea;* F, *C. davidi* in process of fission.

The occurrence of irregular transverse fission of this nature elsewhere in the kingdom of medusae greatly strengthens the view that the restrictions in the aberrant specimen of *Cyclomedusa davidi* have generative significance.

Cyclomedusa radiata Sprigg sp. nov.

(Plate 13, fig. 2; plate xiv, fig. 3; plate xv, fig. 1; plate xviii, fig. 1, text fig. 8)

Holotype: No. 2037, Tate Mus. Coll., Adel. Univ., S. Aust.

Hypotypes: Nos. 2010, 2032, 2027.

Description—Species similar to *C. davidi*, except in that the outer zone is practically free of annular grooves. Radial striations are continuous and prominent in the outer zone.

In specimen 2039 the central (?) stomach zone is relatively narrow, with a central node surrounded by two or three concentric grooves. In radial relation the outer zone is three times the width of the inner. It is traversed by numerous radial striations, and 50 of these can be recognised clearly in one half of the fossil; the striations do not appear to branch and all appear to join the central zone separately. They connect with an epimarginal groove or (?) ring canal at their distal ends. The margin appears to be simple.

Specimens 2032 and 2027 are essentially similar but differ in that the ratio of the radial widths of the inner and outer zones is approxemately 1:1. 2032 is apparently a juvenile form of 2027. Neither of these exhibit an obvious circular canal.

Cyclomedusa gigantea Sprigg sp. nov.

(Plate xv, fig. 2; text fig. 8 E)

Holotype: No. 2035, Tate Mus. Coll.; Adel. Univ., S. Aust.; Coll. R. Ayliffe.

Descriptions — Form essentially similar in many aspects to *C. davidi* and *C. radiata*. There are two zones, the inner of which is devoid of radial striations, whereas they occur weakly in the outer one; the complete form possesses numerous concentric groovings.

The central zone is separated from the outer by an unusually deep sulcus or groove. The margin of the animal is incomplete and ill-defined. In the complete form there would be approximately 200 simple, unbranched radial grooves. These are much more numerous than in *C. davidi* (approximately 50) or *C. radiata* (approximately 100).

Dimensions—Overall diameter greater than 65 mm.; (?) stomach 42 mm. in diameter.

Discussion and comparisons—The foregoing three species have much in common and separation is rather arbitrary on this account. Nevertheless there appears to be some regularity in variation in surface sculpture which it is thought merits specific subdivision.

The anotomical organisation of the animals is unknown except by inference. The central zone, which is free of radial ornamentation, probably delimits the stomach. The significance of the radial grooves is open to argument but their interpretation as radial canals is probably justifiable. If so, these canals were simple and unbranched and mostly continuous from the stomach to the circular canal. The form differs from *Ediacara* in this feature.

The fossils may be discoid Scyphozoans, but such classification is too optomistic for the present.

Genus **Madigania** Sprigg gen. nov.

Genotype: **Madigania annulata** Sprigg gen. et sp. nov.

Pound Quartzite: Upper Adelaide System (Lower Cambrian), Ediacara, S. Aust.

Generic characters—Circular form with numerous conspicuous annular grooves, ridges or undulations. No radial ornamentation. It may or may not have a central conspicuous papilla or node.

Madigania annulata Sprigg gen. et sp. nov.

(Plates xvi, fig. 1 and 2; plate xvii, fig. 1 and 2)

Holotype: No. 2031, Tate Mus. Coll., Univ. Adel., S. Aust.

Hypotypes: 2025, and T9 and T14.

Descriptions — Impression circular, with numerous conspicuous annular undulations. Essentially flat; margin simple.

Specimen 2031 has a very conspicuous central papilla, but this is suppressed or poorly developed in the other specimens.

There is no evidence of radial canals, marginal appendages or notches, gonads or manubrial structures. The stomach cannot be defined.

T 9 is the largest fossil medusa yet found at Ediacara, its greatest radius is 110 mm.

Diameter of holotype, 170 mm.

Comparisons—As the genus is founded solely on rather irregular cyclic surface sculpture useful comparison with other living or fossil forms is practically impossible. The annular undulations may reflect musculations in the umbrella of a medusa.

As in the case of *Cyclomedusa* it is impossible to be certain whether *Madigania* is Scyphomedusan or Hydromedusan. It differs from *Cyclomedusa* in that there are no conspicuous radial striations.

Genus Dickinsonia, Sprigg 1947

The affinities of the fossil group which will now be described are extremely uncertain. Practically nothing is known of the anatomy of the fossils concerned, and diagnostic characters are restricted to the possession of a strong bilateral symmetry, an elliptical form, numerous radial grooves, a submarginal groove marking off a flange, and a median furrow.

The fossils may well belong to an extinct order or class, but until more is known of the group no attempt will be made to erect any such new categories. Obscure relations with some of the jellyfishes could be argued, as some have a tendency towards bilateral symmetry, and the possession of radiating (?) canals is a strong feature.

The presence of a well-developed bilateral symmetry may indicate higher specialisation and organisation, and perhaps the assumption of creeping habits. Bilateral symmetry is a common characteristic of the Siphonophora and the fossils in question may eventually be referred to that Order. However, for the present, even the assumption that they are Coelenterate may be questionable, but considering their geological age, their mode of occurrence and the few obvious details of their organisation, the coelenterate category seems the most logical association for the present.

Genus **Dickinsonia**, Sprigg 1947

Genotype: **Dickinsonia costata** Sprigg 1947

The genus was founded on a single ovoid form which possessed a marginal crenulate flange and a median longitudinal furrow giving off very numerous subradial grooves to the outer crenulate margin. The form was considered to be inflated aborally in life.

Since describing this form much new material is available from the same horizon with which to make comparisons and study variation. Variation has been found to be considerable while still preserving the same general form. The major differences concern the shape of the fossil and prevalence of radial grooves. It was felt that shape alone is insufficient evidence of specific variation, especially in view of the distortion which some forms have suffered and the probability that organisms in various stages of development are being dealt with.

To overcome these complications, it was felt by plotting the radial grooves in either symmetrical half of the individual animals against respective overall dimensions, that some clearer relations might show up. This has been the case, and a fairly direct relation is seen to exist between growth stage and the number of radial grooves. All the specimens form into two series (fig. 9) which it is

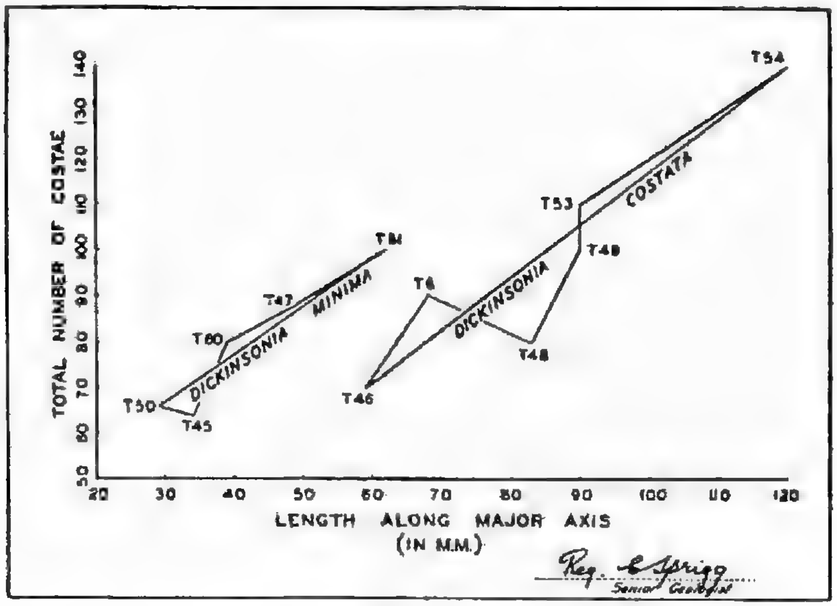

Fig. 9

assumed relate to specific differences. One series indicates less density of costae per unit length and, without exception, includes the larger specimens. It includes the genotype specimen *Dickinsonia costata*. The alternate series has been named *Dickinsonia minima*.

Dickinsonia costata—Length 60-120 mm.; 70-140 costae.

Dickinsonia minima—Length less than 60 mm.; 60-100 costae.

Dickinsonia costata Sprigg 1947

(Plate xviii, fig. 2; plate xix, fig. 1 and 2; plate xx, fig. 1 and 2, text fig. 9 and 10)

Holotype: No. T5, Tate Museum Coll. Adel. Univ., S. Aust.

Hypotypes: 2050, 2012, 2004, 2007, 2009.

Description — Impression ovoid, bilaterally symmetrical, essentially flat; median longitudinal furrow approximately 35 mm. long gives off 70-140 radiating or diverging grooves or costae (?) alternatively to the margin of the fossil. Margin slightly crenulate when complete, the notches corresponding with the intersection of the radiating grooves. There is a definite crowding of costae towards one end in several specimens. This could be related to a specialisation leading to the development of an anterior end, or simply to distortion during burial. The well developed concentric epi-marginal sulcus in the holotype specimen marks off a marginal flange. In other specimens the flange is absent or weakly developed.

Variation—The smallest specimen of the series (pl. xix, fig. 2) exhibits characters not seen in the others. It is (?) deformed with the production of annular folds. The character is thought not to be of anotomical or morphological significance.

Certain of the specimens show considerable variation in their length over breadth ratios. Specimens 2012 and 2009 for example are exceedingly broad, whereas 2007 is at first sight much narrower. This apparent important difference is resolved however upon the closer inspection of specimen 2007. The deeper costae of the central region cut out relatively sharply away from the central plane of symmetry, but finer grooves of somewhat different type continue considerably further. These fainter lines are quite similar to the radial sculpture of 2012. It

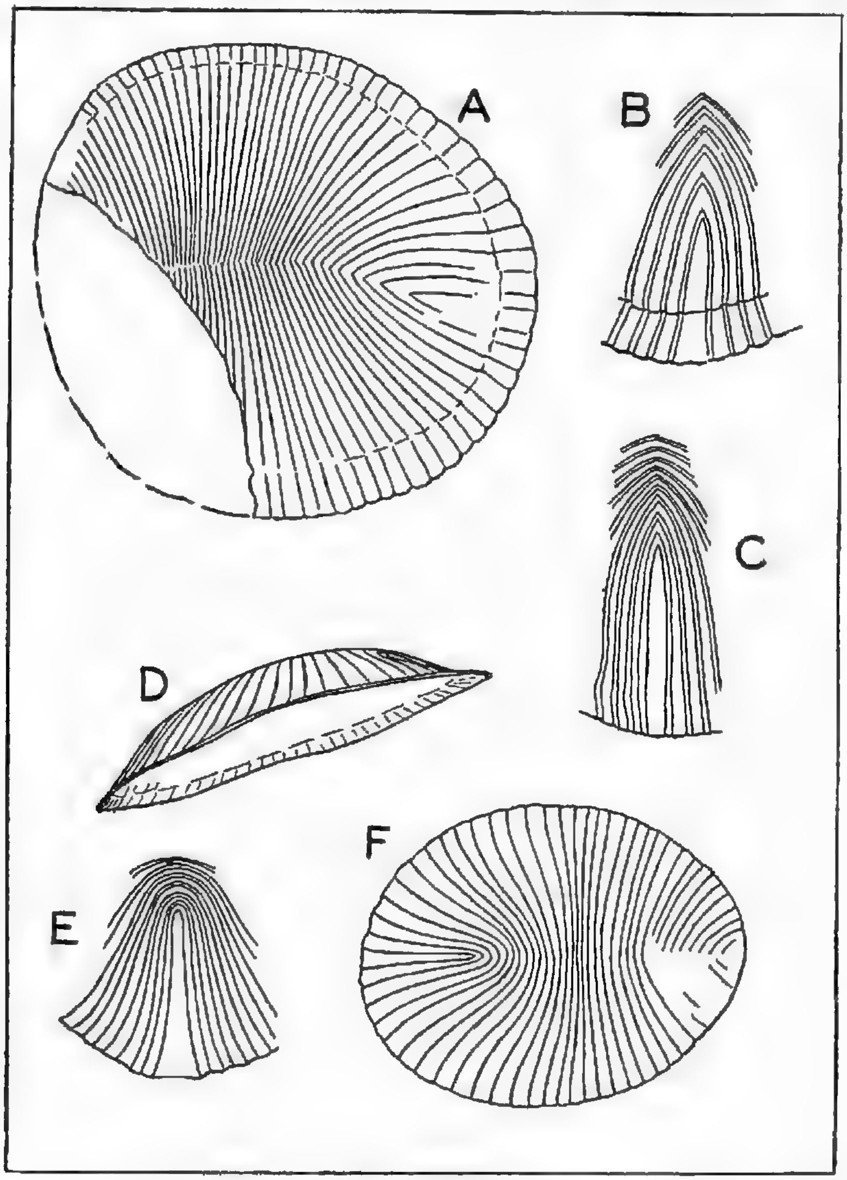

Fig. 10
A, B and C, *Dickinsonia costata;* D, reconstruction of *Dickinsonia;* E. and F, *D. minima.*

would appear moreover that the latter sculpture is more of a skeletal nature—perhaps representing chitinous rods. The coarser sculpture would appear to be more of surface significance. In this way there is a complete relationship between the apparently different fossils 2009 and 2012.

Fig. 1 *Protoniobia wadea*, Sprigg

Holotype No. 192, Commonwealth Palaeontological Collection, Canberra, F.C.T. Specimen collected by Dr. A. L. Wade from Lower Cambrian flags, Mount John Osmond Range, Western Australia. The impression occurs on the bedded surface of laminated sandstone.

Fig. 2 *Protodipleurosoma wardi*, Sprigg

Holotype No. 2023, from the Lower Cambrian "Pound" Sandstone-quartzite at Ediacara, South Australia. This specimen and others figured below occur as impressions in fissile flaggy and poorly laminated quartzites.

Fig. 1 *Beltanella gilesi*, Holotype No. 2056

Fig. 2 *Ediacaria flindersi*, Holotype No. 2058

Fig. 1 *Tateana inflata*, Holotype No. 2017

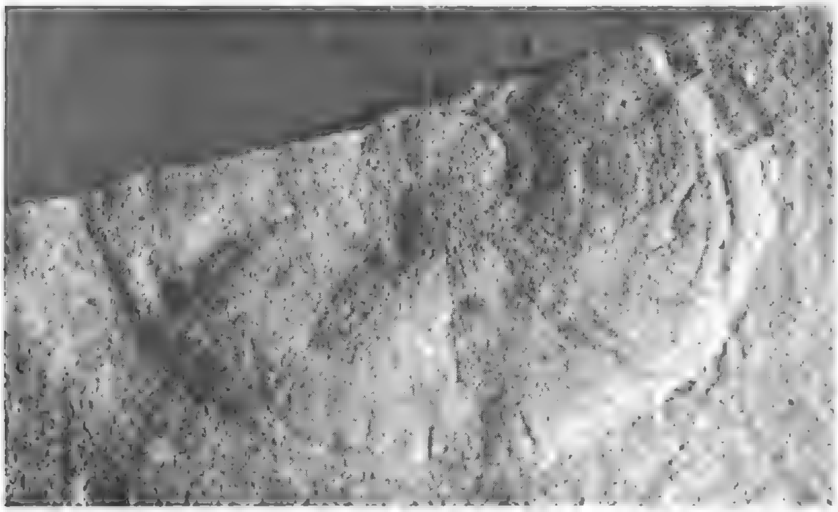

Fig. 2 *T. inflata*, Specimen No. 2018

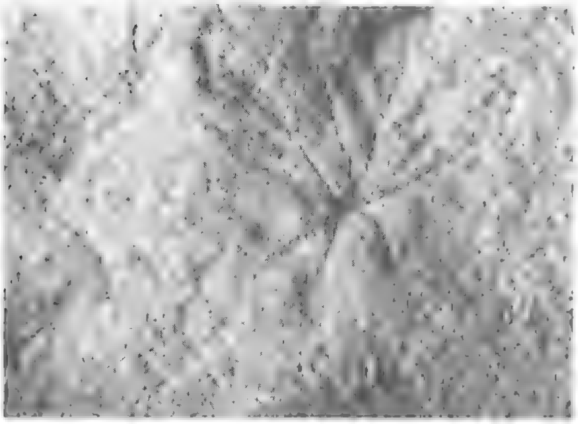

Fig. 1 *Pseudorhizostomites howchini*
Holotype No. 2034

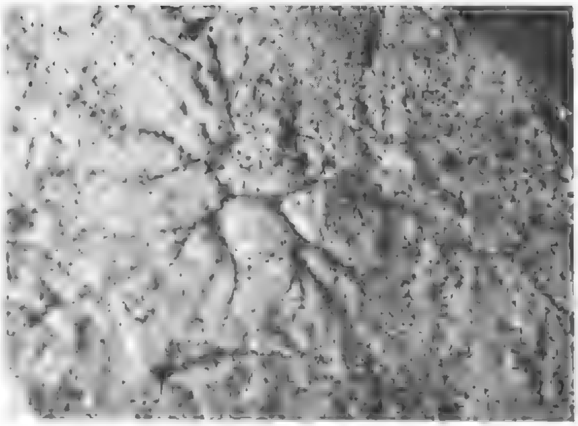

Fig. 2 *Pseudorhopilema chapmani*
Holotype No. 2036

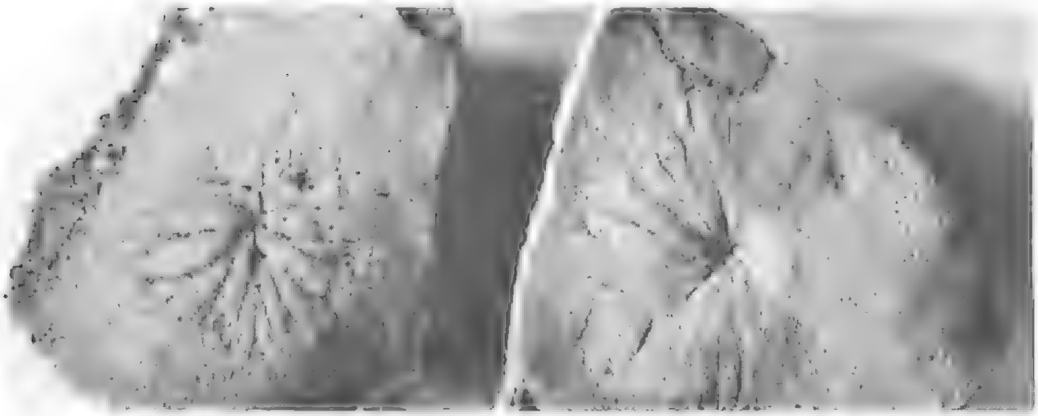

Fig 3 *Pseudorhizostomites*, Specimens No. 2043 and T116

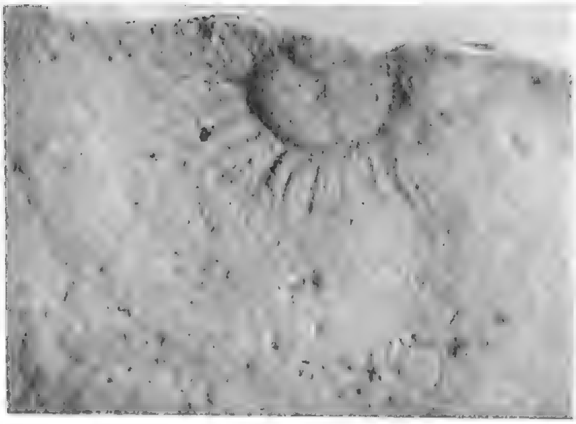

Fig. 1 *Medusina filamentis*
Holotype T68

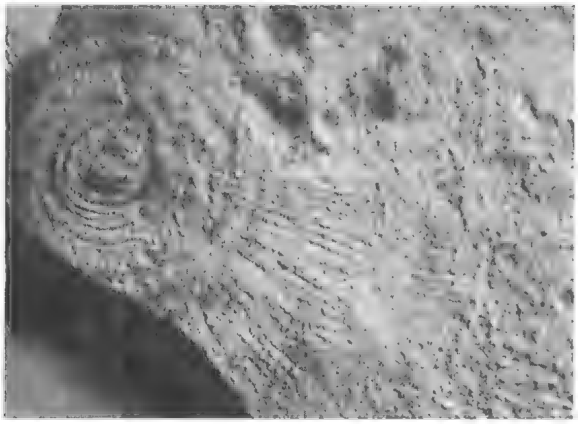

Fig. 2 *Cyclomedusa radiata*
Specimen No. 2027

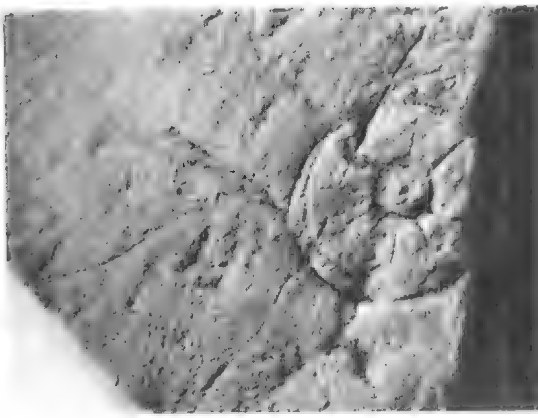

Fig. 3 *Medusina asteroides*
Holotype No. 2021

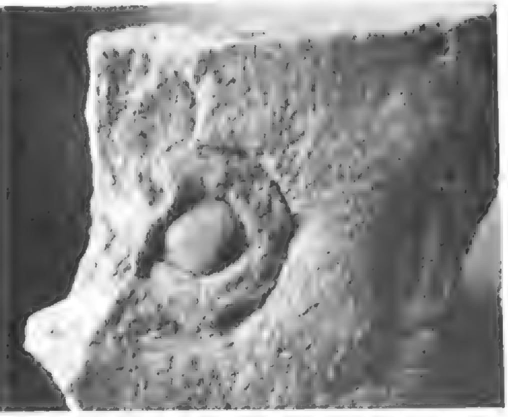

Fig. 4 *Medusina mawsoni*
Holotype No. T39

Fig. 1 *Cyclomedusa davidi*, Holotype No. T5

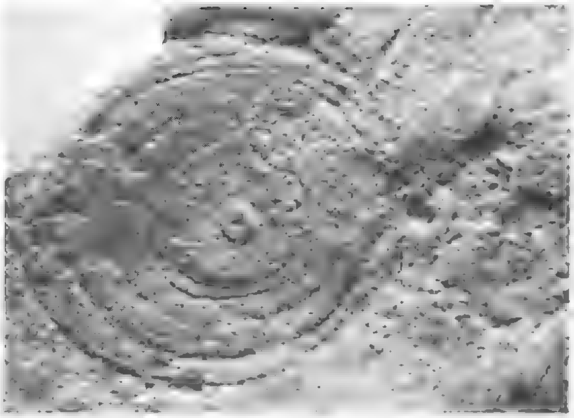

Fig. 2 *C. davidi*, Specimen No. 2020

Fig. 3 *C. radiata*, Specimen No. 2032

Fig. 4 *C. davidi*, Specimen No. 2040

Fig. 1 *Cyclomedusa radiata*, Holotype No. 2037

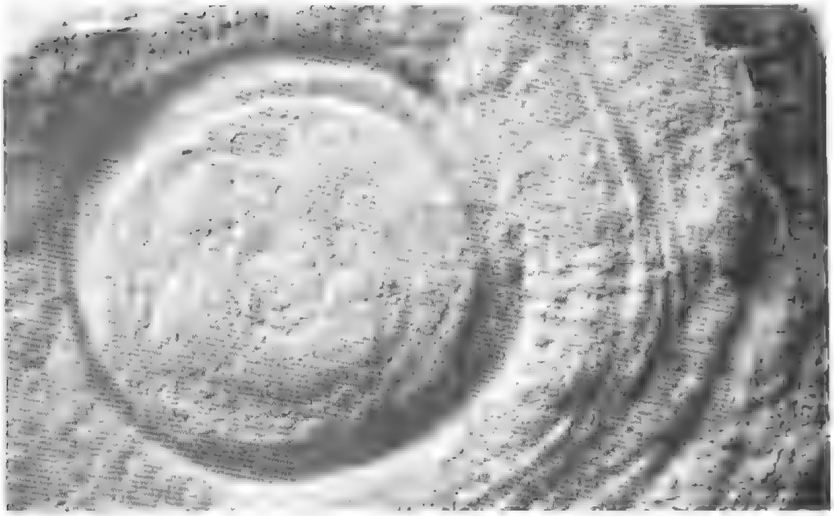

Fig. 2 *C. gigantea*, Holotype No. 2035

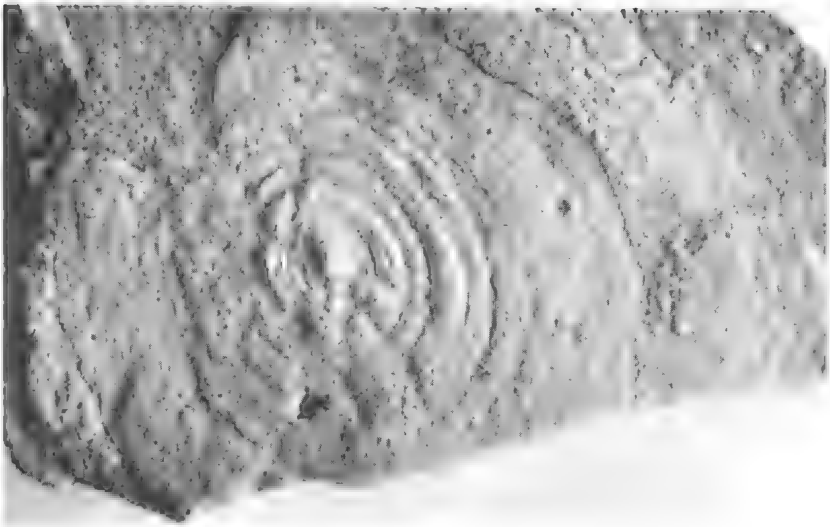

Fig. 1 *Madigania annulata*, Holotype No. 2031

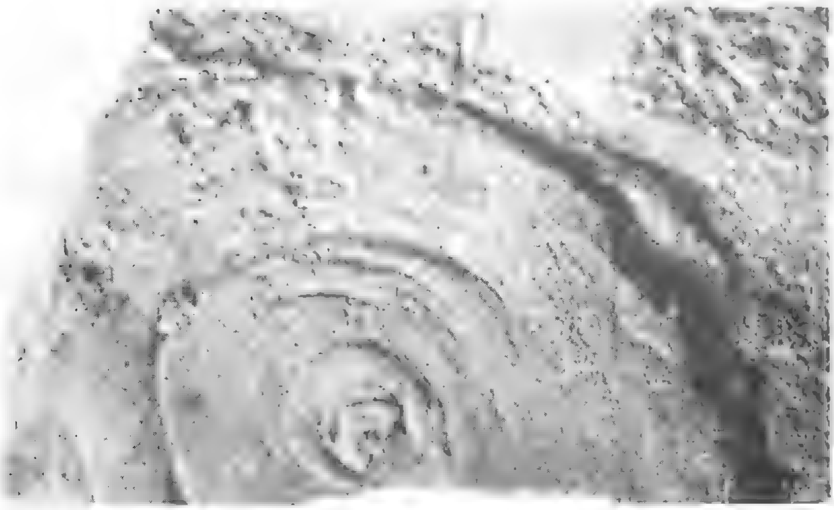

Fig. 2 *M. annulata*. Specimen No. 711

Fig. 1 *Madigania annulata*, Specimen No. 2025

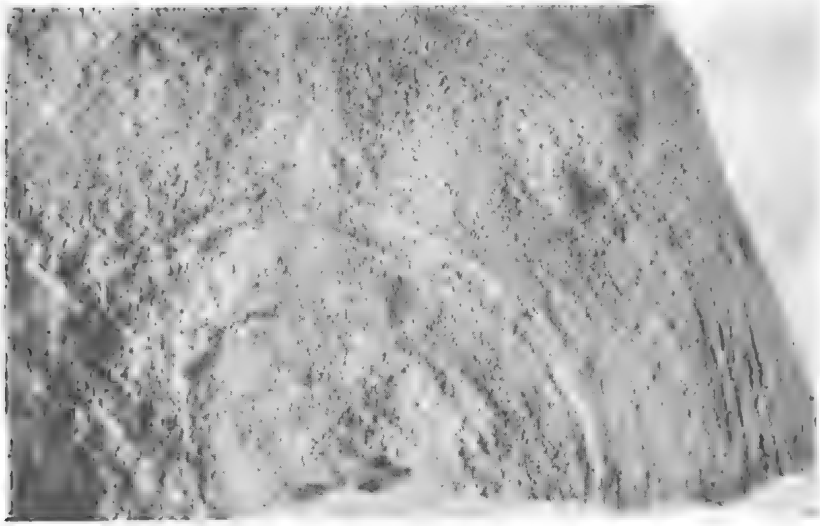

Fig. 2 *M. annulata*, Specimen No. T9

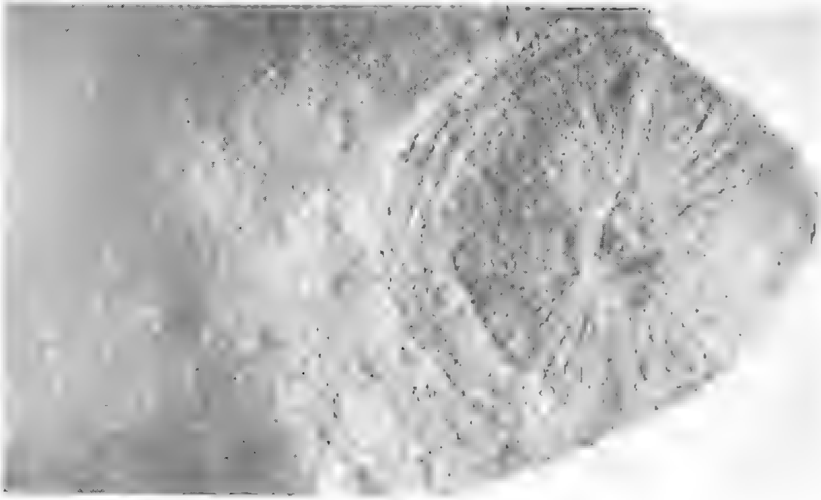

Fig. 1 *Cyclomedusa radiata*, Specimen No. 2010

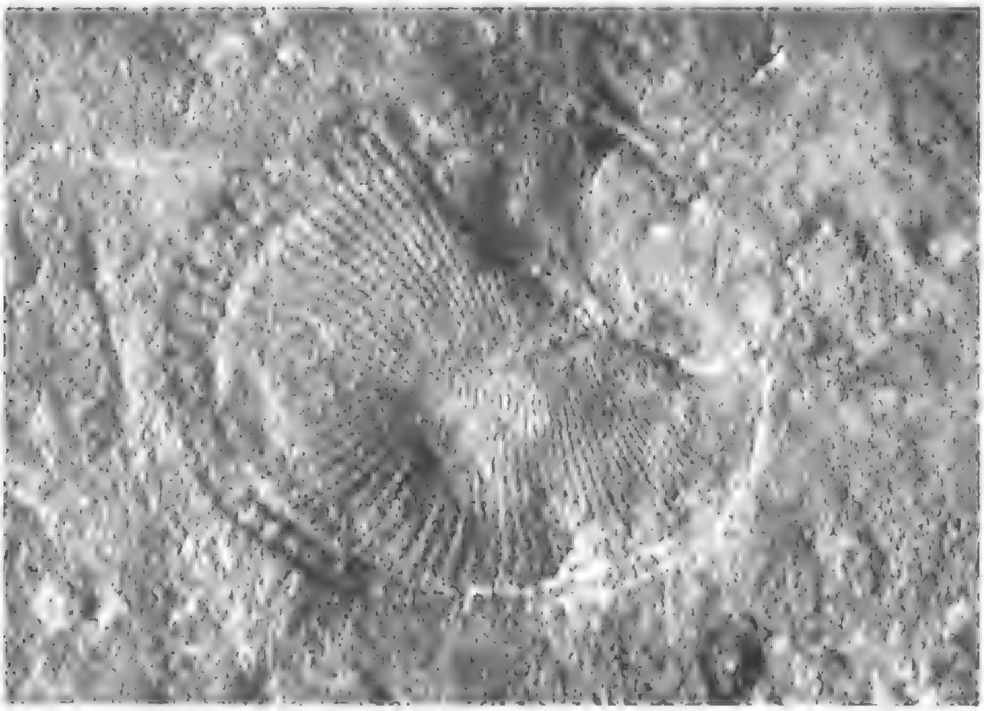

Fig. 2 *Dickinsonia costata*, Holotype No. T5

Fig. 1 *Dickinsonia costata*, Specimen No. 2050

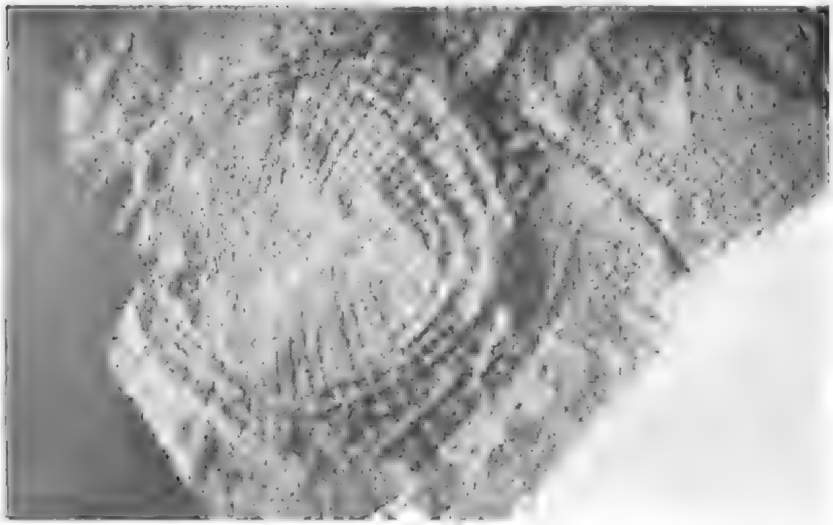

Fig. 2 *D. costata*, Specimen No. 2009

Fig. 1 *Dickinsonia costata*, Specimen No. 2012

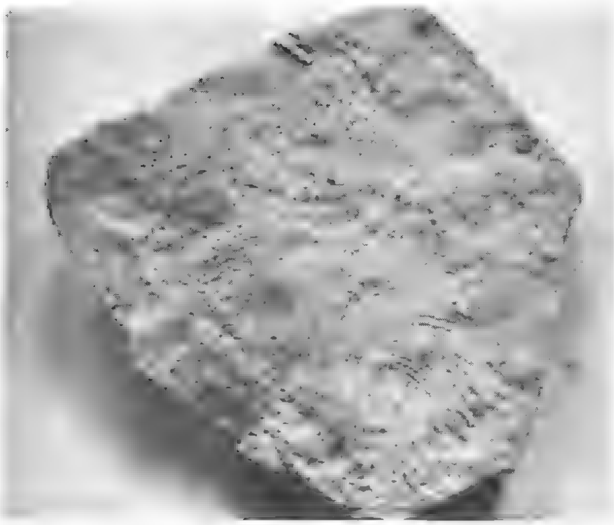

Fig. 2 *Dickinsonia costata*, Specimen No. 2007

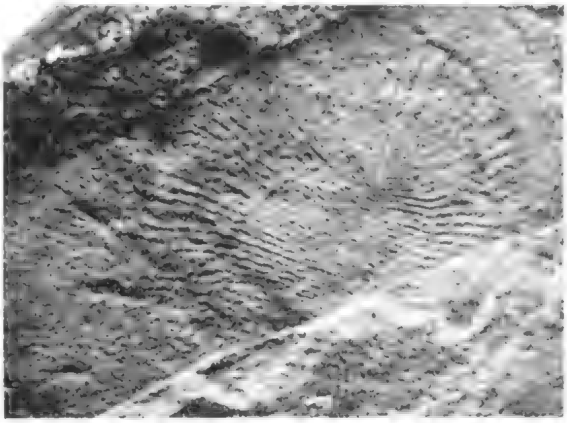

Fig. 1 *Dickinsonia minima*
Specimen No. 2052

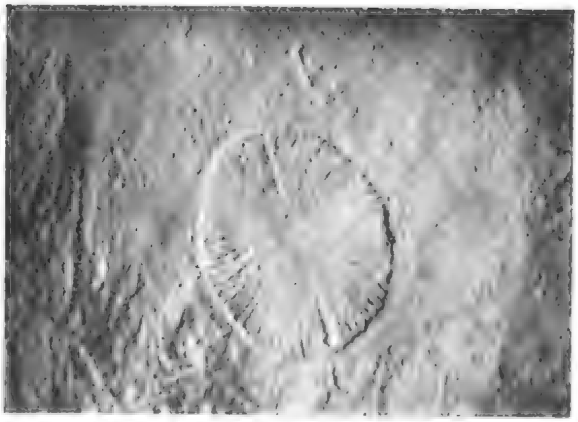

Fig. 2 *D. minima*, Specimen No. 2054

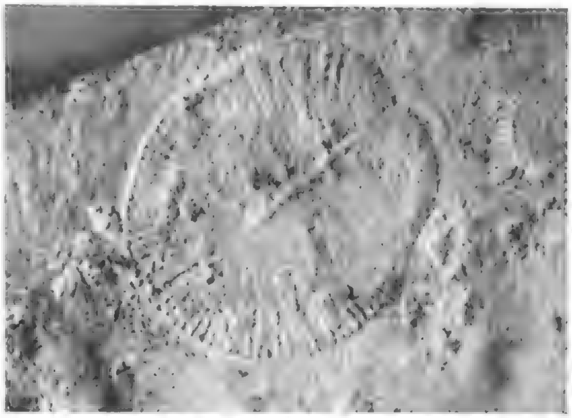

Fig. 2 *D. minima*, Holotype No. 2000

Fig. 4 *D. minima*, Specimen No. 2001

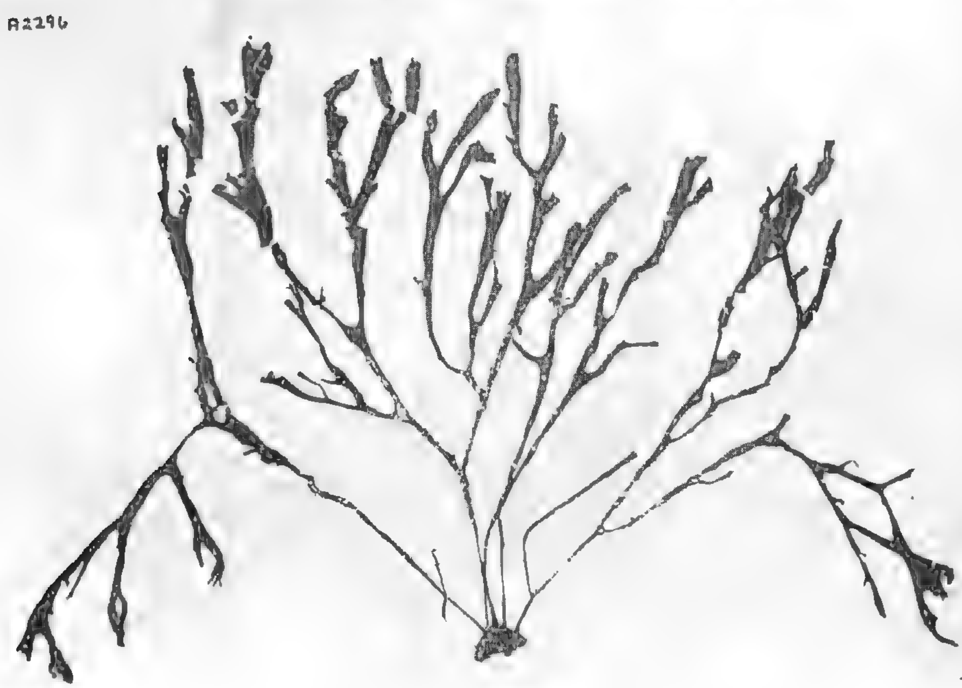

Fig. 1 (above)—An authentic specimen of *D. crassinervia* in Melbourne National Herbarium (x $\frac{1}{4}$).

Fig. 2 (below)—The type specimen of **D. nigricans** (x $\frac{3}{5}$).

Variation in the importance of the marginal flange of the species is puzzling. In 2055 it is exceedingly well defined, while in other specimens a complete gradation into insignificance can be observed. It probably has little diagnostic value. In specimen 2004 the transition can be observed in the one specimen.

Discussion and affinities—The fossils are the impressions of the (?) dorsal aspects of bilaterally symmetrical, soft bodied animals of very doubtful affinities. During burial the animals were flattened and compressed, often slightly obliquely in a manner which suggests that they were strongly convex dorsally. The animal was bilaterally symmetrical. Costae may represent superimposed chitinous rods and surface ornamentation. The epimarginal groove may represent a form of circular canal or simply delineate a marginal flange.

The classification of *Dickinsonia* is still virtually impossible, although the animal was probably coelenterate. The animal might well belong to an extinct order or even class. It therefore remains highly problematical.

Dickinsonia minima Sprigg sp. nov.

(Plate xxi, fig. 1-4; text fig. 9 and 10 E and F)

Holotype: No. 2000, Tate Mus. Coll., Adel., S. Aust. Coll. by W. Reidl.
Hypotypes: 2001, 2052, 2054, 1005.
Type Locality: Pound Quartzite, Ediacara, S. Aust.

Description—Impression essentially similar to, but smaller than, *D. costata*. The longitudinal furrow is well developed in the holotype, but there is only slight evidence of marginal flange formation. There is a slight notching at one end but this appears to be fortuitous.

The various specimens can be arranged serially, varying in length from 29 to 57 mm. and with costae ranging in number from about 60 to 100. The number of the latter increases fairly regularly with elongation.

The continuation of the costae across the central longitudinal furrow is well shown in specimen 2052, which is apparently the youngest of the series. The grooves are not disturbed over their full length, and the last one describes an arc of almost 180 degrees as it reaches the longitudinal furrow. Its reflected half almost parallels its counter-part and leaves a narrow zone not traversed by sculpture.

Dimensions (of holotype)—length 62 mm.; width 57 mm.; (of all specimens) length 29-62 mm.; widths 22-57 mm.

Discussion—The crowding of the subradial grooves towards one end as noted in *D. costata* is also apparent in most of the specimens of *D. minima*. In specimen 2001 this is particularly noticeable and strengthens the impression that there is a tendency towards the development of an anterior extremity. The animal might have developed a creeping habit.

CONCLUSIONS

Study of the suite of fossils from the basal Cambrian of Ediacara, South Australia, and the single form from Mount John, Western Australia, has supported the theory that the immediate late Precambrian was an age of jellyfishes. It has also demonstrated that many and probably all the modern orders of jellyfishes were in existence by early Cambrian times.

The presence of so many stranded jellyfish within restricted horizons of the Pound Quartzite at Ediacara suggests at least local conditions of the tidal flat type. The nature of the enclosing sediments supports this view. The widespread areal distribution of this particular quartzite with little variation and thickness of up to 7,000 feet (Gammon Ranges, South Australia) indicates a great development of shallow continental seas. The quartzite in South Australia appears originally to have covered 30,000 square miles or more. At about the same stratigraphical horizon similar great sandy beds were deposited over great areas in Central Australia (MacDonnell geosyncline) and in the Kimberley Region of Western Australia.

The modern jellyfish with which several of the forms appear closely related are dominantly subtropical or temperate water forms. The early Cambrian climate was therefore probably warm and equable—a fact which is borne out by other marine fossils of this time.

ACKNOWLEDGMENTS

The writer wishes to express appreciation to the numerous palaeontologists and zoologists in North America and England who have offered helpful suggestions in the study of these fossils. In particular, indebtedness is expressed to Dr. Christina Balk, of Chicago University, and Dr. J. W. Rees, of the British Museum, for their keen interest and stimulation. Opportunity is also taken to thank Mr. W. B. Dallwitz for directing attention to Dr. A. Wade's figure of the impression herein described as *Protoniobia wadea,* and to Dr. H. G. Raggatt, of the Mineral Resources Bureau, for permission to borrow the original specimen.

REFERENCES

Agassiz, L. 1862 "Contributions to the Natural History of the United States of America," **4**, 63

Allman 1873 "On Some Recent Results with the Towing Net on the South Coast of Ireland." Nature **1**, 73-74

Ammon, 1886 Abhandle, Math.-Phys. Classe Konigl. boyerischen, Akad. Wiss., **15**

Brandt, J. P. "Ueber Fossile Medusen," Mem. Acad. Imp. Sci. St. Petersbourge, 7th Series, **16**, No. 11

Browne, E. T. 1897 "On British Medusae," Proc. Zool. Soc., London

Caster, 1945 "A New Fossil Jellyfish (*Kirklandia texana,* Caster) from the Lower Cretaceous of Texas," Palaeontographica Americana, 3, No. 18

Cuvier 1799 Journal de Phys., tome, **49**, 436

Fewkes 1887 Amer. Journ. Sci. Ser. 3, **33**, 119

Gegenbaur 1856 "Versuch eines Systems der Medusen," Zeitschr. Wiss. Zool., Bd. 8, Leipzig

Haeckel, E. 1866 Neues Jahrbuch fir Min. Geol. und Paleont.

Lyman, L. B. 1940 McGraw, Hill & Co., New York

Parker, T. J., and Hasswell, W. A. 1940 "Text Book of Zoology," MacMillan & Co., London

Pompeckj, F. 1896 "Die Journal des Cambrium con Tejvovie und Skrej in Bohem," Jahrbuch. K. Geol. Reichsanstelt, **45**, pts. 2 and 3, 501, pl. 14

Linnarson 1871 Kongl, Svensk. Vt.-Akad., Hande, **9**, No. 7

Lang 1886 Jena. Zeit fur Naturwissen., Bd. 19

Mawson, D. 1939 "The Cambrian Sequence of the Wirrealpa Basin." Trans. Roy. Soc. S. Aust., **63**, (2)

Moyer, A. G. 1910 "Medusae of the World," Carnegie Inst., Wash., Publict. No. 109, **1**, **2** and **3**

Narhorst, A. G. 1881 "Om Aftryck af Medusor," K. Svenska Vetensk Akad. Handl Bd. XIX, Nr. I.S. 22, Taf. VI, Stockholm. Kongl. Svensk. Vet.-Akad. Handle, **19**, No. 1

SPRIGG, R. C. 1947 "Early Cambrian (?) Jellyfishes from the Flinders Ranges, South Australia." Trans. Roy. Soc. S. Aust., 71, (2)

WADE, A. 1924 "Petroleum Prospects, Kimberley District, Western Australia and Northern Territory." Parliament of Commonwealth of Australia

WALCOTT, C. D. 1898 "Fossil Medusae," U.S. Geol. Survey, Monograph 30

GESTURE LANGUAGE OF THE WALPARI TRIBE, CENTRAL AUSTRALIA

BY CHARLES P. MOUNTFORD

Summary

Whilst attached to the 1936 Adelaide University Anthropological Expedition to the Granites, Central Australia, I was able to photograph a small number of the hand signs used by the members of the Walpari tribe who inhabit the surrounding country. The accompanying test figures were traced from the photographs taken at the time.

GESTURE LANGUAGE OF THE WALPARI TRIBE, CENTRAL AUSTRALIA

By CHARLES P. MOUNTFORD *

[Read 8 September 1949]

Whilst attached to the 1936 Adelaide University Anthropological Expedition to the Granites, Central Australia, I was able to photograph a small number of the hand signs used by the members of the Walpari tribe who inhabit the surrounding country. The accompanying text figures were traced from the photographs taken at the time.

In a previous paper on the subject (1), I listed the references in literature to the gesture language of the Australian aborigines, and recorded, at the same time, some fifteen hand signs in use in the Ngada tribe of the Warburton Ranges of Western Australia.

This paper records thirteen hand signs of the Walpari tribe.

KANGAROO (*Macropus rufus*), fig. 1, a.

The tips of the thumb and the fingers are first bunched together, then flicked outward.

DINGO (*Canis dingo*), fig. 1, b.

The hand, with the fingers turned tightly inward, is moved upward and downward from the wrist.

LIZARD, small, fig. 1, c.

The hand, held with the forefinger in a pointing position, is vibrated sideways from the wrist.

EMU (*Dromaius novae-hollandiae*), fig. 1, d. and h.

These are alternative gestures for the emu. In the former sign, the hand, turned upward, and lightly clenched, is moved up and down from the wrist. In the latter, the hand is kept stationary, with the hand partly closed and the thumb placed between the second and third fingers.

YAM, fig. 1, e.

The hand is fully extended, held edgewise, and vibrated sidewise rapidly.

RABBIT (*Oryctolagus cuniculus*), fig. 1, f.

The arm is extended and the large ears of the rabbit indicated by the first two fingers of the right hand.

OPOSSUM (*Trichosurus vulpecula*), fig. 1, g.

The hand is partly closed, faced away from the body, then moved upward and downward from the wrist.

WATER, fig. 1, i.

The presence of water is indicated by the hand being lightly closed, held on its edge, vibrated quickly and rotated slightly. The position is not unlike that used to indicate the dingo (fig. 1, b), except that the hand is closed.

CAMEL, fig. 1, j.

The hand, fully extended and facing downward, is moved in an undulating motion in imitation of the movement of the head of a camel.

SNAKE, fig. 1, k.

The thumb and forefinger are bent sharply at the first joint and vibrated in a similar manner to that used in the yam sign.

MOUNTAIN DEVIL (*Moloch horridus*), fig. 1, m.

The second and third fingers are bent sharply inward while the hand and arm are held in a stationary position.

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* Associate Curator in Ethnology, South Australian Museum.

PLAIN TURKEY (*Eupodotis australis*), fig, 1 n.

The hand, fully opened and turned face downwards, is moved from the wrist, in imitation of the movement of the bird's wing.

This paper records a small number of the interesting and practically unknown hand signs of gesture language of the Australian aborigines. It was only the lack of time that prevented me from collecting a much greater number.

REFERENCE

MOUNTFORD, C. P. 1938 Oceania, 9, (2)

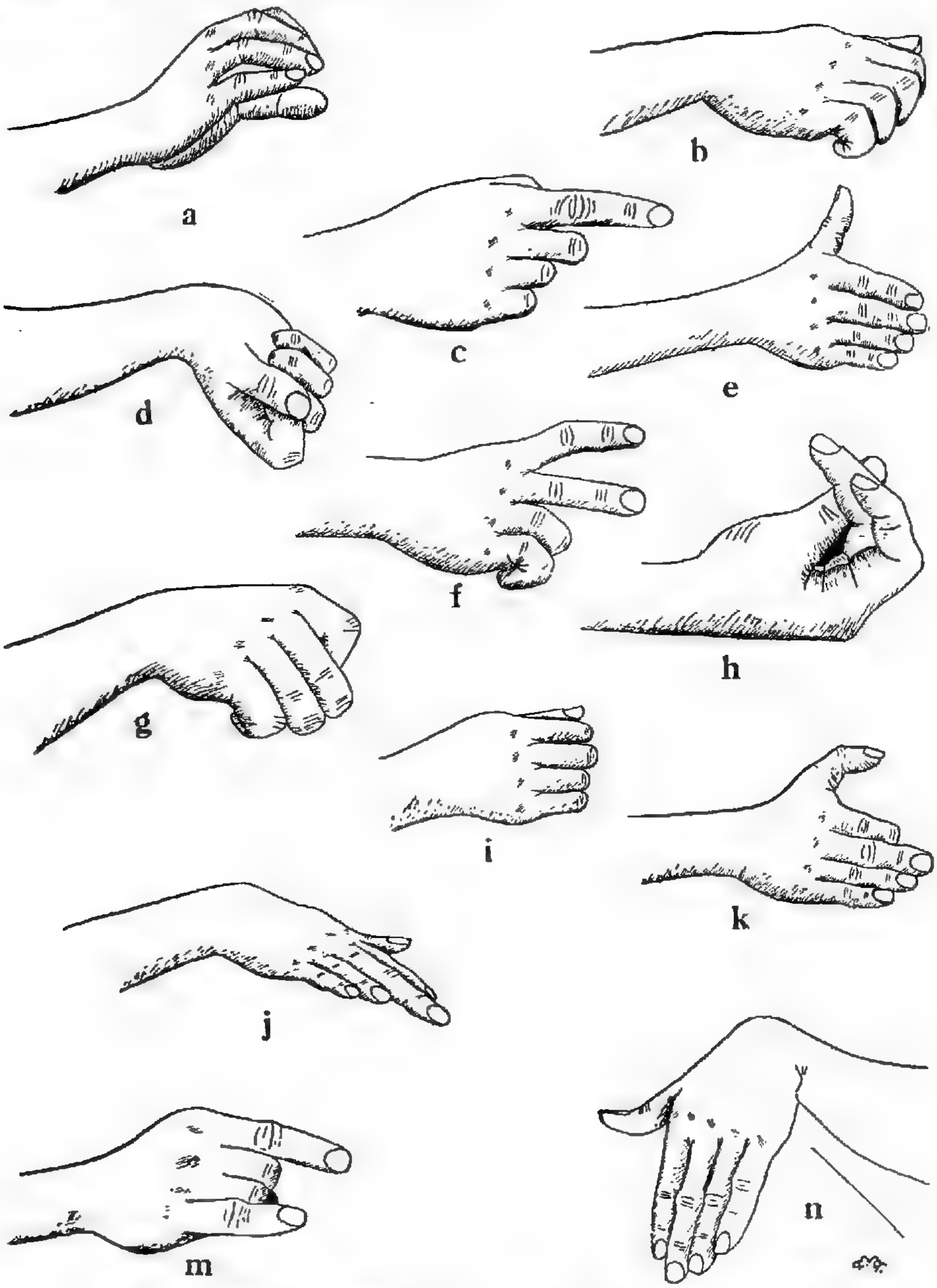

Fig. 1 Gesture Language of the Walpari Tribe, Central Australia

LARVAL TREMATODES FROM AUSTRALIAN FRESHWATER MOLLUSCS PART XIV

BY T. HARVEY JOHNSTON AND NANCY G. MUIRHEAD

Summary

In December 1948 a new echinostome cercaria was found infecting 2 of 77 Planorbis isingi. The infected snails were collected from a small shallow lagoon beside the River Murray at Wood's Flat near Blanchetown. In January 1949, 2 out of a total of 236 snails were found infected in the same locality. In February 1949 the same cersaria was found again, this time at Tailem Bend, where one snail from a total of 28 was infected. Although Planorbis snails were collected from the swamp at Wood's Flat in April 1949 and at Tailem Bend in the following June, no infections with this parasite were found.

LARVAL TREMATODES FROM AUSTRALIAN FRESHWATER MOLLUSCS PART XIV

By T. Harvey Johnston and Nancy G. Muirhead *

Cercaria natans n. sp.
(Fig. 1-6)

In December 1948 a new echinostome cercaria was found infecting 2 of 77 *Planorbis isingi*. The infected snails were collected from a small shallow lagoon beside the River Murray at Wood's Flat near Blanchetown. In January 1949, 2 out of a total of 236 snails were found infected in the same locality. In February 1949 the same cercaria was found again, this time at Tailem Bend, where one snail from a total of 28 was infected. Although *Planorbis* snails were collected from the swamp at Wood's Flat in April 1949 and at Tailem Bend in the following June, no infections with this parasite were found.

Under laboratory conditions the cercariae were observed to emerge from the host snail at about mid-day, and after about two hours of swimming they encysted in the host snail. On some occasions one cercaria only was given off during a day. They swam about or floated in the bottom of the tube with periodic excursions towards the surface of the water. When at rest on the bottom or suspended in the water the body was curved and made an obtuse angle with the tail.

Measurements were made after fixing by the addition of an equal volume of hot 10% formalin to the quantity of water in which the cercariae were swimming. In fixed specimens the body is flexed. Measurements based on 20 such specimens are:—body length, 252-269μ; breadth, 184-176μ.

Average length of 10 living specimens in fairly extended condition is 460μ. Diameter of acetabulum, 100μ; of oral sucker, 66μ; giving a sucker ratio of 5:3. The acetabulum has a fringed margin. The tail, 460-482μ in length in fixed material, is longer than the body, and, like it, is capable of a considerable degree of extension. There is a dorsal as well as a ventral fin fold on the distal half of the tail, but these folds do not extend to the tip. They can be seen best when a little pressure is exerted on the cercaria after staining with dilute neutral red. There are fin folds at the base of the tail also, but they appear to have no connection with those situated distally (fig. 2, 3). The tip of the tail which is free of any fin fold, is capable of contraction and extension, as well as threshing movements, quite independently of the rest of the tail.

The collar of 35 spines is not readily visible in living specimens but is obvious in killed material. There are 5 corner spines on each side ventrally, about 5 lateral spines on each side in a single row, and the rest are arranged in two alternating rows dorsally. The spines widen slightly at about the middle of their length and then taper to a broad point. The corner spines are larger than the rest. The dorsal alternating spines of the two series are all the same size (fig. 5). Average measurements which were made from the metacercaria, are:—corner spines, 15·5μ long; lateral, 14μ; dorsal, 13·5μ. Spinules cover both dorsal and ventral surfaces of the cercaria; they are most abundant anteriorly and ventrally.

There is a prepharynx followed by a spherical pharynx. The oesophagus, when seen from the ventral aspect, appears to be composed of a single column of about 8 crescentic cells. It bifurcates just anterior to the acetabulum and the caeca extend almost to the posterior end of the body.

The details of the excretory system are difficult to determine. A long descending tube on each side opens into a terminal bladder which at times has

* University of Adelaide.

the shape shown in fig. 1. This tube is widest at the level of the acetabulum and is packed with granules from this point to near the anterior loop where the granules become smaller.

The ascending tube is narrower than the descending and runs parallel with it. At a point half-way between the acetabulum and the front of the bladder it divides into an anterior and a posterior collecting tubule. The anterior one extends to the level of the pharynx where a group of 3 flame cells is connected

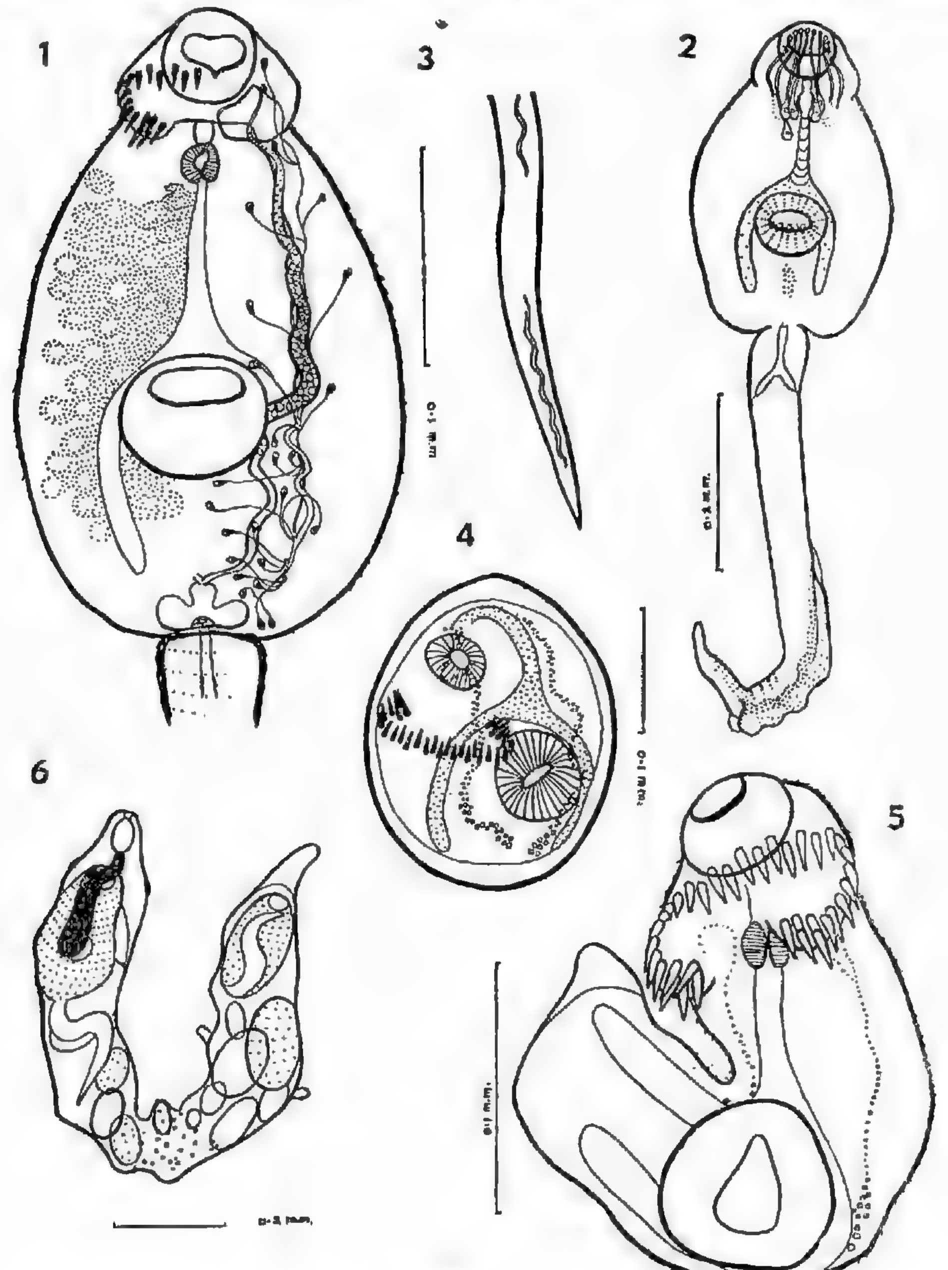

Fig. 1-6

Cercaria natans—1, cercaria showing collar spines and excretory system; 2, cercaria showing gland cells and fin folds after staining with neutral red; 3, sketch of dorsal view of tail, indicating anterior and posterior fin folds; 4, cyst; 5, metacercaria; 6, redia.

with it. Between this point and the acetabulum there are two pairs of flame cells. Level with the acetabulum are two groups each of 3 flame cells, and at the point where the ascending tube divides there is another group of probably 3, though only 2 flame cells of this group were actually observed. Posterior to this point there are three groups, each of 3 flame cells, giving a total of 25 on each side. Ciliary flames are present in the descending and ascending tubes. The arrangement of the groups of flame cells is shown in fig. 1. A caudal excretory pore opens dorsally at the base of the tail. From the bladder an excretory duct extends into the tail, and at a point about 70μ from the base of the latter, divides into two.

On the dorsal lip of the mouth are the openings of eight ducts which can be traced backwards to about the level of the pharynx, on each side of which are about 4 pyriform gland cells, which stain only very faintly with neutral red. On either side of the oral sucker is a group of greenish refractive bodies. Granular cystogenous cells are densely aggregated beneath the cuticle from about the level of the pharynx to the posterior end of the body (fig. 1).

Rediae containing living cercariae were dissected from the liver of the snail. They contained up to five or six cercariae. Nearly all the rediae possessed bright orange pigment spots. Anteriorly the pharynx opens into a short darkly coloured intestine which occupies only about one-eighth of the body length. The collar is not obvious but in some specimens a birth pore can be seen opening a short distance from the anterior end. Foot processes are short and of equal length and are more obvious in young specimens (fig. 6).

We successfully infected the pond snail, *Amerianna* sp., and the tadpole of *Limnodynastes tasmaniensis* with the cercaria. The host snail, *Planorbis isingi*, is a host also for the metacercaria, the cysts occurring mainly in the liver among the rediae. Generally the host snail bears a large number of cysts. Measurements of 30 cysts from *Planorbis* ranged from 176μ x 176μ to 191μ x 206μ. In the experimentally infected *Amerianna* sp. 10 cysts were found in each snail, mainly in the tissue of the mantle, and measurements of 20 of these cysts ranged from 168μ x 183μ to 191μ x 191μ. Two cysts were dissected from one of the infected tadpoles (fig. 4) and only one cyst from the other. They were found in the peritoneum surrounding the kidney and in the kidney tissue. Measurements of two of these cysts were 229μ x 168μ and 168μ x 139μ.

The cysts are thick-walled and difficult to break but metacercariae could be expressed from them in some cases. The spines of the metacercaria are larger than those of the cercaria and their arrangement is shown in fig. 5. Their measurements have been given above. The spination of the body of the metacercaria is more pronounced than in the cercaria. The digestive system is similar and the sucker ratios are the same. The acetabulum lies in the posterior half of the body.

This cercaria belongs to the *Echinostomum* group as the spines of the collar are in a double row, uninterrupted dorsally, and the spines of the two dorsal rows are equal in size.

The presence of a fin membrane on the tail, according to Sewell (1922) separated his *Cercaria Indica XLVIII* from other Echinostomes. He placed it with others in a specially erected group—the Echinatoides group. Our cercaria in some respects falls into this group. However, the presence of spines on the body and the fact that the excretory tubule divides into anterior and posterior tubules at a point half-way beween the acetabulum and the bladder would, according to Sewell's diagnosis, exclude our cercaria from that group.

Wesenberg-Lund (1934) placed *C. echinostomi* Dubois in the Echinatoides group and stated that at first he determined this species as *C. limbifera* Seifert 1926 (later described by Brown 1931), but that after seeing Brown's description he decided that the two species were distinct though closely allied. Like our species the two cercariae just mentioned have 35 spines but both are larger; *C. limbifera* has hairs anteriorly; and both *C. limbifera* and *C. echinostomi* have fin folds extending to the tip of the tail.

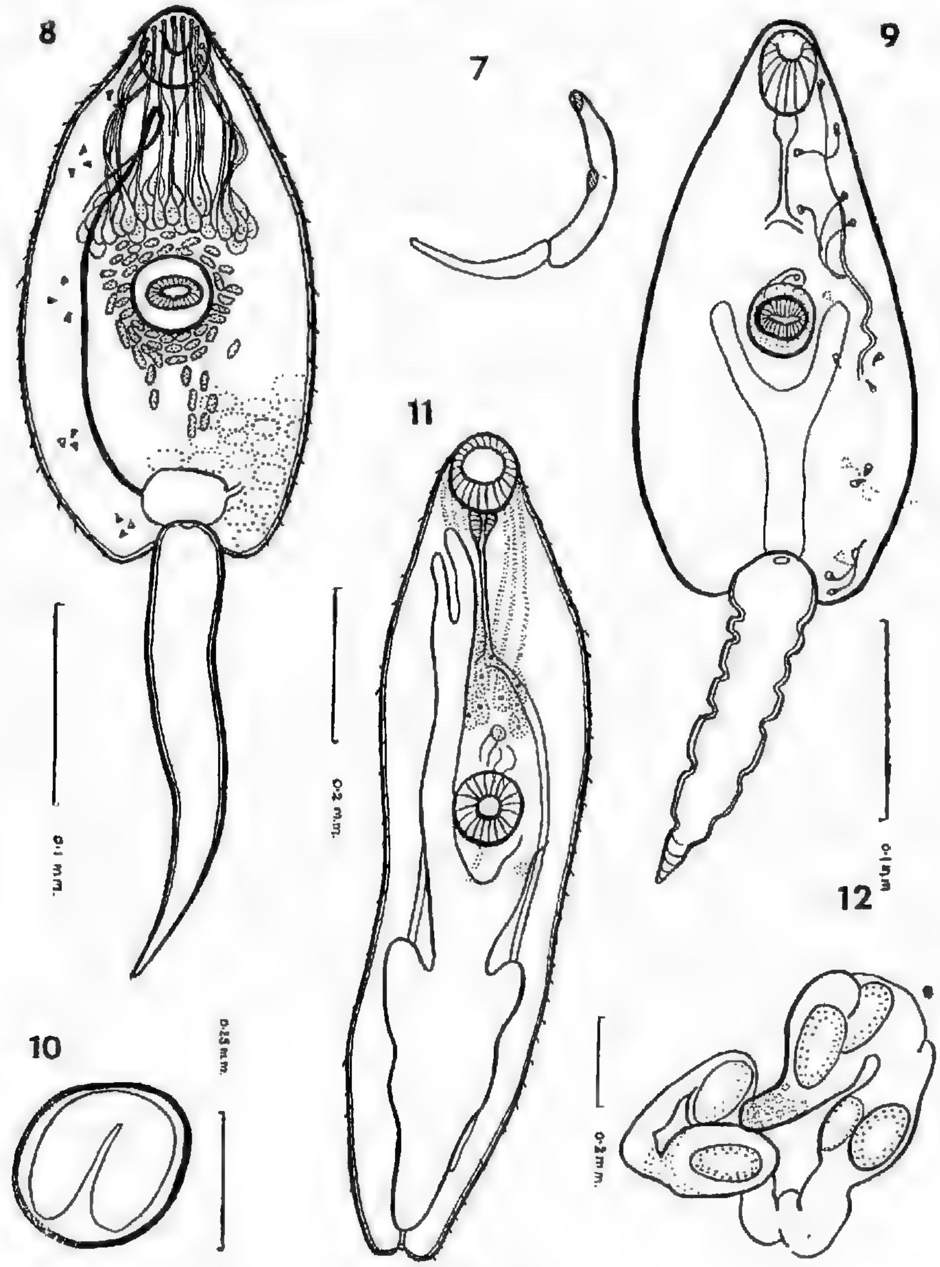

Fig. 7-12

Cercaria lethargica—7, sketch, showing usual flexed condition; 8, ventral view, showing gland cells, also pigmented cells surrounding acetabulum; 9, excretory system; 10, cyst; 11, metacercaria; 12, sporocyst.

We might mention having found in *Amerianna pyramidata* and *Planorbis isingi* from Wood's Flat in February 1949 an echinostome cercaria possessing an anatomy very like that of *C. natans* but having 37 spines. It is not the larva of *Echinostomum revolutum* because it has dorsal and ventral fin folds like *C. natans*. Its gland cells stain very readily with dilute neutral red whereas those of *C. natans* are very difficult to stain even after prolonged immersion in the dye. Its metacercaria has been obtained in the host snails, *Amerianna pyramidata* and *Planorbis isingi*, and in the tadpole of *Limnodynastes tasmaniensis*.

Cercaria lethargica n. sp.

(Fig. 7-12)

Since December 1937 a gymnocephalous cercaria has been found infecting the gastropod, *Plotiopsis tatei*, at various places along the lower River Murray. In April 1939, at Tailem Bend, it was found in 40 out of 200 of these molluscs. After February 1940 the incidence of the infection decreased until in February 1948, out of 250 *Plotiopsis* collected near Mannum, only one snail was found infected with this cercaria. In April 1949 at Wood's Flat, near Blanchetown, 1 out of 30 snails was found infected. The parasite has never been collected earlier than December but has been found as late as June. It is not an actively moving cercaria but remains for long periods suspended in the water with the tail, which is attached ventrally, and the body forming a continuous curve so that the whole organism is crescent-shaped (fig. 7). When in movement the tail is a little longer than the body and in this extended condition the cuticle is smooth. In a contracted state, as in preserved specimens, the cuticle is thrown into folds which become smaller towards the tip of the tail.

Measurements of the body of 30 specimens after fixation by the method described above, ranged from 268μ in length by 114μ in breadth to 190μ in length by 130μ in breadth. The breadth was measured across the widest part of the cercaria, just posterior to the acetabulum. The oral sucker and the acetabulum are approximately equal, with an average diameter of 32μ. The tail varies in length from 153μ to 268μ. The cuticle of the cercaria bears small spines which are arranged in rows and are embedded for part of their length in the cuticle. They are more obvious anteriorly than posteriorly.

Around the acetabulum and to a less extent behind it, the cercaria is coloured a yellowish-brown due to the presence of many cells containing yellowish granules. Beneath these cells are densely granular cystogenous cells which stain readily with many dyes. These latter cells do not extend much further forward than the acetabulum.

The oral sucker is oval in some preserved and extended specimens, round in living material. The mouth is subterminal. The pharynx can be seen only in stained preparations. The oesophagus is even more difficult to observe but in one or two stained specimens it could be followed to its bifurcation about midway between the oral and ventral suckers. Caeca were not observed.

Anterior to the ventral sucker and extending forwards to a point about midway between the suckers is a conspicuous group of clear gland cells from which ducts extend forwards to open on the oral sucker in 3 groups, a dorsal and two ventro-lateral.

The bladder in its contracted state is approximately circular. Extended, it forms a conspicuous Y with a broad stem and with the arms reaching forwards on each side of the acetabulum. An excretory pore opens into the depression into which the tail fits. When the bladder is contracted an excretory duct may be seen extending from it on each side to the level of the pharynx where it forms a loop (fig. 8). When the bladder is in its extended condition, excretory ducts can be seen anteriorly but their points of entry into the bladder could not be detected. Several groups of flame cells have been seen (fig. 9). They are in groups of 3, two groups are anterior to the acetabulum and there are perhaps 3 groups behind it.

A rudimentary cirrus sac lies partly anterior to and partly dorsal to the acetabulum and terminates in the midline or slightly to one side, at the genital pore.

The liver of the host snail may contain many sporocysts varying in length from 1·5 to 2 mm. At intervals along their length, between the contained cercariae, they are constricted and have the appearance of a string of beads. There are many refractive globules which in some specimens collect at one end of the sporocyst (fig. 12).

Successful experimental infections were carried out using the aquarium fish, *Gambusia.* In 1940 when many infected snails were present with the fish, as many as 56 cysts were found in the muscles and body cavity of one fish, and 3 others in the liver. In the experimental infections carried out in 1948 cysts were found in the liver only, in the two fish which were successfully infected. These cysts measured from $311\mu \times 311\mu$ to $328\mu \times 303\mu$.

The metacercaria, when excysted from the thick-walled cyst (fig. 10), shows many of the characters of the cercaria. The body has lengthened and measures from 1·1 mm. - 1·2 mm. in length and from 250μ - 229μ in breadth. The oral and ventral suckers which are about equal in size, measuring 78μ - 82μ, retain their positions relative to each other. The spination is more marked than in the cercaria.

The digestive system is observable in stained specimens. The oesophagus bifurcates about midway between the suckers and the caeca extend to the posterior end. A group of gland cells is present as in the cercaria, and their ducts open on the oral sucker. A few yellowish granular cells which were a feature of the cercaria, are present near the acetabulum.

The most obvious feature of the metacercaria is the excretory system which still retains its Y-shape. However, the arms of the Y extend anteriorly until they are level with the pharynx and the outline of the Y is not as well defined as in the cercaria. The excretory system is crowded with refractive material which makes the metacercaria appear dark and obscures other features of the living specimen. When the metacercaria is fixed and stained other structures can be seen (fig. 11).

There is a genital pore and cirrus sac in about the midline some distance anteriorly to the ventral sucker. A fine tube (possibly the uterine rudiment) extends from behind the ventral sucker to the region of the cirrus sac. Posterolaterally from the acetabulum is a group of cells which may be the ovarian rudiment.

This cercaria belongs to the Leptocercous group of Lühe (1909). Sewell (1922) modified Lühe's scheme of classification and included a number of different groups in the Gymnocephalous cercariae. That classification was modified by Dubois (1929) and Wesenberg-Lund (1934). Sewell (1922) has described a cercaria very like ours—*C. indica XIV.* He stated that it fell into no known group or sub-group. It differs from our species however in size, amount of pigment, and in the arrangement of its excretory canals and tubules, although it has the Y-shaped bladder. The excretory system of our carcaria is more like that of an echinostome and it is therefore possible that the adult may belong to the family Psilostomatidae in which the life history is similar to that of Echinostomes. However, the Psilostome cercariae described by Beaver (1939) and by Szidat (1937) are different in many respects from ours and their development occurs in rediae not in sporocysts. The Y-shaped excretory system, packed with refractive material, of the metacercaria of our species is suggestive of the Fellodistomatidae.

Summary

A new 35-spined echinostome cercaria, *C. natans,* is described from *Planorbis isingi* from the lower Murray. The metacercaria has been obtained experimentally from the gastropods, *Planorbis isingi* and *Amerianna* sp., and from the tadpole of *Limnodynastes tasmaniensis.*

A closely allied 37-spined cercaria is reported from *Amerianna pyramidata* and *Planorbis isingi,* its metacercaria having been obtained experimentally from these two species of snails as well as from the tadpole just named.

Cercaria lethargica n. sp. is described from the gastropod, *Plotiopsis tatei,* the metacercaria occurring (experimentally) in a fish, *Gambusia.* The adult is perhaps a Psilostome or a Fellodistome.

Acknowledgments

We desire to acknowledge assistance rendered by Messrs. G. G. and Bryce Jaensch of Tailem Bend. The work was carried out with the aid of the Commonwealth Research Grant to the University of Adelaide.

Literature

Beaver, P. C. 1939 The Morphology and Life History of Psilostomum ondatrae Price, 1931 (Trematoda, Psilostomidae). J. Parasit., **25,** 383-393

Brown, F. J. 1931 Some Freshwater Larval Trematodes from Cheshire. Parasitology, **23,** 88-98

Dubois, G. 1929 Les cercaires de la Région de Neuchâtel. Bull. Soc. Neuchâtel. Sci. Nat., **53,** n.s. 2, 1928, 1-177

Lühe, M. 1909 Trematodes. Die Süsswasser Fauna Deutschlands. Heft 17

Seifert, R. 1926 Cercaria limbifera, eine neue Echinostome Cercaria. Zool. Anz., **67,** 112-199

Sewell, R. B. S. 1922 Cercariae Indicae. Ind. J. Med. Res., **10,** Suppl. Number, 1-370

Szidat, L. 1937 Uber die Entwicklungsgeschichte von Sphaeridiotrema globulus Rud. 1814 und die Stellung der Psilostomidae Odhner im natürlichen System, I. Z. Parasitenk., **9,** 529-542

Wesenberg-Lund, C. 1934 Contributions to the development of the Trematoda Digenea. Part II. The biology of the freshwater Cercariae in Danish freshwaters. D. Kgl. Dansk. Vidensk. Selsk. Skr. Naturw. Math. Afd., Raekke 9, **5,** (3), 1-223

A SODA-RICH COMPOSITE INTRUSIVE STOCK LOCATED IN THE BOOLCOOMATTA HILLS, SOUTH AUSTRALIA

BY E. R. SEGNIT

Summary

Situated about one and a half miles south of the homestead of Old Boolcoomatta sheep station is a composite stock-like intrusive body of unusual nature. In plan it measures about 200 yards by 100 yards. The intruded formation consists of mica schist and other meta-sediments of middle Precambrian age. On one side of the intrusion the enveloping schistose rocks are riddled with a maze of large quartz feldspar pegmatites.

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[Read 10 November 1949]

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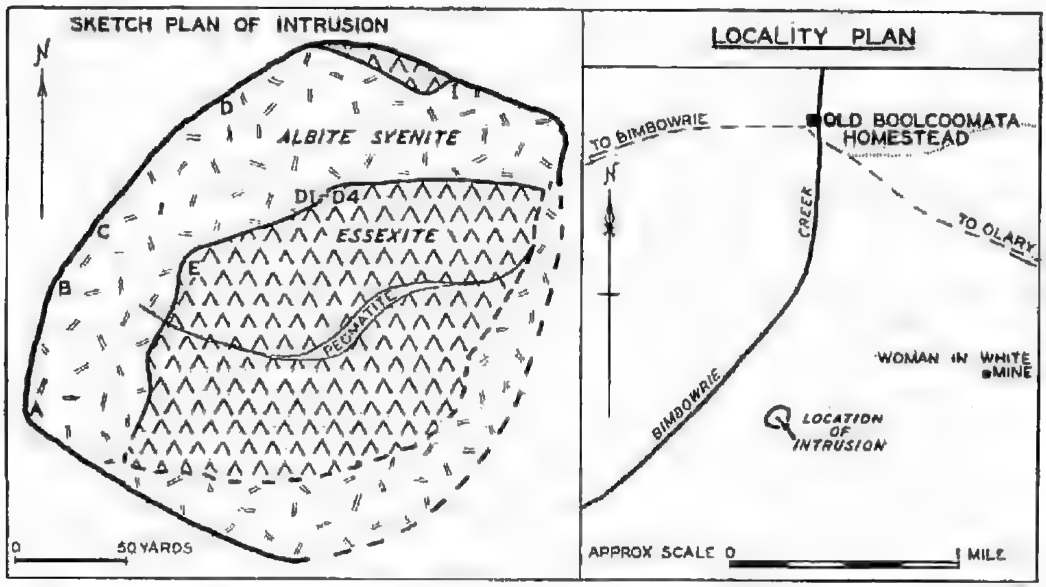
The metamorphosed intruded formation is of the aureole of the granite bathylith of the Boolcoomatta Hills. The great outcropping mass of Binberrie is distant scarcely more than one and a half miles.

The intrusion is approximately oval in shape. The long axis of the ellipse trends north-east to south-west, which conforms to the directions of schistosity of the surrounding rocks.

The outcrop itself is rather wanting in topographic relief and soil cover limits exposures in such critical areas as the mutual contacts of the intrusions and the encircling Precambrian formation. The area of intrusion is irregularly occupied by two distinct igneous magma types: one is more feldspathic and lighter in colour; the other is darker and obviously more femic. The relative areas occupied by each of these and their relation in the outcrop is plotted in the plan herewith.



As will be noted from the analysis the lighter rock is syenitic but abnormally high in soda. Its outcrops are semi-continuous piles of broken rock only a few feet high at most. The blocks are small and equidimensional, having broken up along closely spaced joints.

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The more basic rock, which may be described as a soda-rich dolerite, occupies outcrops only slightly above the ground level and in general has a pronounced schistosity parallel to the long axis of the intrusion.

The main outcrop of albite syenite occurs along the north edge of the intrusion. A feature of it, especially in some areas, is that it contains in small grains a surprising amount of magnetite. In one part of the outcrop coarse magnetitic loadstone in lumps up to two inches in diameter has been shed. Outcrops of the syenite occur all around to the north-west projection of the intrusion and isolated small outcrops appear at the north-east corner. Along the eastern side nothing can be seen due to soil cover, but it seems probable from the little shed material, that the syenitic rock extends right around the intrusion.

The central, more basic part of the intrusion is essexitic in nature. It is in part massive, but has been affected by the local metamorphism. A considerable part has been changed to epidote-biotite schist. Some unaltered rock occurs near to the contact with the syenite (apparently having been protected by the more massive character of this rock), and this has been taken as representative of the original intruded rock. It is characteristically rich in hornblende as compared with the biotite-rich altered rock.

Epidote is abundant in the central part of the intrusion. It occurs commonly as large nodules up to 12 inches in diameter, but generally 5 to 6 inches or less. These are almost pure bright green finely crystalline epidote. The biotite schist is frequently rich in small green lenticles of epidote about half to one inch in length. The unaltered essexitic rock contains a small amount of epidote which appears to be a primary constituent. It would seem that some at least of the epidote present is primary.

The transition from essexite to syenite is clearly seen on the northern side of the intrusion. There is no sharp line of demarcation, although the transition is relatively sudden and takes place over a distance of 3 to 4 feet. The syenite becomes coarser nearer the transition, while in parts the two rocks seem to be mixed. In some places magnetite is very abundant.

The outcrops on the southern side are poor or non-existent. Only occasional small patches are seen near the south-east corner. Shed material as well as these few patches of rock indicate that the syenite extends right around the intrusion. Some of the shed material contains coarse hornblende and calcite.

The schistosity of the basic centre is roughly parallel to that of the intruded rock, as would be expected, except where the latter follows the edges of the intrusion.

A quartz-feldspar pegmatite, generally similar though poorer in tourmaline and mica to those traversing the rocks of the surrounding hills, penetrates the intrusion extending right through both constituent rock types. It is up to 20 feet wide in places. A feature of it is a fine-grained border zone where it contacts the intrusion.

PETROLOGICAL FEATURES OF THE ROCKS

The Albite-Syenite—A light-coloured medium-grained rock composed chiefly of elongated albite crystals, with magnetite, quartz and a little apatite, muscovite, chlorite and rutile.

The feldspars tend to be elongated but apart from this show no pretence of crystal outline. They are frequently untwinned. Other crystals show fine multiple twinning, commonly discontinuous. The individuals, although elongated, are arranged at random and give no directional structure to the rock. Minute inclusions are common. Patches of small crystals, possibly due to metamorphic processes, commonly occur along the edges of larger crystals. Extinction angle measurements proved unsatisfactory, but the chemical analysis of the rock and low refractive index of the feldspar indicates it to be albite.

Magnetite is plentiful, distributed evenly throughout the rock. It occurs as aggregates of well-formed crystals, the individuals being of much smaller grain-size than the feldspar lathes. Minute octahedra included in the feldspar are also common.

Clear quartz, making up several per cent. of the rock, is in grains comparable in size to the magnetites.

Accessory minerals are muscovite, chlorite, apatite and rutile. The mica forms small bent flakes; the chlorite is pale green, has low D.R. and is derived from the mica. The transition can be seen in single crystals. Apatite is a common accessory, sometimes well crystallized. Rutile forms groups of very small dark-brown crystals generally associated with the magnetite. They are sometimes distinctly striated, and the occurrence in clusters suggests a secondary origin. The magnetite with which it is associated is well crystallized and shows no sign of alteration.

The chemical composition of the rock is given in the table herewith.

TABLE OF ANALYSES

	I	II		I	II
SiO_2	62·18	50·40	H_2O+	·25	·47
TiO_2	16·91	·79	H_2O-	·01	·08
Al_2O_3		14·91	P_2O_5	·34	·12
Fe_2O_3	8·19	9·21	MnO	—	·03
FeO	3·29	6·92	BaO	·04	—
MgO	·68	4·70	S	nil	—
CaO	·76	5·94			
K_2O	·10	1·16		100·74	99·90
Na_2O	7·99	5·17			

I. Albite Syenite (6228): Old Boolcoomatta Stn. Anal. E. R. Segnit.
II. Essexite (6226): Old Boolcoomatta Stn. Anal. E. R. Segnit.

Another specimen from another point on the outcrop differs from the syenitic rock described above in that it contains a notable quantity of actinolitic amphibole, some included in the feldspars. In this magnetite is less in evidence, apatite is unusually abundant.

The Essexite—A dark grey medium-grained rock in which hornblende crystals 2 to 3 millimetres in diameter are visible in the hand specimen. It is about 35% mafic minerals, chiefly hornblende.

The feldspar is somewhat clouded owing to incipient alteration. In shape it tends to be elongated parallel to 010 face, but the crystal boundaries are irregular and pitted.

Rather fine albite twinning is widespread, although mainly indistinct. The maximum extinction angle observed in the symmetrical zone was about 11°, which with R.I. determination and high soda content of the rock indicates a composition (Chudoba) of about Ab_3An_1 oligoclase.

The dark mineral is chiefly an ordinary green hornblende, strongly pleochroic: X = dark straw yellow, Y = dark green, Z = blue-green. It is plentiful as large irregular crystals which often include biotite, feldspar, epidote, sphene and magnetite.

The following minerals are present as accessories: Biotite as abundant small flakes frequently enclosed in the hornblende; minute flakes are frequently to be seen in the feldspar.

Epidote is distributed patchily. Forms large and small crystals, pleochroic yellow to colourless. Its mode of occurrence, being quite free from any regular association with other minerals, suggests that it is here a primary constituent.

Magnetite is a common mineral occurring with the hornblende. Sphene is colourless, generally associated with magnetite. Apatite appears as occasional crystals.

The abundant oligoclase and the high alkali, particularly soda, content, place the rock in the essexite group of alkali gabbros.

Certain portions of the outcrop have suffered considerable metamorphic change, especially in certain belts where the effects of excessive stress are evidenced. There the feldspars of the essexite group have been greatly crushed, epidote and zoisite are plentiful; quartz appears and biotite, almost opaque in direction of greatest absorption, is very abundant.

Specimens taken across the contact zone of the syenite and essexite show a general intermingling of the minerals of the two types and a rather sudden transition. An interesting and unexpected feature in one of the specimens which is rather coarser in grain than the normal syenite and is notably rich in magnetite, is the presence of calcite in the quite fresh and unweathered rock.

ORIGIN

The form of this intrusion is evidently a small composite stock. The albite syenite was first introduced. When solid, but still hot, the essexite magma was injected into the centre of the stock. The syenite reacted to a small extent with the essexite magma, causing the narrow contact zone of mixed rock seen in the field. At a later date the whole intrusion was subjected to the regional metamorphism of the area, the more readily alterable essexite being changed largely to biotite epidote schist.

The later date of intrusion of the essexite is further supported by the small patch of the basic rock on the northern corner of the intrusion. This was evidently forced at a later stage between the cool syenite and the country rock. The syenite contact here is rather sharper.

The granite pegmatite was of course introduced still later, being one of the abundant acid pegmatites of the area.

The intrusion is apparently a cupola form introduction, derived from an early differentiate of the Boolcoomatta granite magma. A sodic differentiate had been formed probably with the help of volatiles; this further differentiated and then intruded as a small composite stock.

This occurrence recalls other soda rich intrusions, some described as albitites, which appear to have somewhat similar relations to major granite masses of other areas in South Australia.

STUDIES ON THE MARINE ALGAE OF SOUTHERN AUSTRALIA

NO. 3 NOTES ON DICTYOPTERIS LAMOUROUX

BY H. B. S. WOMERSLEY

Summary

Dictyopteris Lamouroux 1809 has been referred to in Australian algal literature as Haliseris Targioni – Tozzetti 1819 (Lucas 1936, p. 89, and previous authors) or Neurocarpus Weber and Mohr 1805 (May 1939, p. 200) but was included in the list of "Nomina Generica Conservanda" of the 1935 International Botanical Congress.

STUDIES ON THE MARINE ALGAE OF SOUTHERN AUSTRALIA
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DICTYOPTERIS AUSTRALIS Sonder 1852 and D. PARDALIS (Harvey 1854) May

Dictyopteris pardalis is supposed to differ from *D. australis* in the absence of fine lateral veins running from the midrib to the margin. Sonder (1871, p. 47) first regarded *D. pardalis* as only a "variety with small thallus" of his *D. australis*, and he was followed by Askenasy (1888, p. 30) and Borgesen (1930, p. 173). Lucas (1936, p. 89) however considered them distinct species.

The type specimen of *D. australis*, collected at Lefevre Peninsula, South Australia, by F. von Mueller on 16 December 1847, and with Sonder's ms. description on the sheet, is in Melbourne National Herbarium. This specimen, though rather battered, is specifically identical with cotype specimens of Harvey's of *D. pardalis* in Melbourne and Sydney National Herbaria, which also show fine lateral veins from midrib to margin. There is also no significant difference in thallus width between the specimens, and the spores in both (though almost denuded in the type of *D. australis*) are arranged in recurved arches.

An examination of all the specimens available in Australian Herbaria of these species shows that the presence, and prominence, of lateral veins is a very variable character. Some specimens show veins in only some parts, others all over the thallus; often lateral veins occur on one side of the midrib and not the other side. All specimens, however, show some veins, though often extremely fine.

D. pardalis (Harv.) May must therefore be relegated to synonomy of *D. australis* Sonder, with the following references:

Dictyopteris australis Sonder herb. Askenasy 1888, p. 30. Borgesen 1930, p. 173. *Haliseris australis* Sonder 1852, p. 664; 1871, p. 47. Kützing 1859, pl. 54. De Toni 1895, p. 257. Lucas 1936, p. 89. *Haliseris pardalis* Harvey 1854, p. 535; 1858, pl. 29. Kützing 1859, pl. 59, II. De Toni 1895, p. 258. Lucas 1935, p. 209; 1936, p 89. *Dictyopteris pardalis* (Harvey) May 1946, p. 274.

Distribution Records—Herbarium abbreviations used below are: Botany Department, University of Western Australia — W; Botany Department, University of Adelaide — A; Melbourne National Herbarium — M; Sydney National Herbarium — S.

Western Australia—Dongarra (A. Baird, April 1930; G. Smith, February 1944—in holes on reefs — W.). Cotteslue (G. Smith, January 1945, 1946—as bushy tufts on rocks in 10 feet of water — A., W.). Fremantle (Harvey, No. 86 A, as *H. pardalis*, M. and S.). Point Peron (G. Smith, June 1949, W.). Bunbury (M.). Champion Bay (M.).

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South Australia — Lefevre Peninsula (F. v. Mueller, December 1847, M.). Port Noarlunga (E. Macklin, 1924, A.). Spencer's Gulf (A.).

Queensland—Caloundra (G. McKeon, August 1948, A.). Moreton Bay (Askenasy). Peel Island (J. Marshall, May 1949, A.). Margate (V. May, December 1943 (as *D. pardalis*). Redcliffe (A. Cribb, July 1949, A; G. McKeon, September 1948, A.). Port Denison (F. Kilner in Sonder). Cape Upstart (M.).

Extra Australia—Lord Howe Island (F. Perrin and A. Lucas, June 1933, S. — as *H. crassinervia*—see later; also Lind and Fullagar, M.). India—Dwarka, Okla Port (Borgesen), Karachi (Harvey).

Most of the Australian specimens, except those of Smith from Dongarra and Cottesloe, were probably collected from the drift. D. *australis* probably occurs in deep pools on reefs and the sublittoral.

DICTYOPTERIS CRASSINERVIA (Zanardini) Schmitz

Schmitz 1937, p. 219. *Haliseris crassinervia* Zan. 1874, p. 487. De Toni 1895, p. 258.

In the Melbourne National Herbarium is a sheet (see pl. xxii, fig. 1) labelled, in O. W. Sonder's writing, *Halyseris Mulleri* Sonder

Halyseris crassinervia Zanard.

The specimens were collected by Fullagar at Lord Howe Island, and probably received by Sonder from F. von Mueller, then Government Botanist at Melbourne. Mr. A. W. Jessep, Director of the Melbourne Herbarium, informs me that "Fullagar and Lind were together on Lord Howe Island for nearly a year, about 1873, and collected extensively for Baron von Mueller." He also states that Mueller apparently submitted the Lord Howe algal collections to Sonder.

Zanardini described a number of species from Lord Howe Island, and this specimen in the Melbourne Herbarium agrees very well with his description of *H. crassinervia*, and is sterile. It seems probable that this is an authentic, probably a cotype specimen of *H. crassinervia*. Sonder apparently (from the label) had doubts as to whether it was distinct from his *H. muelleri*, but although closely related it differs in the much darker, wider and more robust thallus.

In Melbourne Herbarium is also a specimen of *H. australis* collected by Fullagar and Lind on Lord Howe Island, which was not however recorded by Zanardini.

Lucas (1935, pp. 209-210, pl. vii, fig. 1) describes and figures what he considered to be *H. crassinervia*. Lucas' specimens (in Sydney and his own herbaria) are clearly *H. australis*, as is shown also by his description, and are quite distinct from the authentic specimen of *H. crassinervia* in Melbourne Herbarium. Apparently Lucas did not collect true *H. crassinervia* on Lord Howe Island, but presumed his specimens must be this species as it was the only one recorded from the island.

D. crassinervia hence is still only known from the sterile Fullagar collection, and Lucas' comments apply to *D. australis*, as do those of May 1946, p. 274.

The other Australian species of *Dictyopteris* are as follows:

D. acrostichoides (J. Agardh) Borgesen from Victoria, Tasmania, Queensland, New South Wales.

D. muelleri (Sonder) Schmitz from Western Australia, South Australia, Victoria, Tasmania.

D. woodwardii (Brown) Schmitz from North Queensland.

In addition the following species from Kangaroo Island is now described.

Dictyopteris nigricans n. sp.

(Fig. 1, pl. xxii, fig. 2)

Thallus 5-20 cm. altus, ramis subdichotomis et parce lateralibus 2-5 mm. latis, adfixus basi rhizoidibus; apices interdum proliferi; costa prominens infra, venis nullis; cumulus paraphysium sparsus in una linea ab utroque latere costae; sporae sparsae in thallo cum angusta et sterili margine; color thalli fuscus.

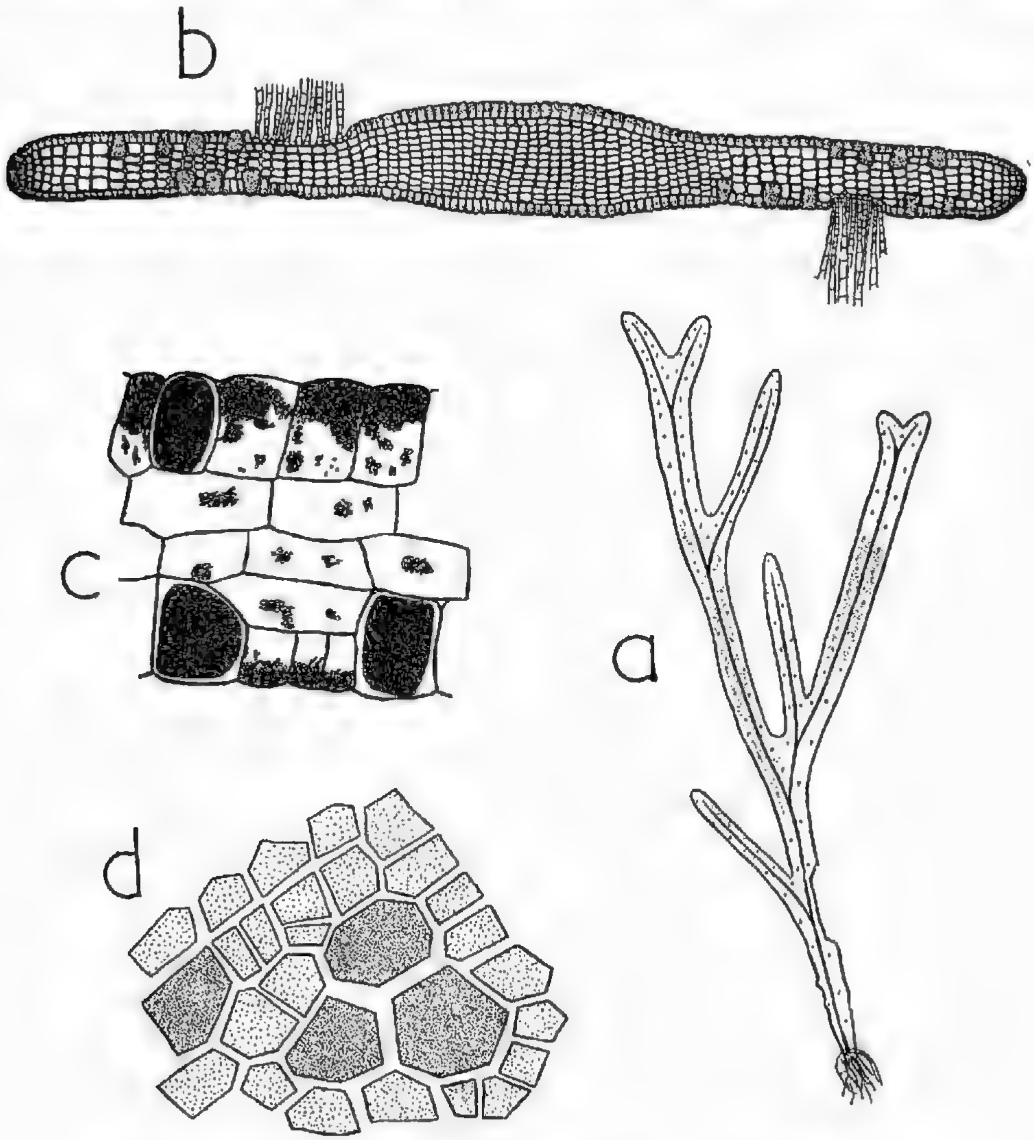

Fig. 1

Dictyopteris nigricans n. sp.: a, Habit, showing hair groups and patches of spores; b, Transverse section of thallus, showing hair groups and spores; c, Section of thallus on a larger scale; d, Surface view of thallus, with spores.

Thallus 5-20 cm. high, usually in tufted masses, subdichotomous with some lateral branches, 2-5 mm. wide, attached at the base by rhizoids; branch tips sometimes proliferous; axils rounded. Midrib conspicuous, lateral veins absent. Hair groups in a single irregular line on each side of midrib. Spores scattered, not on midrib and with a narrow sterile margin at edge of thallus. Colour very dark brown.

LOCALITIES—On Kangaroo Island, South Australia:

Pennington Bay: in deeper pools on reefs, all seasons.

Vivonne Bay: in pools on reefs in the bay, January 1948; drift, January 1949.

West Bay: drift, January 1946.

D. nigricans probably occurs in deeper pools on reefs and in the upper sub-littoral along the south and west coasts of Kangaroo Island. The type specimen is A 2296 in the Algal Herbarium of the Botany Department, University of Adelaide.

D. nigricans resembles *D. muelleri* in possessing scattered spores, but differs in the much narrower and darker coloured thallus, with hair groups in a single irregular series on each side of the midrib It resembles *D. acrostichoides* in the spores tending to be in a band on each side of the midrib, with a narrow sterile margin; the thallus of *D. acrostichoides* however is wider and the hair groups tend to occur in recurved arches.

Only 3 or 4 fertile plants of *D. nigricans* have been found in several hundred examined, and the spores in these may not be fully developed as they consist only of large cells with much darker, denser contents, scattered among the epidermal cells, and they do not protrude above the surface (fig. 1, b, c, d).

REFERENCES

ASKENASY, E. 1888 "Algen," Forschungsreise S.M.S. "Gazelle." IV Theil. Botanik

BORGESEN, F. 1930 "Some Indian Green and Brown Algae, especially from the Shores of the Presidency of Bombay." Journ. Indian Bot. Soc., **9**, 151

DE TONI, G. B. 1895 Sylloge Algarum, **3**, Fucoideae

HARVEY, W. H. 1854 "Some Account of the Marine Botany of the Colony of Western Australia." Trans. Roy. Irish Acad., **22**, 525-566

HARVEY, W. H. 1858 Phycologia Australica, **1**

KÜTZING, F. T. 1859 Tabulae Phycologicae, **9**

LUCAS, A. H. S. 1935 "The Marine Algae of Lord Howe Island." Proc. Linn. Soc. N.S.W., **60**, 194-232

LUCAS, A. H. S. 1936 "The Seaweeds of South Australia. Pt. I"

MAY, V. 1939 "A Key to the Marine Algae of New South Wales. Pt. II, Melanophyceae." Proc. Linn. Soc. N.S.W., **64**, 191-215

MAY, V. 1946 "Studies on Australian Marine Algae, III." *Ibid*, **71**, 273-277

SCHMITZ, O. C. 1937 "Beitrage zur Systematik der Phaeophyten, I." Hedwigia, **77**, 213-230

SONDER, O. W. 1852 "Plantae Muellerianae. Algae." Linnaea, **25**, 657-709

SONDER, O. W. 1871 "Die Algen des tropischen Australiens."

ZANARDINI, J. 1874 "Phyceae australicae novae vel minus cognitae." Flora, **57**, 486-490, 497-505

THE ELATINA GLACIATION A THIRD RECURRENCE OF GLACIATION EVIDENCED IN THE ADELAIDE SYSTEM

BY D. MAWSON

Summary

Early in the year 1938 an apparently unbroken succession of beds directly underlying the fossiliferous Cambrian was located on Oraparinna Station in the Flinders Ranges. A geological section was run from near Mount Sunderland to the west, through the Brachina Gorge.

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A THIRD RECURRENCE OF GLACIATION EVIDENCED IN THE ADELAIDE SYSTEM

By D. Mawson

[Read 10 November 1949]

Early in the year 1938 an apparently unbroken succession of beds directly underlying the fossiliferous Cambrian was located on Oraparinna Station in the Flinders Ranges. A geological section was run from near Mount Sunderland to the west, through the Brachina Gorge.

In the description of this succession subsequently published (Mawson 1939), item (44), outcropping in the vicinity of the locality known as Elatina, is 190 feet of flaggy argillaceous limestone with some beds of massive limestone. At its upper limit some sand and tiny pellets up to 6 mm. diameter were observed embedded in the calcareous strata.

Then follows, in upward succession, (item 45) 75 feet of a pinkish red sandy formation. At its base it carries some coarser layers composed of mineral particles distinguishable to the naked eye as feldspar, etc. Towards its upper limit the constituent particles are mainly dust-like, with in addition a little sand and odd very small pellets. When first observed in the year 1938, this formation was entered as being of a tuffaceous nature.

Above the foregoing is an unstratified formation, 12 feet in thickness (item 46) composed mainly of a very fine-grained base of a brownish red colour, in which are embedded random pebbles and boulders up to 2 feet in length, though most are but a few inches in diameter. These pebbles are mainly fine-grained melaphyres, some vesicular, and dolerites with only minor contributions of other rocks; several pebbles of coarse tuff and dolomite were met with.

Overlying this unusual formation is massive pink limestone, (item 47), 10 feet in thickness, which in turn passes upwards into a great thickness of chocolate shales.

When encountered in 1938, the boulder-bearing formation (item 46) was rather puzzling. Glacial transportation first suggested itself, but as the rocks contained in it are overwhelmingly of a basic igneous nature, and further, as the fine dust-like base is of a reddish chocolate colour, the conclusion reached was that it must be of a tuffaceous origin. Further investigation at that time could not to be undertaken owing to a breakdown of our transport unit, necessitating return south for repairs.

On another visit to Oraparinna during 1938, an examination was made of the sedimentary succession of the eastern side of the Flinders Ranges in the locality known as The Bunkers. In the published (Mawson 1938) geological section, items (43 and 44) include a reddish sandy and pebbly horizon, some features of which suggest tuffaceous contributions in a fluviatile formation. We were able to satisfy ourselves that some part of this horizon at The Bunkers is approximately equivalent in time of deposition with item (46) of the section through Elatina. These two outcrops are separated by about 18 miles.

Since publishing the geological sections mentioned above, opportunities have arisen for further investigation. On passing through Oraparinna with students in 1944, we visited Elatina to collect boulders shed along the outcrop of the boulder-bearing bed in question with a view to checking the possibility of glacial

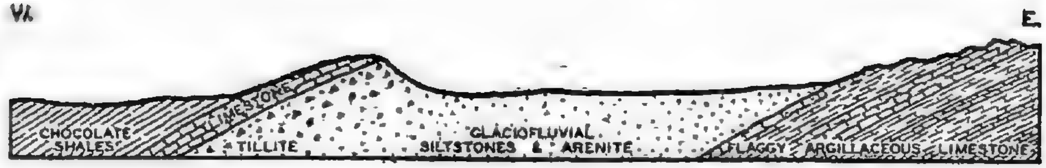

Fig. 1

Cross section of strata on the Elatina Creek.

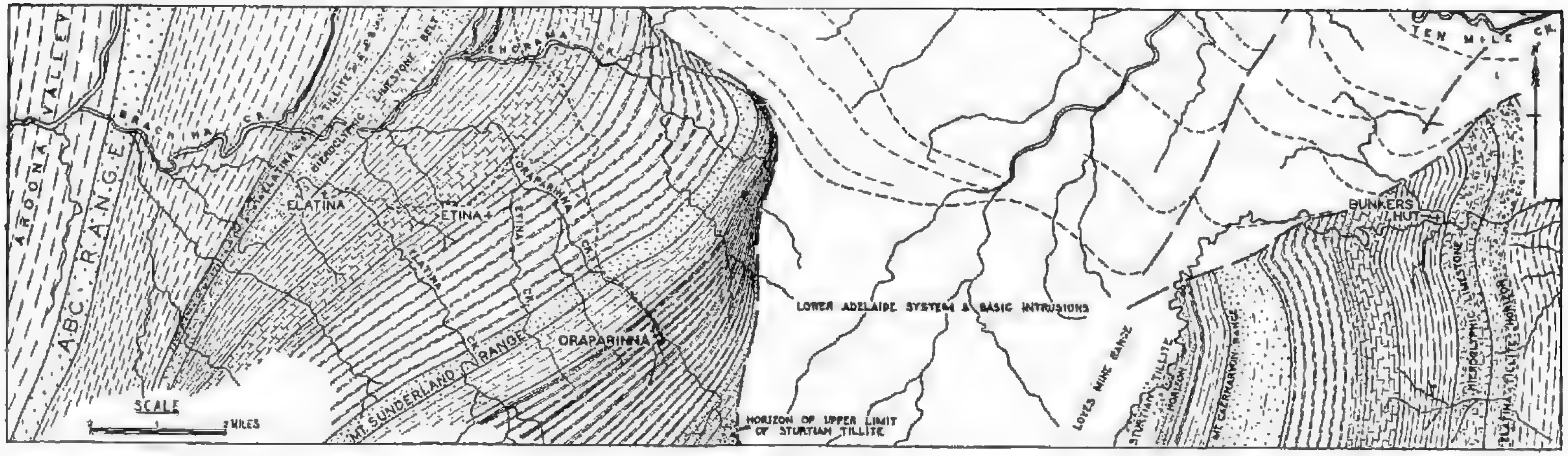

Fig. 2

A sketch plan of part of Oraparinna Station defining the location of the Elatina Tillite. The north-eastern area crossed by structure lines is occupied by the upper Adelaide System. The blank central area is a region of lower Adelaide System rocks and basic igneous contributions. The hatched sediments of the western side of the plan all dip regularly to the west; those on the east side of the range all dip regularly to the east.

transport. On that occasion many faceted pebbles were collected, some of which retain poorly preserved striae. One of the students, A. F. Wilson, tracing the outcrop further to the north, picked up a really well preserved, smoothed and striated example which left little doubt that it owed these features to glaciation. As, however, the formation presents unusual features and is located in the Proterozoic sequence at an horizon far above the well-known Sturtian Tillite, publication was held in abeyance pending still further investigation.

Since then the Bunkers outcrop has again been visited, and boulders there shed along the outcrop have again been examined. It was found that the types of rock illustrated in the pebbles embedded in this formation are notably more variable than is the case at Elatina: there granitic and metamorphic rocks are common. Pebbles with facets were found to be not uncommon, but no good convincing example of glacial striae was met with, though in several cases there were visible what appeared to be faint traces of striae.

Early this year, en route with students to the northern extremity of the Flinders Ranges, a break was again made at Oraparinna to allow of examination of the Elatina outcrop in its extension further to the north than previously investigated. On this occasion we proceeded west from Etina, meeting the outcrop in question at a point one or two miles to the north of where previously observed along the Elatina Creek. In this locality the glacial formation is thicker, more than 20 feet. We soon collected numbers of well facted and striated specimens. Thus, doubt no longer remains that this is a case of glacial transport.

THE CHARACTER OF THE TILLITE

It would now appear that much, at least, of the very fine-grained dust-like base of the rock is of the nature of glacial rock flour. In certain places along the outcrop, the percentage of coarser grit and pebbles is locally increased to produce the physical character of a normal tillite, with the exception that in this case it is of a reddish to chocolate colour. We have not yet met Sturtian Tillite in South Australia of this colour. It is usually of a light to dark grey colour, often of an ashy to bluish-grey tone.

We may now regard thin bands of coarse arenites composed of fresh grains of feldspar, quartz and other primary minerals appearing in chocolate beds associated with and about the horizon of this tillite as water transportations and concentrations from glacial debris.

The marked predominance of basic volcanic rocks among the erratics in the Elatina locality suggests that the ice-shed was probably localised as cappings on high basaltic volcanic piles. One such area can be visualised as having existed in the neighbourhood of Blinman, some 20 miles to the north of Elatina. Another possible location for such conditions is an area of basic volcanic rocks appearing below the heiroglyphic limestones, extending on Oraparinna down the east central portion of the Ranges. Those igneous effusions appear to have burst through the dolomites of the lower Adelaide System. The case at Wooltana (Mawson 1948) well exemplifies this.

It is presumed that transportation of the boulders was effected by floating ice in lakes or the sea surrounding the volcanic highlands. As already mentioned the physical nature of this formation is in places that of normal tillite, but for the main part it is of a finer than usual texture. The rock flour may in part have been transported by water, but where, as in some places, it is wanting in any kind of lamination it may, in part at least, be loessial. It is expected that fine volcanic ash has contributed to the formation either directly or after reworking by ice.

Our knowledge of local atmospheric circulation in regions of high ice-caps leaves no doubt that violent outflowing winds would be a feature of the time, transporting rock flour and fine ash widely over neighbouring regions. It seems probable therefore that the chocolate shales of the upper Adelaide System owe much to such aeolian activity which must have marked the closing stages of the great Late-Proterozoic glaciation.

The high iron content of the basic volcanic effusions, ground up by over-riding ice, would be a notable factor in developing the depth of colour in the chocolate shales of that time. That some of the chocolate shales (Mawson and Segnit, 1948) contain flakes of mica and grains of quartz, microcline, etc., suggests that this loess was derived not only from the glaciation of basaltic highlands, but from granitic and gneissic terrains elsewhere located and subjected to ice sheet erosion.

This proved record of glacial activity at the Elatina horizon of the Adelaide System has not yet been demonstrated to have wide distribution and may indeed be very local. In this connection there should be considered the report (Segnit, R. W., 1940) of tillite occurring near Hallett Cove.

POSSIBLE ECHO OF THE ELATINA GLACIATION OUTCROPPING AT MARINO ROCKS

In his geological map of the Hallett Cove region, R. W. Segnit shows the occurrence along the coast, from Marino Rocks to the south, of an extensive area of tillite which he held to be Sturtian. No other geologist has yet been able to find a convincing tillite in that area (Sprigg, 1942) and it has been demonstrated (Mawson, 1940) that, if by any chance the chocolate-coloured rock formations there were tillite, they could not be the equivalent of the Sturtian Tillite horizon of the nearby Sturt Creek.

There are, however, along that strip of coast, some bands of arkose and pebbly arkosic grits of an unusual nature, part of the Chocolate Series overlying the Brighton Limestones. Features unusual for normal sedimentary water-deposited rocks also occur there in another belt somewhat higher in the chocolate shales.

The late Sir Edgeworth David and I carefully examined that area in the year 1921 and on account of unusual features again studied it in 1925. We came to the conclusion that there was there no definite evidence of work of ice. However, though there is no normal tillite, it would now appear, in the light of our discovery at Elatina, that in all probability some of the unusual sedimentary phenomena of the coastal strip north of Hallett Cove may be the echo, so to speak, of distant glaciation. This horizon approximates to that of Elatina and it is noteworthy that similar arkosic bands are met with in the chocolate series at Elatina.

This new record of glaciation, it will be observed, post-dates the Brighton Limestones and in our Brachina Creek section (Mawson,, 1939) and its subsequent extension (Mawson, 1942) is shown to be located somewhere in the neighbourhood of 9,000 feet stratigraphically above the topmost erratic-bearing horizons of the Sturtian glaciation of that area of South Australia. For distinction I propose that this new discovery be referred to as the Elatina tillite, a product of Elatina glaciation.

Already attention has been drawn (Mawson, 1948 b) to the existence in the Adelaide System of the records of two older and major glaciations separated by a prolonged interglacial period. As that evidenced in the Sturt Creek near Adelaide appears to be the uppermost of these two, the distinction of Sturtian should be reserved for it. For the lowest I have advocated (Mawson 1948 b) the adoption of the term Bibliando glacial stage.

The evidence so far forthcoming indicates that the Elatina Glaciation was a comparatively weak and fading phase of the Late-Proterozoic glaciation; in all probability represented by isolated minor cappings on the higher topographic features of the region affected.

REFERENCES

MAWSON, D. 1938 The Mount Caernarvon Series of Proterozoic Age. Trans. Roy. Soc. S. Aust., 62, 347-351

MAWSON, D. 1939 The Late Proterozoic Sediments of South Australia. Trans. A.N.Z.A.A.S., 24, 79-88

MAWSON, D. 1940 Tillite and other Rocks from Hallett Cove, S. Aust. Trans. Roy. Soc. S. Aust., 64, 362

MAWSON, D. 1942 The Structural Character of the Flinders Ranges. Trans. Roy. Soc. S. Aust., 66, 262-272

MAWSON, D. 1948a Sturtian Tillite of Mount Jacob and Mount Warren Hastings, North Flinders Ranges. Trans. Roy. Soc. S. Aust., 72, 244-251

MAWSON, D. 1948b The Late-Precambrian Ice-Age and Glacial Record of the Bibliando Dome. Proc. Roy. Soc. N.S.W., 82, 150-174

MAWSON, D., and SEGNIT, E. R. 1948 Purple Slates of the Adelaide System. Trans Roy. Soc. S. Aust., 72, 276-280

SEGNIT, R. W. 1940 Geology of Hallett Cove and District, with special reference to the distribution and age of the Younger Glacial Till. Trans. Roy. Soc. S. Aust., 64, 3-44

SPRIGG, R. C. 1942 The Geology of the Eden - Moana Fault Block. Trans. Roy. Soc. S. Aust., 66, 185-214

THE MURRAY BRIDGE AND MONARTO GRANITES AND ASSOCIATED ROCKS OF THE METAMORPHIC AUREOLE

BY R. K. JOHNS AND J. M. KRUGER

Summary

The area under discussion forms a belt on the eastern scarp of the Mount Lofty Ranges from the township of Monarto to the River Murray on the east.

THE MURRAY BRIDGE AND MONARTO GRANITES AND ASSOCIATED ROCKS OF THE METAMORPHIC AUREOLE

By R. K. Johns and J. M. Kruger*

[Read 10 November 1949]

Contents

I. INTRODUCTION

The area under discussion forms a belt on the eastern scarp of the Mount Lofty Ranges from the township of Monarto to the River Murray on the east.

Woolnough (1908) recorded petrological descriptions of several rocks from the Rocky Gully area.

Jack (1923), when dealing with the Building Stones of South Australia, makes reference to the Monarto and Swanport granites and quotes analyses thereof by W. S. Chapman.

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More recently, Kleeman (1934) has notably contributed to knowledge of the Swanport outcrop of the Murray Bridge Granite and its Aplite. He furnished a chemical analysis and description of the aplite and, after estimating the fluorine in the Swanport granite, corrected Chapman's analysis accordingly.

The Murray Bridge type of fluoriferous granite has recently been traced by Professor Mawson (1945) as appearing at intervals on a south-easterly course almost to Bordertown. The outcrop at and near Murray Bridge is thus part of a very extensive batholyth. Because of its importance in this connection, Professor Mawson suggested our undertaking this investigation.

We are indebted to the Professor and to Mr. Kleeman and to others of the Department of Geology for suggestions and facilities for the work. To S. B. Dickinson, Director of Mines, our thanks are due for facilities offered in the final stages of field mapping.

In this paper we pay special attention to the Rocky Gully area, while at the same time extending general observations over a wider field to include some of the important outcrops of the Monarto Granite type. The region thus selected is portion of a wider belt of granitic and metamorphic rocks extending along the eastern flank of the Mt. Lofty Ranges. This area of regional metamorphism is well marked as far west as Nairne and beyond Palmer to the north. The Murray Bridge and Monarto granites are located in the region of most intense metamorphism. Progressively to the west, there is a well marked falling off in the metamorphic grade exhibited by the rocks.

The location from which each of the various specimens described was collected is indicated by the specimen numbers printed on the accompanying map of the area.

II. GENERAL GEOLOGY AND PHYSIOGRAPHY

Between the Murray River and an elevated region to the west, chiefly occupied by metamorphic rocks, is a low-lying belt underlain by a variable thickness of tertiary limestones resting at depth in granite, schists and gneisses.

West of Murray Bridge, this lower country extends for about two and a half miles before meeting the eastern, fault-defined face, of the elevated block. This latter is one of the block fragments of Kosciuskan orogeny which contributed to the elevation of the Mount Lofty Ranges. This particular fragment which extends west to the Bremer Valley, offers for inspection many well exposed areas occupied by granite, schist and a range of migmatites.

The Bremer Valley is separated, by a ridge formed of schists, from a much wider one in which Monarto lies. This valley, though possessing a well-defined north to south trend, is not occupied by a stream like the Bremer. The absence of such a water course is to be accounted for by repeated captures by small streams running direct to the Murray, as for instance, the Rocky Gully Creek, through whose gorge the railway line passes.

Monarto Valley is filled with drift sand which hides the bed rock from view. Where the sand drifts have been stripped, there are large areas of solid ringing travertine, whose conspicuous development near Monarto and thence in patches east to Murray Bridge, is due to the occurrence of thin patches of Tertiary fossiliferous limestone lying on the upturned edges of the schists. This limestone outcrops at intervals over the floor of the valley, but does not there give rise to conspicuous features. The development of a dense capping of kunkar travertine has doubtless contributed to its preservation. The fragmentary nature of the fossil remains and included pebbles and boulders of granite indicate a shallow water littoral deposit.

The elevated block to the west of Murray Bridge is characterised by a notable development of migmatites and lit-par-lit "injection." Quartz-plagioclase-biotite schists are abundant, also coarse biotite schists composed essentially of biotite, but in places enclosing large crystals of fluorapatite which have grown in place: these have been met with exceeding 4 cms. by 2·5 cms. in size. Interesting rocks here are actinolite and anthophyllite-schists which are in association with coarse mica-schists which are often puckered and close folded. The quartz-biotite-plagioclase schists, as they extend westwards, become richer in feldspars and grade insensibly into the so-called Monarto granite. This granite is typically of a fine and even grain, but it varies in texture and grain-size and often contains small segregations of biotite flakes.

Pegmatites, the crystallised residual liquids from the Murray Bridge granite, discordantly intrude the schists along the eastern scarp—these are rich in quartz, microcline, muscovite and tourmaline.

Discordant pegmatic veins cut the schists and are exposed along Rocky Gully Creek—they vary from merely quartz-feldspar veins to a pegmatitic granite.

Two dolerite dykes are exposed along the bed of Rocky Gully Creek—one about 4 feet wide, with strike N 60° E, crosses the bed of the creek near the bridge (towards Monarto). The dyke is broken up into small blocks—large along the centre while the margins are more fragmentary. The second dyke is about 300 yards along the creek towards Murray Bridge, and stands out in relief across the bed of the creek—this one is about 100 feet wide. Neither could be traced beyond the creek as they became lost under the cover of recent alluvium. These dykes are roughly parallel in disposition.

III. PETROGRAPHY

Murray Bridge Granite

Specimen (7885) was obtained from a small quarry opened up for building stone in Murray Bridge township, between the river and Noske Bros.' Flour Mill. This quarried rock is exceptionally fresh. In the hand-specimen it has a handsome appearance dominated by large pink potash-feldspars. These attain 2 to 3 cms. diameter. They exhibit Carlsbad twinning. Much of the rock is composed of vitreous smoky quartz, which forms a matrix setting for the large pink feldspars. White plagioclase is much less abundant, but observed in some cases to mantle the pink potash feldspar crystals. Small flakes of black biotite are also present. The specific gravity of the rock is 2.66.

Observed in microscope slide it exhibits a holocrystalline, hypidiomorphic, granular texture, dominated by the elongated feldspars averaging 2.5 cm. in length. Plagioclase, quartz and biotite are the more obvious minerals of the finer grained base. Minerals present in order of abundance are as follows:—

Microcline-microperthite is present in large crystals becoming slightly turbid. It displays typical "cross-hatching." It is biaxial negative. In section $\perp$ to Z, $X' \wedge 001$ is 11°. The intergrown soda feldspar has a higher R.I. and is more clouded than the host mineral.

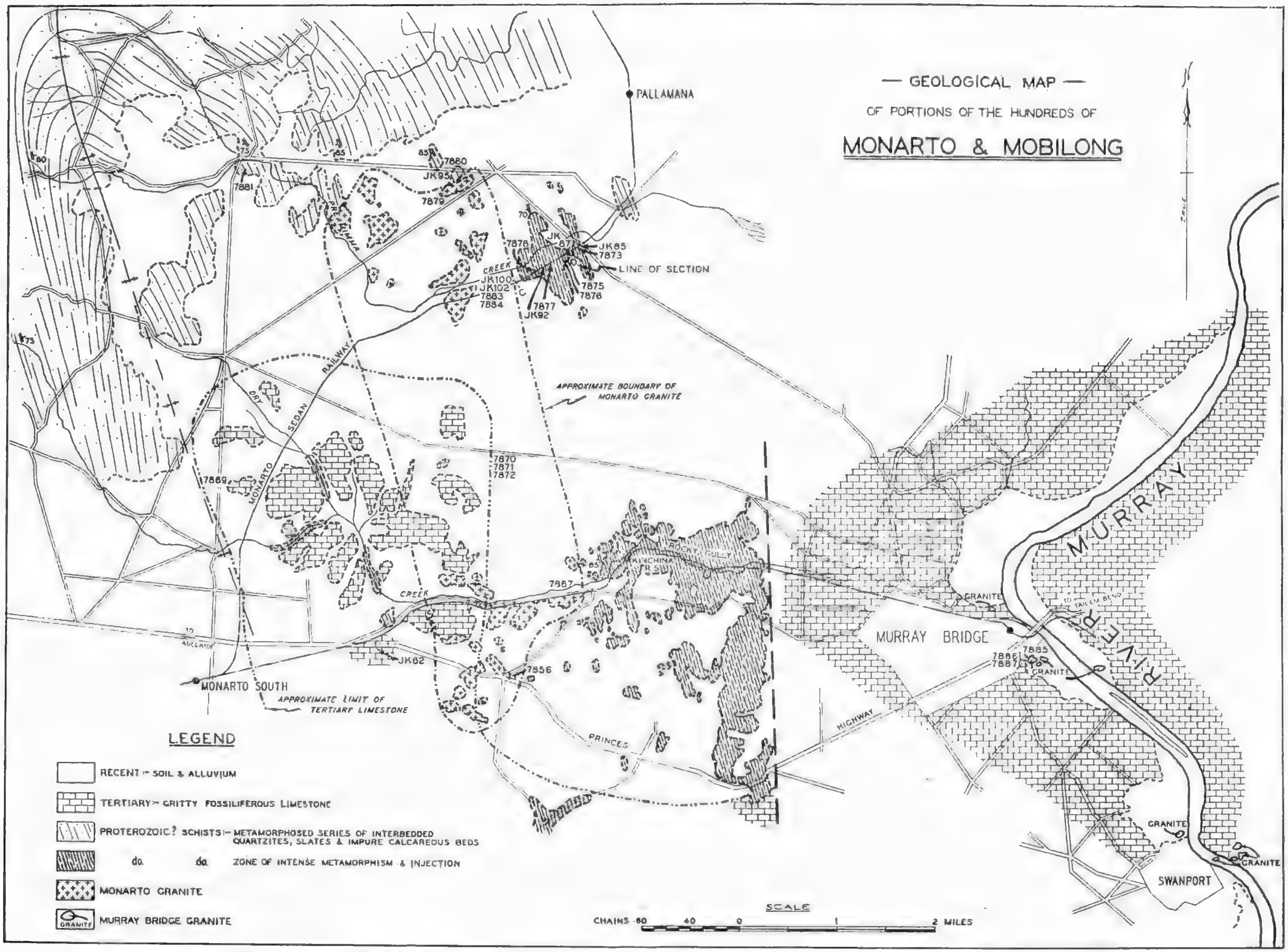

Fig. 1 Map of locality under consideration. The township area of Murray Bridge is underlain by Tertiary limestone (though such is not indicated on the map). The locations of rocks referred to in the text are indicated by numbers. The line of Section C — D, detailed in fig. 2 (page 130), is shown on this plan.

Plagioclase is present, less altered than the potash feldspar. It is twinned on the Carlsbad, pericline and abite law. Extinction angle measured in the zone ⊥ to 010 is + 16°, biaxial negative; R.I. > balsam; thus corresponding to Andesine of composition $Ab_{67}An_{33}$.

Quartz is present as clear colourless anhedral crystals and contains lines of fluid inclusions often as two sets at right angles.

Biotite has a subhedral tabular habit. Strongly pleochroic: X = light golden yellow, Y = Z = dark brown (almost opaque). Biaxial negative with a very low optic axial angle so as to appear almost uniaxial. It exhibits slight alteration to chlorite in marginal areas. Associated with the biotite are small grains of magnetite and zircon. The small grains of zircon embedded in the mica are surrounded by pleochroic haloes.

Sphene is present in small euhedral crystals with high relief. It is a weakly pleochroic, biaxial positive variety with birefringence masked by the depth of colour. Apatite occurs in the usual rod-shaped crystals. Zircon and magnetite are present but not common. The former appears as small rounded grains of high relief and strong birefringence. No fluorite is contained in the sections examined but has been observed in other outcrops. The presence of fluorine is indicated in the analysis.

An analysis of this granite (No. 7885) was made by one of us and is given below.

TABLE A

	I	II	III	IV
SiO_2 - - - -	73·83	74·20	76·07	70·18
TiO_2 - - - -	0·30	0·29	0·11	0·39
Al_2O_3 - - - -	12·45	14·53	13·96	14·47
Fe_2O_3 - - - -	0·74	1·14	0·14	1·57
FeO - - - -	1·64	0·90	0·42	1·78
MnO - - - -	trace	0·03	trace	0·12
MgO - - - -	0·24	0·20	trace	0·88
CaO - - - -	1·04	1·00	0·68	1·99
Na_2O - - - -	4·29	3·06	3·90	3·48
K_2O - - - -	5·13	3·55	4·64	4·11
H_2O+ - - - -	0·26	0·15	0·18	0·84
H_2O- - - - -	0·02	0·15	0·07	—
CO_2 - - - -	—	0·11	—	—
P_2O_5 - - - -	0·09	0·08	0·01	0·19
ZrO_2 - - - -	0·06	—	trace	—
BaO - - - -	0·05	—	—	—
S - - - - -	0·06	—	—	—
F - - - - -	0·11	0·19	0·10	—
Cl - - - - -	—	0·03	—	—
FeS_2 - - - -	—	0·10	0·13	—
	100·31	99·71	100·41	100·00
Less 0 for F & Cl - -	00·05	0·09	0·04	—
Total - - - -	100·26	99·62	100·39	100·00

I. Murray Bridge Granite (7885). Quarry near Noske's Mill. Anal. J. M. Kruger.

II. Swanport Granite. Swanport Quarry. Anal. W. S. Chapman; fluorine by A. W. Kleeman.

III. Aplite of the Swanport Granite Quarry. Anal. A. W. Kleeman.

IV. Granite of all periods. Daly's average of 546 analyses.

TABLE B

Norm of Rocks of Table A

	I				II				III			
Quartz - -		Q	27·45			Q	41·40			Q	34·26	
Orthoclase -	30·02	F	66·17	93·62	21·13				27·24			
Albite - -	36·15				25·68	F	49·31	95·40	33·01	F	63·03	98·82
Anorthite -	—				2·50				2·78			
Corundum -	—				4·69	C	4·69		1·53	C	1·53	
Diopside Wo -	1·63				—				0·53			
Fs -	0·50				—				—			
En -	1·72	P	3·85		—	P	0·76		—	P	0·53	
Hypersthene Fs	—				0·76				—			
En	—				—				—			
Magnetite -	0·93	M	1·54		1·62	M	2·23	3·97	0·23	M	0·38	
Ilmenite - -	0·61			6·31	0·61				0·15			1·24
Pyrite - -	0·24				0·10							
Apatite - -	0·34				0·20				0·13			
Fluorite - -	0·16	A	1·00		0·43	A	0·98		0·20	A	0·33	
Calcite - -	—				0·25				—			
Zircon - -	0·18				—				—			
Water - -	0·28		0·28	0·28	0·30		0·30	0·30	0·25	H_2O	0·25	0·25
Total - - -				100·01				99·67				100·31

C.I.P.W. Classification:—

I. 1 4 1 3′ — Liparase – Liparose

II. 1 3 1 (2) 3′ — Magmatic name is Tehamose – Alaskose

III. 1 (3) 4 1′ 3′ — Alaskase – Liparose

XENOLITHS IN THE MURRAY BRIDGE GRANITE

The following two xenoliths were collected from the granite quarry and petrologically examined.

Xenolith (7886) is a grey rock in which are set pink feldspars of porphyritic dimensions. Microcline-microperthite predominates over plagioclase. It is observed to be undergoing sericitization. The plagioclase, which has a composition $Ab_{70}An_{30}$ is less altered than the potash feldspar. Quartz is in small grains with sutured margins and is easily distinguished from feldspar by its clarity. Biotite is similar to that in the granite. Hornblende with extinction angle about 16° and strongly pleochroic in green and brown. Sphene, light brown and weakly pleochroic. Zircon associated with the biotite but in small rounded grains and apatite in minute rods.

In this xenolith there is a small development of myrmekitic intergrowth of quartz and feldspar; the quartz is in vermiculate blobs and drops in the feldspar.

Xenolith (7887) is a grey compact, fine-grained, equigranular rock composed mainly of quartz, feldspar and biotite. In microscope slide the quartz shows strain phenomena and bears abundant inclusions of iron ore, apatite and biotite. The feldspars are microcline-microperthite and andesine. Biotite, showing some alteration to chlorite; sphene is fairly abundant. Fluorite is present in large, clear colourless individuals with high negative relief; these grains are associated with biotite, some are purple.

Rocks of the Inner Migmatitic Belt Margining the Murray Bridge Granite

Schists, gneisses and pegmatites of the inner, severely metamorphosed belt margining the Murray Bridge granite mass on its west side are well exposed along Rocky Gully Creek and north-north-west thereof. Hornblende gneiss and biotite gneiss were described from this locality by Woolnough. Herein the petrographic characters of selected rocks from this area are given.

Actinolite-Cordierite Schist (7862). This is of a yellowish-green overall colour. Long needles of green actinolite in sheaves and bundles stand out in relief on the weathered surface. The rock cleaves readily along foliation planes.

Actinolite is abundant in idioblastic needles, present to the extent of 41% by volume; its extinction angle is very small.

Cordierite is present to the extent of 49% as xenoblasts forming a groundmass mosaic. Pleochroic haloes are absent although inclusions of apatite are common. Biaxial negative with large optic axial angle. R.I. on cleavage flakes lies between 1·543 and 1·533. Occasional strings of granular quartz are seen on the face of the rock but practically absent in the micro-slide.

Apatite as long needles is present as inclusions in the cordierite. Magnetite is common and zircon present in small amounts.

Actinolite-Albite-Quartz-Schist (J. K. 38). A very dark-coloured rock with schistosity developed by great abundance of oriented long needles of amphibole. Besides amphibole there is present some fresh albite ($Ab_{92}An_8$), and a considerable amount of granular quartz. Apatite is scarce.

Actinolite-Oligoclase-Quartz-Biotite-Schist (7865). In hand-specimen the rock is seen to consist of long needles of black amphibole, with well-marked preferred orientation, set is a matrix of white feldspar and quartz.

The mineral assemblage is controlled by the parallel alignment of the green actinolite. The interstitial feldspar matrix is crowded with fine rods and needles of apatite. It is fairly fresh and free from alteration.

Actinolite with typical amphibole cleavage and extinction angle $Z \wedge c = 15°$. Pleochroism strong; $X =$ pale yellow, $Y =$ greenish-yellow, $Z =$ dark green. Granular, interstitial oligoclase ($Ab_{71} An_{29}$) is abundant.

Quartz occurs as xenoblasts in the matrix with feldspar. Biotite is sparsely represented; pleochroism strong; $X =$ light yellow, $Y = Z =$ dark brown; included are small rounded crystals of zircon. Apatite occurs as small masses and as rods and needles throughout the slide, and as abundant minute inclusions in the feldspar.

Quartz-Andesine-Actinolite-Epidote-Schist (7854). This is a dark grey, fine-grained, schistose rock, on the face of which black needles of actinolite are apparent. The actinolite is similar to that in (7862). Quartz is fairly abundant as clear xenoblasts. Andesine ($Ab_{60} An_{40}$), is abundant in association with the quartz; it exhibits good cleavage and albite twinning.

Epidote is present only in small amounts in xenoblastic masses of high positive relief: it is pleochroic from colourless to lemon yellow; biaxial negative, with large 2V. Apatite, zircon, iron ore and sphene are present in small amounts as accessories.

Actinolite-Andesine-Biotite-Schist (7872). This is a dense, black compact rock of fine grain and displays a poor schistose structure.

The plagioclase which is abundant is an acid andesine ($Ab_{68}An_{32}$). Occasional grains of quartz may be present but were not distinguished with certainty. Biotite is well represented. Apatite and magnetite also present as minor accessories.

Albite-Actinolite-Quartz-Cordierite-Biotite-Schist (J. K. 87). This is a light-coloured rock composed of grey saccharoidal albite and quartz through which are greenish-black needles of actinolite which imparts schistosity to the rock. The actinolite is in sheaf-like bundles with individuals to 1 cm. in length.

In section this rock displays a granoblastic texture, the result of the association of xenoblasts of cordierite, quartz and plagioclase; this being modified by the directional structure imparted by the pale green-brown amphibole and biotite. The grain is fairly fine but occasional porphyroblasts of plagioclase are present.

Albite ($Ab_{94}An_{6}$) is very abundant. The actinolite is strongly pleochroic. Quartz is not abundant but forms a mosaic with the albite. Cordierite in present in small amounts as xenoblasts bearing abundant minute inclusions; it displays poor multiple twinning, has a biaxial character, and it is undergoing decomposition to give rise to chlorophyllite. Weakly pleochroic, yellow haloes surround crystals of zircon included in the cordierite. Biotite occurs as small highly pleochroic idioblasts. Zircon is a sparse accessory.

Actinolite-Oligoclase-Schist (J. K. 85). A dark-coloured, friable, pronouncedly schistose rock. In section it is seen to be composed almost entirely of green amphilbole (50%) and turbid oligoclase ($Ab_{71}An_{29}$) to the extent of 45%.

As accessories, apatite is abundant; zircon, magnetite and haematite are in less amount, the latter occurring as minute crystals in association with the amphibole.

Biotite-Actinolite-Oligoclase-Quartz-Schist (7875). A fine-grained schistose rock of greenish-grey colour seen in the hand specimen to consist chiefly of grey salic mineral, shiny flakes of black biotite and needles (in bundles) of greenish-black amphibole.

In order of abundance, the minerals present are as follows. Biotite (somewhat bronzy in the hand specimen) is a highly pleochroic variety; $X =$ light golden yellow, $Y = Z =$ dark brown to opaque. Actinolite is abundant, present in long needles. Albite-Oligoclase ($Ab_{90}An_{10}$) is plentiful. Quartz is less abundant. Accessories are apatite, zircon and magnetite.

Quartz-Feldspar-Anthophyllite-Schist (7866). A fawn-coloured rock cleaving readily in the direction of schistosity. Yellow needles of an almost colourless amphibole are set in a matrix of fine-grained quartz. The needles are in bundles and have a common orientation.

In section, the granoblastic texture of the rock is seen to be modified by the strong directional structure of the colourless amphibole. Quartz is abundant, amounting to 50% by volume. Feldspar is in less amount, namely 25%.

Anthophyllite is abundant to the extent of 24%, as long needles with a more or less common orientation; longitudinal sections show transverse fractures but transverse sections show poorly defined cleavage traces at 120°; extinction is straight in longitudinal sections; D.R. fairly high; R.I. high; very weakly pleochroic; the crystals are length slow; indistinct biaxial positive figure displayed in transverse sections.

Rutile is an abundant accessory, that shows true crystal outlines; geniculate twins are fairly common; however, in most crystals the outlines are modified by a change to opaque ilmenite. Zircon and apatite are present in far less amount.

Tremolite-Actinolite-Oligoclase-Schist (7877). This is a striking rock showing a gradational transition from a white tremolite-oligoclase-quartz-granulite to a dark green, actinolite-rich schist in which there is little quartz or feldspar.

In section, the rock is seen to possess a well-defined schistosity which controls the mineral assemblage. The colour of the tremolite becomes tinged with green until it merges into the iron-bearing member of this series—a green actinolite.

Tremolite occurs as long colourless prismatic needles with positive elongation; maximum extinction angle ($Z \wedge c$) is 12°. Oligoclase ($Ab_{71}An_{29}$) is not abundant; it is more common in association with tremolite but dwindles when actinolite makes its appearance. Quartz is present as small xenoblasts in the tremolite phase but dwindles in the actinolite-rich variety. Accessories are zircon and idioblasts of iron ore.

Granulitic Cordierite-Quartz-Oligoclase-Biotite-Schist (7858). This is a dense greyish-green, fine-grained, saccharoidal rock breaking with a conchoidal fracture. On the weathered surface are to be seen shining brown and black flakes of biotite with preferred alignment.

In section the rock displays a granoblastic texture in which grains of quartz, cordierite and feldspar average about 0·25 mm. in diameter. Due to the alignment of biotite flakes the rock has a rough schistosity.

Cordierite, which is the most abundant mineral, occurs as clear, colourless xenoblasts that exhibit poor twinning in some sections. It is thus very similar to the quartz and plagioclase, from which it is distinguished by its yellow pleochroic haloes and biaxial character. It has a high optic axial angle value.

The quartz is clear and colourless. Oligoclase ($Ab_{79}An_{21}$) exhibits albite twin lamellae. Biotite altering to chlorite is in minor amount. Zircon crystals and also idioblasts of magnetite and pyrites are abundant as accessories.

Bimica-Quartz-Albite-Schist (J. K. 50). A light grey, compact rock of granular quartz and albite, with both white and black mica whose preferred alignment has developed schistosity.

Albite ($Ab_{90}An_{10}$) exhibiting albite twinning is abundant. Quartz is present in approximately equal amounts to the feldspar. Muscovite is present in approximately equal amounts to the feldspar. Muscovite is present as clear colourless laths. The biotite is a strongly pleochroic variety; often it is associated with muscovite and green chloritic material which encloses spindles and radiating needles of iron ore. Accessories in small amount are zircon, sphene, ilmenite and rutile.

Quartz-Albite-Cordierite-Schist (7860). A dense, compact, off-white coloured rock, in which black plates of oriented biotite impart a marked directional structure.

Microscopically the rock displays a pronounced schistosity which modified the otherwise granoblastic texture formed by the almost equi-granular aggregate of quartz and feldspar, and the alteration products of cordierite.

Albite ($Ab_{91}An_{9}$) is abundant. Clear quartz with fluidal inclusions is in less amount. Biotite is abundant; a strongly pleochroic, pale yellow to brown variety showing a little incipient alteration to green chlorite. The cordierite has suffered alteration and is now represented by change products amongst which is chlorophyllite (pleochroic in greens). Zircon and iron ore are present as accessories.

Quartz-Albite-Cordierite-Biotite-Granulite (7861). A light-coloured saccharoidal rock with narrow bands of black shining flakes of biotite with a marked directional trend; these bands are too few and too widely separated to impart a well-defined cleavage to the rock.

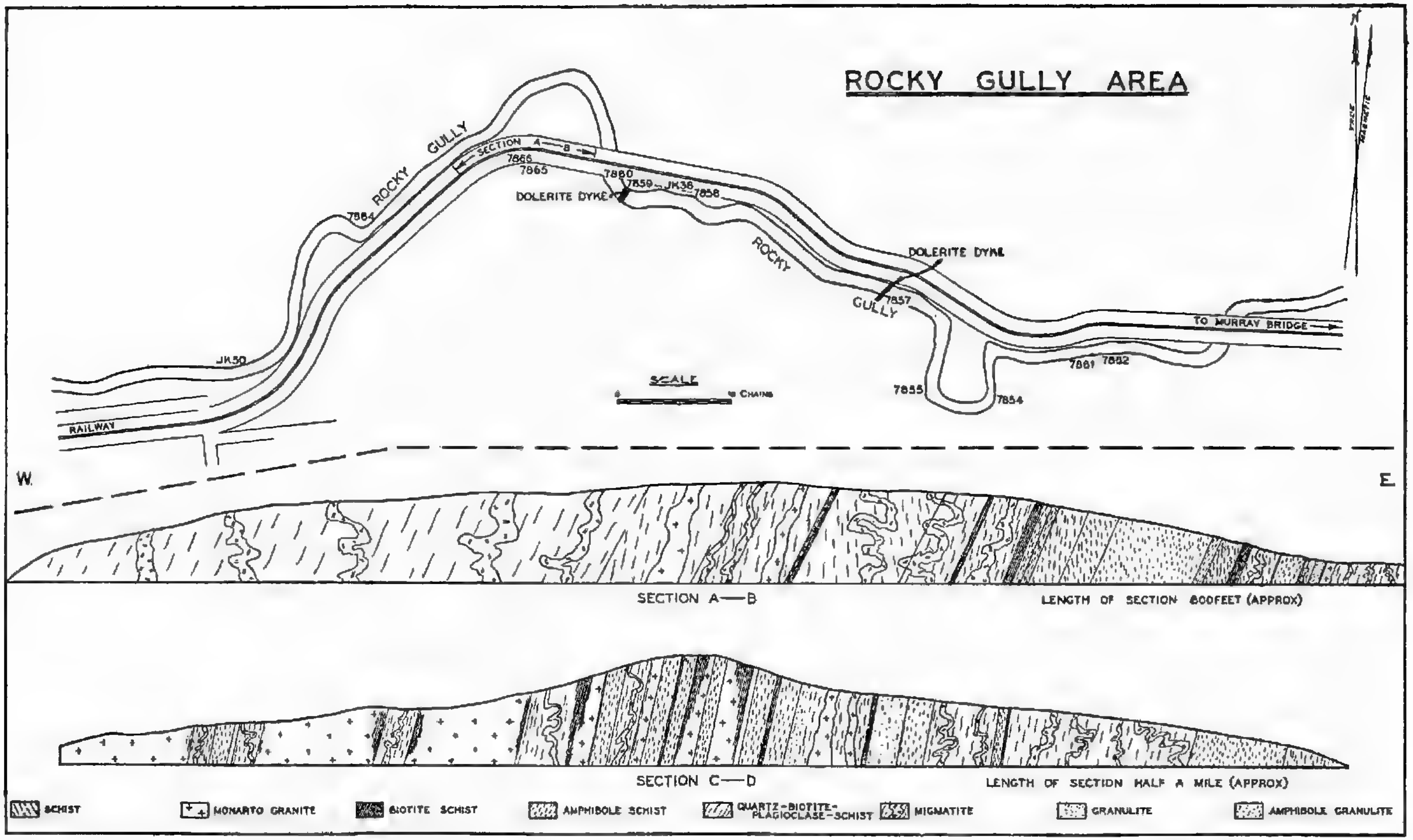

Fig. 2

Enlarged plot of the course of Rocky Gully; also geological cross-sections of special areas A – B (in Rocky Gully) and C – D (near Pallamana: see fig. 1, between p. 124 and p. 125).

In micro-section the rock is seen to be mainly a granoblastic, very fine, even-grained aggregate of cordierite, albite and quartz.

Cordierite with yellow pleochroic haloes and the yellow-green change product chlorophyllite is fairly abundant. Quartz, in clear colourless grains, is the predominant mineral. Albite ($Ab_{91} An_{9}$) granules, some clear and others exhibiting lamellar twinning are plentiful. Biotite with preferred orientation, in weakly pleochroic and partly corroded laths, is sparsely distributed, restricted to certain bands in the rock. Accessories are magnetite, in fairly abundant, black, opaque idioblasts and sparse zircon.

Quartz-Tourmaline-Migmatite (J. K. 100). A dark-grey, fine-grained rock composed of white granular quartz in which are set "clots" of segregated granular tourmaline. These latter are slightly elongated and about 0·5 cm. in diameter.

In section the rock is observed to consist essentially of brown tourmaline and quartz. The "clots" which were visible in the hand specimen are seen to consist almost wholly of tourmaline with a little interstitial quartz. The tourmaline is strongly pleochroic, from yellow to dark brown.

Poikiloblastic Andesine-Hornblende-Scapolite-Clinozoisite-Schist (7883). In the hand specimen this is dark, greenish-grey rock in which porphyroblasts of feldspar as much as 5 mm., but averaging 3 mm., are set in a finer greenish-grey base. Evidently this was originally a phaneric basalt subsequently scapolitized and zoizitized.

In microscope section the feldspar in most individuals is observed to be rimmed, and at times completely replaced, by colourless scapolite. The replacement has taken place along small veins through and along the margins of the plagioclase. Elsewhere clinozoizite is developing.

The minerals present are Andesine ($Ab_{50} An_{50}$) considerably changed over to scapolite and clinozoizite. Pleochroic from light to dark green and exhibiting typical amphibole cleavage. Scapolite, colourless, uniaxial negative, straight extinction on longitudinal sections which latter also yield flash figures. Clinozoizite, slightly turbid; interference colours are anomalous (deep blue); biaxial positive. It displays one poor cleavage and extinction with reference to this is inclined. Sphene is a very abundant accessory as brown xenoblasts.

Another related metamorphosed basic igneous rock (J. K. 102) of somewhat coarser original texture than (7883) was collected in the same locality. This can be described as a poeciloblastic albite-hornblende-clinozoizite schist with accessory biotite, notably sphene and sparse apatite and zircon. In this rock the albite is practically 100% Ab.

Porphyroblastic Andesine-Hornblende-Schist (7884). This also represents a metamorphosed basic igneous rock. The feldspar is white, and occurs as porphyroblasts up to 2·5 cm. diameter set in a mass of green hornblende.

In section it is seen to consist of colourless feldspar and green hornblende in approximately equal amount. The plagioclase, which is little altered, is andesine ($Ab_{61} An_{39}$).

The amphibole is a strongly pleochroic hornblende; X — yellow green, Y = olive green, Z = dark green. A little brown biotite is in intimate association with the hornblende. Sphene is an accessory.

Pegmatite Intrusives of the Migmatitic Belt

Tourmaline-bearing pegmatites were observed in Sections 508, 533, 535, and 175. These vary in width from less than one inch to many feet. They are intrusive into the schists. The vein fillings vary greatly in grain-size and composition but most contain black tourmaline, pink feldspar, milky quartz and muscovite.

Dr. Woolnough described several pegmatites from Rocky Gully. He states that the feldspars of the pegmatites are remarkable for their variety, including orthoclase, microcline, anorthoclase, albite and oligoclase. Woolnough mentions that in one of the pegmatites two small crystals of beryl were observed. This occurrence is interesting, for beryl is a feature of granite pegmatites occurring at Mount Crawford and also in the suite of the Boolcoomatta granite bathylith.

Basic Dykes of the Migmatitic Belt

As already mentioned two clearly defined dykes outcrop in the bed of Rocky Gully, Section 514, Hundred of Mobilong. In the fresh unweathered state these are dark grey rocks; both discordantly intrude the schists. They possibly post-date the granitic intrusion.

Meta-Dolerite (7859). The doleritic intersertal structure is still well preserved. Minerals present are labradorite in interlaced laths, chlorite and magnetite resulting from the breakdown of original pyroxene. A little biotite and sphene, apatite and pyrite as accessories.

Meta-Lamprophyre? (7858). This is more basic, there being very little in the nature of feldspars or their change products. The principal minerals observable are chlorite and black iron ores. It is possible that the rock was originally a basic lamprophyre.

Monarto Granites

Adamellite (7867) is an even, medium-grained, light grey, granitic rock. The obvious minerals are quartz, greyish-white feldspar, small black flakes of biotite and some silvery flakes of muscovite.

A chemical analysis and the norm are tabulated herewith:

Norm of I, Rock 7867

Quartz		33·30
Orthoclase		19·46
Plagioclase:	Ab 33·01 An 8·34	41·35
Corundum		2·45
Hypersthene:	Fs 1·20 En 0·53	1·73
Magnetite		0·93
Ilmenite		0·46
Apatite		0·13
Zircon		0·18
Water		0·30
		99·99

	I	II	III	IV
SiO_2	73·20	72·40	84·25	90·73
TiO_2	0·23	0·22	0·18	0·13
Al_2O_3	15·46	15·49	8·64	4·01
Fe_2O_3	0·64	0·44	0·18	0·68
FeO	0·80	1·03	1·10	0·26
MnO	tr.	0·02	tr.	tr.
MgO	0·48	0·20	0·23	0·05
CaO	1·73	1·44	0·19	0·18
Na_2O	3·90	4·30	4·06	3·66
K_2O	3·34	3·78	0·84	0·31
H_2O+	0·22	0·12	0·36	0·03
H_2O-	0·08	0·18	0·02	0·05
P_2O_5	0·08	0·19	0·04	0·04
ZrO_2	0·11	—	0·04	0·05
BaO	0·06	—	tr.	tr.
S	0·02	—	0·12	0·13
FeS_2	—	0·11	—	—
	100·35	99·98	100·35	100·29

I. Adamellite from Monarto (7867). Anal.: R. K. Johns.

II. Monarto "granite". Anal.: W. S. Chapman. See R. L. Jack (1923).

III. The more basified part of rock (7871). Anal.: J. M. Kruger.

IV. The less basified part of rock (7871). Anal.: R. J. Johns.

In the micro-section, potash feldspar as microcline appears to be a little less abundant than plagioclase; these with quartz constitute the bulk of the rock. The feldspars are somewhat turbid and show the effects of strain. Quartz, next in abundance, is clear and free from cracks but shows strain shadows. There are present a few small myrmekitic intergrowths—these are of quartz and plagioclase, such developments taking place on the borders of microcline crystals, due to the replacement of that mineral by plagioclase. Biotite is fresh; it is the essential ferromagnesian mineral but often associated with clear plates of muscovite. The disposition of the micas defines a rough directional structure. The average grain-size of constituent minerals as seen in the slide is about 0·6 mm.

The plagioclase is faintly zoned; individuals are twinned on the albite and combined albite—Carlsbad laws. Maximum extinction angle measured in the zone ⊥ 010 is 5° corresponding to oligoclase on composition $Ab_{76}An_{24}$. Biotite is a normal variety, strongly pleochroic; X = light yellow, Y = Z = almost opaque; it bears pleochroic haloes surrounding small crystals of zircon. Muscovite occurs as broad tabular flakes. Zircon, as an accessory, is abundant in small rounded grains. Apatite in rod-like forms is a sparse constituent.

The mode of (7867) was obtained by a Rosiwal measurement on a single small slide is as follows: quartz, 42·4%; microcline, 21·5% plagioclase, 26·5%; muscovite, 2·2%; biotite, 7·3%; accessories, 0·1%. By the relation of the feldspars, the rock is thus to be defined as an *adamellite*.

Granite (7856). This is the most typical and widely developed of the plagioclase than does (7867). It exhibits an obvious directional arrangement of minerals. Average size of constituent grains as measured in the slide is about 0·2 to 0·3 mm., although they attain to 1 mm. in diameter. A micrometric determination of the mode in a single slide gave the composition as: quartz, 50·1%; microcline, 33·3%; plagioclase, 6·7%; biotite, 7·7%; muscovite, 2·0%; accessories, 0·2%.

Microcline is abundant, as also is quartz (which bears abundant rods of apatite as inclusions). Plagioclase, which is an oligoclase ($Ab_{77}An_{32}$) is sparse. Biotite and muscovite are present in association. Accessories are apatite, magnetite, zircon; the latter relatively abundant.

Adamellite (7878). Another of this granitic suite with marked directional features. It is somewhat coarser grained than (7867). In this the oligoclase is predominant over microcline: it is also irregularly zoned.

Granite (7856). This is the most typical and widely developed of the Monarto granites. It is coarser grained than the preceding types and exhibits a well-defined gneissic structure in which the bands of biotite are more widely separated. It is of an even grain-size, the latter averaging 0·80 mm. as viewed in the micro-section.

Quartz and microcline are both abundant constituents, the former as anhedral individuals bearing fluid inclusions and also small apatite crpstals. The plagioclase is an Oligoclase ($Ab_{76}An_{24}$); Biotite is strongly pleochroic from yellow to almost opaque; it shows slight alteration to green chlorite; ratio of elongation of flakes 2:1. Muscovite is not abundant. Apatite, zircon and magnetite are accessory minerals in small amount.

The mode obtained by micrometric measurement gave: quartz, 42·9%; microcline, 35·9%; plagioclase, 16·7% biotite, 4·0%; muscovite, 0·4%; accessories, 1·1%.

Adamellite (7876). This rock was observed in the field to grade out into a coarse biotite-quartz schist, in which biotite is predominent as coarse flakes imparting a pronounced schistosity.

In microscope slide it is seen to have an allotriomorphic granular texture, with average size of grain about 1 mm. but with a few individuals as much as 2·2 mm. in diameter.

Feldspar is represented by approximately equal amounts of microcline and oligoclase ($Ab_{74}An_{26}$). Other notable minerals are quartz, biotite and muscovite in small amounts and accessory zircon.

Schists, Granulites and Basified Arenite Associated with the Monarto Granites

The belt of rocks bounding the Monarto Granite on the north, west and south is constituted of a range of fine-grained quartz-plagioclase-biotite schists. In this area fresh exposures are scarce: those showing least weathering were obtained from dam excavations and water-main trenches.

Outcrops of such rocks were met with in sections 213, 214, 524, 528, 529, 530 of the Hundred of Mobilong, and in sections 43, 45, 219, 220, 222, 228, 229, 230, 231, 232, 233, 249, 250, 257, 260, 461, 462 and 464 of the Hundred of Monarto.

In these schists the original bedding and stratification planes have been almost obliterated. Regional foliation of these schists is 347° with dip 65° west.

Basified Arenite (7871). This is a white, compact, fine-grained, granular feldspar-quartz rock without obvious schistose features. It is suggested that it originated from an arenite by feldspathization. An irregular schlier in the hand specimen is somewhat darker coloured and contains obvious tiny flakes of biotite feebly oriented towards a parallel arrangement. This schlier appears to be an area which has suffered a more advanced degree of basification. Specimen (7870) appears to be intermediate in composition between the two phases exhibited in (7871).

The rock slide exhibits a granoblastic texture with grainsize averaging 0·20 mm.; xenoblasts of quartz and feldspar constitute the bulk of the slide. The quartz displays undulose extinction. The plagioclase is albite ($Ab_{91}An_{9}$). Microcline-perthite is present in small amount. Biotite is sparse but more abundant in the more highly basified patch. Accessories are muscovite, zircon and magnetite.

Chemical analyses of both the less basified and the more basified portions of (7871) are given in the table on page 132. Comparison of these analyses with each other and with that of the Monarto granite (7867) reveals progressive loss of SiO_2 and S but demonstrates additions to the content of Al_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5 and ZrO_2 in the passage from original (?) arenite to granite. This strengthens the view that the Monarto granite has in fact developed as a migma (see page 136).

Quartz-Biotite-Plagioclase-Schist (J. K. 62). A dark-grey, fine-grained rock. In section it is seen to be a granoblastic aggregate of quartz and feldspar, shot through with a bundant biotite flakes in parallel alignment.

Quartz is present to the extent of 59·4%. The larger individuals exhibit undulose extinction. Biotite to the extent of 30·5% is the next most abundant constituent: pleochroic from yellow to brownish-red. Pleochroic haloes are common. Muscovite is present only in very small amounts, about 0·4%. Plagioclase to the extent of 9·7% is distributed throughout the slide as slightly clouded xenoblasts. It corresponds to oligoclase ($Ab_{71}An_{29}$). Zircon is abundant as rounded individuals. Apatite is sparse. Magnetite as black opaque octahedra is also sparse.

Rock (7869) is a dark grey, fine-grained, schlieric rock consisting essentially of quartz and biotite—closely similar to (J. K. 62). Tourmaline in small crystals is present in appreciable amount.

Rock (7881) is similar to (J. K. 62) and (7869) except that plates of white mica are visible in the hand specimen. Contains a little tourmaline as one of the accessories.

Quartz-Biotite-Plagioclase-Schist (7880). A fine-grained, grey schistose rock. Microscopically it displays a fine, even, granoblastic texture somewhat modified by the more or less parallel alignment of the micas. Mineralogically it is very similar to (J. K. 62). Rock (J. K. 97) is also very similar but here the plagioclase is an albite ($Ab_{91} An_9$).

Bimica-Quartz-Plagioclase-Schist (7879) is another rock of this group in which muscovite appears in larger amounts. Here the plagioclase comes into the range of the oligoclase ($Ab_{88} An_{12}$).

Rock No. (J. K. 92) is an even-grained, grey schistose variety that grades from a biotite-quartz schist (rich in biotite) into a rock that has the appearance of a schistose granite of the Monarto type. The average grain-size is 0·20 mm. The plagioclase is an Albite ($Ab_{92} An_8$).

Quartz-Plagioclase-Biotite-Gneiss (7873). This is a fine-grained foliated rock in hand specimen. It consists of greyish leucocrats and oriented biotite flakes.

In section it is seen to be composed of a granoblastic association mainly of quartz, with abundant olioglase ($Ab_{71} An_{29}$) and little orthoclase, with considerable biotite, a very little muscovite, abundant black iron ore and small rounded zircons.

Quartz-Plagioclase-Biotite-Schist (7864). A light grey rock with pronounced schistose structure due to the parallel alignment of biotite flakes. The majority of the slide is constituted of a granoblastic aggregate of quartz (grain-size to 0·4 mm.) and turbid albite ($Ab_{91\ 9}$). The latter is clouded with minute flakes of sericitic mica. There is present just a little granular orthoclase, a very small amount of muscovite and occasional zircon grains.

Plagioclase-Quartz-Biotite-Schist (7855). A rock similar to but not so coarse as (7864). In hand specimen it has the appearance of a fine-grained schistose granite. The section displays a granoblastic texture modified by oriented mica flakes.

Quartz with undulose extinction is next in abundance to oligoclase. Microcline is present in lesser amount in xenoblasts displaying poor polysynthetic twinning. Biotite is plentiful. Muscovite, apatite, zircon and black iron ore are accessories.

SUMMARY

The broader geological features of the older rocks of this region as defined in the foregoing are as follows:—

(1) The existence on the eastern side of the area, at Murray Bridge, of a large scale granite intrusion, part of a batholythic mass which has been traced as extending towards the Victorian border in the south-eastern corner of South Australia. The granite of this batholyth has all the characters indicating it to have been originally a mobile magma.

(2) The schists and gneisses bordering it on the west, well exposed in Rocky Gully and neighbourhood, are of a high grade of metamorphism and in part migmatitic. They include types common in the inner zones of granite aureoles.

(3) Further west, in the Monarto area, away from the Murray Bridge granite mass are schists of a lower grade of metamorphism, much of which it would appear could have originated from the basification of original arenites. The field mapping indicates that rocks of a large part of this latter area were originally quartzites of a synclinal basin, since metamorphosed to a greater or less degree. In this locality the Monarto granite is met with. The nature of this granite, particularly in its physical characters, varies greatly in the different outcrops. In some small areas it is without directional features but elsewhere its minerals exhibit preferred orientation which appears to be a relic of an earlier schist stage. Two examples are given with chemical analyses illustrating intermediate stages in the basification of arenite in the development of a granitic migma of the general character of certain of the varieties of Monarto granite. It thus seems apparent that part at least of the Monarto granite has developed as a migma.

The variable chemical composition of the Monarto granite outcrops and variability in size of grain and structure, have been demonstrated in this contribution. In some areas it is within the range of the alkali-granites, elsewhere it is an adamellite. It is mostly fine-grained, but locally may be coarser. All graduations may be traced from a feldspathic, somewhat basified quartzite through schist, to a mineral assemblage and structure typical of "granite". As may be expected of a granite that has been derived from the feldspathization *in situ* of arenite, xenoliths are absent in the Monarto outcrops Furthermore, the Monarto granite is concordant with the surrounding schists.

REFERENCES

JACK, R. L. 1923 The Building Stones of South Australia. Geol. Survey of S. Aust., Bull. 10

KLEEMAN, A. W. 1934 The Murray Bridge Granite. Trans. Roy. Soc. S. Aust., **58**

MAWSON, D., and SEGNIT, E. R. 1945 Granites of the Tintinara District. Trans. Roy. Soc. S. Aust., **69**

READ, H. H. 1943 Meditations on Granite. Proc. Geol. Ass., **54**

READ, H. H. 1944 Meditations on Granite. Proc. Geol. Ass., **55**

WOOLNOUGH, W. G. 1908 Notes on the Geology of the Mount Lofty Ranges, chiefly the portion east of the Onkaparinga River. Trans. Roy. Soc. S. Aust., **32**

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THE MARINE ALGAE OF KANGAROO ISLAND

III. LIST OF SPECIES

BY H. B. S. WOMERSLEY

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THE MARINE ALGAE OF KANGAROO ISLAND
III. LIST OF SPECIES 1

By H. B. S. Womersley*

SUMMARY

Four hundred and one species of marine algae are recorded from Kangaroo Island, South Australia, together with comprehensive references, and notes on many species.

INTRODUCTION

This paper records 401 species of marine algae (Cyanophyta 26, Chlorophyta 46, Phaeophyta 96, Rhodophyta 233) from Kangaroo Island. Records derived from a small collection from the "south coast," made by J. Cork in the winter of 1939, and also records given by Cleland and Black from Sou' West River mouth, December 1934 (determined by A. H. S. Lucas) have been incorporated.

Further species will be recorded in a second list, as over 100 remain undetermined, some of which are as yet undescribed. Kangaroo Island is a very rich region for marine algae, and although extensive collections have been made during the last five years, doubtless more species remain to be discovered in localities which have not been thoroughly investigated.

Over 100 species comprise new records for the State of South Australia, but as Southern Australia forms a distinct geographic region (with probably 35-40% of species occurring from Tasmania to Western Australia), and so few localities have been thoroughly examined, such new records have little significance for the present and have not been indicated.

The specimens on which this list is based are deposited in the Algal Herbarium of the Botany Department, University of Adelaide.

Visits were made to Kangaroo Island at the following times: 1944, January; 1945, January, May; 1946, January, August; 1947, January, April, May, June, July, October, November; 1948, January, September, December; 1949, January.

In determining the species in this list recourse has been made wherever possible to original literature, and to authentic specimens in Australian Herbaria, especially the Melbourne National Herbarium. Unfortunately, few type specimens of Australian algae exist in Australia, making sure determinations very difficult in many cases; and many other specimens in herbaria are incorrectly named, so that comparisons with specimens other than the type have to be done with caution. Melbourne National Herbarium fortunately possesses O. W. Sonder's Australian collection, including his type specimens, and also a set of W. H. Harvey's Australian algae, J. G. Agardh's "Algae Muellerianae" and duplicates of J. B. Wilson's collections. The Adelaide University Herbarium possesses a few of T. Reinbold's cotypes from Investigator Strait. It is evident, however, that extensive series of nearly all Australian species should be checked with the type specimens, and also with related species to define limits of variability. Many other species, such as those of Zanardini, are very poorly known, and require re-examination of the original specimens. Until this can be done some determinations must necessarily be provisional, and description of new species must await comparison with authentic material of closely related species.

In this list notes on the habitat of each species are given where possible. The ecological terms used have been defined in Pt. I of this series (Womersley 1947), and references to Pt. I and Pt. II apply to this and the second paper (Womersley 1948). Where a species is listed as from the drift (*i.e.*, found cast up or floating), it almost certainly grows in the sublittoral, as the littoral and

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upper sublittoral have been extensively collected in most localities and are listed as such. The month (abbreviated) and year of most collections are given, as this gives positive evidence of the seasonal occurrence of many species (and also facilitates future reference to the specimens in the herbarium). In many cases, especially at Pennington Bay and American River inlet where the seasonal occurrence of many species is comparatively well known it has been possible to generalise and give the period of their occurrence. However, probably the majority of species known from a few records are present during all seasons.

Although positive records only are given, generalisations about the distributions of many species around the island can be made. Thus species found at Pennington Bay or Vivonne Bay probably occur in similar habitats anywhere along the south and west coasts. In fact, the formations and subformations described in Pt. I are usually broad habitat regions.

No attempt has been made to give a complete list of references to the species, nor in some cases is the reference to the original description given. A selection has been made of the more important and useful references, especially those available to the author, and De Toni in most cases gives fairly complete lists.

Throughout this series of papers Recommendation XLIII of the 1935 Botanical Rules referring to the use of capital letters for patronymic and certain other specific names has not been followed. I am in full agreement with the reasons expressed for this in the Journal of Ecology, **31**, (1943), p. 93.

The following authors have been followed in the classification adopted: Cyanophyta (Fritsch 1942), Chlorophyta and Phaeophyta (Smith 1938, Papenfuss 1947a), Rhodophyta (Kylin 1924, 1931, 1932, Falkenberg 1901, and Fritsch 1945).

The localities have been abbreviated to the first letters of the names, as in the list below. The order of localities is from American River inlet along the north, west, south and east coasts and back to American River inlet (see fig. 1, Pt. I). Brief notes on the areas examined are also given below, and reference should be made to Pt. I and II for further details.

North Coast—

AR, American River inlet: an extensive tidal inlet (not a river) with small islands (Shag Rock, Pig, Wallaby Islands) in Pelican Lagoon. *BH*. Ballast Head; a rocky headland immediately north of American River inlet. The east side only has been examined. *K*. Kingscote. *BS*. Bay of Shoals: a shallow sandy bay with calm conditions. *EB*. Emu Bay: the rocky coast near the old jetty was examined. *SB*. Stokes Bay. *MR*. Middle River: the mouth is normally closed by a sand bar and rocky coast occurs at both ends of a sandy beach. *WR*. Western River: the river mouth is also usually closed by a sandy bar. *HR*. Harvey's Return: about four miles east of Cape Borda.

West Coast—

WB. West Bay.

South Coast—

CC. Cape Coudie. *VB*. Vivonne Bay: rock platforms occur within the bay while the western extremity—Ellen Point—is of steeply sloping rock. Pools 1 and 2 are referred to in Pt. I, p. 245. *DB*. D'Estrees Bay: reefs briefly examined are at the eastern end of the bay. *PB*. Pennington Bay: see Pt. II *CW*. Cape Willoughby.

East Coast—

AB. Antechamber Bay: The rocky area at the north end of the bay was examined. *HB*. Hog Bay.

North Coast—

RP. Rocky Point: "drift" specimens from here were mostly collected between Rocky Point and American River inlet.

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CYANOPHYTA

CHROOCOCCALES — Chroococcaceae

COCCOCHLORIS Sprengel

Coccochloris castagnei (Kützing) Drouet and Daily 1948, 77. *Palmella castagnei* Kützing 1846, t. 9. *Aphanothece castagnei*, Rabenhorst 1932, 171. Tilden 1910, 31, pl. 2, f. 13. — *AR*. Sublittoral, near Muston, Jan. 1948.

ENTOPHYSALIS Kützing

Entophysalis deusta (Meneghini) Drouet and Daily 1948, 79. *Gloeocapsa deusta*, Kützing 1949, 224. Rabenhorst 1932, 190. — *AR*. Amongst other algae in a mat on buoys near American River jetty, Jan. 1946.

PLEUROCAPSALES — Pleurocapsaceae

DERMOCARPA Crouan

Dermocarpa schousboei (Thuret) Bornet. *Xenococcus schousboei* Thuret in Bornet and Thuret 1880, 74, pl. 26, f. 1, 2. Tilden 1910, 50, pl. 3, f. 7. Rabenhorst 1932, 335, f. 170 — *EB*. In littoral rock scrapings, Jan. 1946.

NOSTOCALES — Oscillatoriaceae

HYDROCOLEUM Kützing

Hydrocoleum cantharidosmum (Montagne) Gomont 1892, (Pt. I), 336, pl. 12, f. 647. Tilden 1910, 135, pl. 5, f. 57. Rabenhorst 1932, 1,148, f. 755. *Calothrix limbata* Harvey 1863, syn. n. 792, Alg. Aus. exs. n. 596. — *PB*. Lower littoral, on well washed rock, Dec. 1948.

Hydrocoleum comoides (Harvey) Gomont 1892, (Pt. I), 335, pl. 12, f. 3-5. Tilden 1910, 134, pl. 5, f. 56. Rabenhorst 1932, 1,148, f. 756. *Calothrix comoides* Harvey 1863, syn. n. 793. Alg. Aus. exs. n. 597, 598. — *VB*, Edge of rock pool, south side of Ellen Pt., May 1945.

Hydrocoleum glutinosum (Agardh) Gomont 1892 (Pt. I), 330. Tilden 1910, 136, pl. 5, f. 59. Newton 1931, 29. Rabenhorst 1932, 1,149. — *AR*. As irregular masses on *Hormosira* (Aug. 1948) and *Zostera* (Sept. 1946) on the tidal flats. *MR*. On *Cystophyllum muricatum* and *Cladostephus verticillatus*, upper sublittoral, Jan. 1947. *VB*. On rocks near jetty, mid littoral, and on reef in bay, Jan. 1947. *PB*. On ledge, main reef, all seasons, and on *Corallina cuvieri* in sublittoral fringe, Jan. 1946. CW. On rocks and on *Hormosira*, lower littoral, Jan., Aug. 1948.

Hydrocoleum lyngbyaceum Kützing 1849, 259. Gomont 1892 (Pt. I), 337, pl. 12, f. 8-10. Tilden 1910, 135, pl. 5, f. 58. Setchell and Gardner 1919, 85, pl. 1, f. 10. Newton 1931, 29, f. 20. Rabenhorst 1932, 1,150, f. 757. — *PB*. Forming tufts at the constrictions of *Hormosira*, lower littoral, Jan. 1946. *AB*. On *Cystophora subfarcinata*, lower littoral, Jan. 1947.

LYNGBYA Agardh

LYNGBYA CONFERVOIDES Agardh. Gomont 1892 (Pt. II), 136, pl. 3, f. 5, 6. Tilden 1910, 119, pl. 5, f. 39. Setchell and Gardner 1919, 77. Rabenhorst 1932, 1,061, f. 672 b. — *AR*. In a mat on buoys near American River jetty, Jan. 1946. *EB*. Littoral rock scrapings, Jan. 1946.

LYNGBYA LUTEA (Agardh) Gomont 1892 (Pt. II), 141, pl. 3, f. 12, 13. Tilden 1910, 114, pl. 5, f. 30, 31. Rabenhorst 1932, 1,057, f. 670 a. b. — *MR*. Littoral rock scrapings, Jan. 1946.

LYNGBYA MAJUSCULA (Dillwyn) Harvey. Gomont 1892 (Pt. II), 131, pl. 3, f. 3, 4. Tilden 1910, 123, pl. 5, f. 42. Rabenhorst 1932, 1,060, f. 672 c, d. — *VB*. In shaded part of pool 1, south side of Ellen Pt., Dec. 1945.

LYNGBYA SEMIPLENA (Agardh) J. Agardh. Gomont 1892, (Pt. II), 138, pl. 3, f. 7-11. Tilden 1910, 118, pl. 5, f. 38. Setchell and Gardner 1919, 78. Rabenhorst 1932, 1,061, f. 672 a. — *MR*. In scrapings from a shallow pool, Jan. 1946.

LYNGBYA SORDIDA (Zanardini) Gomont 1892, (Pt. II), 126, pl. 2, f. 21. Tilden 1910, 118, pl. 5, f. 37. Rabenhorst 1932, 1,039, f. 657 b. — *PB*. In a shaded pool, rear littoral of main reef, Jan. 1948.

PLECTONEMA Thuret

PLECTONEMA BATTERSII Gomont 1899, 36. Tilden 1910, 211. Setchell and Gardner 1919, 79, pl. 1, f. 1. Newton 1931, 25, f. 18. Rabenhorst 1932, 684. — *AR*. Amongst other algae in a mat on buoys near American River jetty, Jan. 1946.

PLECTONEMA NORVEGICUM Gomont 1899, 34. Newton 1931, 26. Rabenhorst 1932, 684. — *AR*. Amongst other algae in a mat on buoys near American River jetty, Jan. 1946.

SYMPLOCA Kützing

SYMPLOCA HYDNOIDES Kützing 1849, 272. Setchell and Gardner 1919, 81, pl. 1. f. 12, 13. Newton 1931, 21, f. 16. Rabenhorst 1932, 1, 1,119, f. 724. — *AR*. On tidal flats, May 1945. *WR*. In littoral rock scrapings, Jan. 1946. *VB*. In pool 1, south side of Ellen Point, Jan. 1949. *PB*. On sloping and vertical rock in the rear littoral, all seasons. *CW*. Littoral, Jan. 1946.

RIVULARIACEAE

CALOTHRIX Agardh

CALOTHRIX AERUGINEA (Kützing) Thuret 1875, 10. Tilden 1910, 261, pl. 17, f. 1. Rabenhorst 1932, 599, f. 375 a. — *MR*. On *Enteromorpha* and *Cladophora* in littoral pools, Jan. 1948. *PB*. On *Polysiphonia* on littoral sloping rock, Dec. 1948. *CW*. On *Chaetomorpha aerea* in littoral pools, south side Jan. 1948.

CALOTHRIX CONFERVICOLA (Roth) Agardh. Tilden 1910, 256, pl. 16, f. 6-8. Rabenhorst 1932, 601, f. 376. Epiphytic on other algae in the littoral zone in most localities, all seasons. Often dense on *Jania fastigiata* (*VB, PB, AB*), *Centroceras clavulatum* (*VB*, Jan. 1946), *Hymenocladia polymorpha* (*DB*, sublittoral fringe, Jan. 1947) and *Chaetomorpha aerea* (*CW*, littoral pool, Aug. 1948).

CALOTHRIX CRUSTACEA Thuret. Tilden 1910, 264, pl. 17, f. 2-6. Rabenhorst 1932, 601. — *EB, MR, WR, WB*. On littoral rock, sometimes forming extensive slippery patches, all Jan. 1946. *HB*. Upper littoral, Jan. 1945.

CALOTHRIX SCOPULORUM (Weber and Mohr) Agardh. Bornet and Thuret 1880, 159, t. 38. Tilden 1910, 258, pl. 16, f. 11, 12. Setchell and Gardner 1919, 96. Rabenhorst 1932, 600, f. 374, f, g. — *AR.* Amongst other algae in a mat on buoys near American River jetty, Jan. 1946.

ISACTIS Thuret

ISACTIS PLANA (Harvey) Thuret. Bornet and Flahault 1886, (Pt. II), 343. Setchell and Gardner 1919, 104, pl. 1, f. 8, 9. Womersley 1946a, 128, f. 1A. — *VB.* Edge of rock pools and on the mollusc *Cellana tramoserica,* south side of Ellen Pt., Jan. 1946. *PB.* Littoral, main reef, all seasons. *HB.* Lower littoral, Jan. 1944.

RIVULARIA Agardh

RIVULARIA ATRA Roth. Bornet and Flahault 1886, (Pt. II), 353. Setchell and Gardner 1919, 107, pl. 8, f. 1, 2. Womersley 1946a, 132, f. 1B. — *AR.* On dead *Posidonia* and shells, Jan. 1946. *SB.* Upper littoral, Jan. 1946. *VB.* Edges of rock pools and on molluscs, south side of Ellen Point, May 1945. *PB.* Littoral, main reef, Jan. 1948.

RIVULARIA AUSTRALIS Harvey 1854, 566. Bornet and Flahault, 1886, (Pt. II). 362. Womersley 1946a, 133. — *MR.* Upper littoral, west side, Jan. 1948.

RIVULARIA FIRMA Womersley 1946a, 130, f. 2A, B. — East, south west and rougher parts of the north coast, in middle and upper littoral, all seasons, but variable in occurrence and amount.

RIVULARIA NITIDA Agardh. Bornet and Flahault 1886, (Pt. II), 357. Womersley 1946a, 133, f. 1C. — *AR.* On rock in mid littoral, Pelican Lagoon, Jan. 1946.

RIVULARIA POLYOTIS (Agardh) Bornet and Flahault 1886, (Pt. II), 360. Womersley 1946a, 134, f. 2C. — *AR.* On *Posidonia, Zostera* and larger algae on the tidal flats and floating, mainly summer. *BS.* Upper sublittoral, Jan. 1947.

STIGONEMATACEAE

BRACHYTRICHIA Zanardini

BRACHYTRICHIA QUOYI (Agardh) Bornet and Flahault 1886, (Pt. II), 373. De Toni 1907, 680. Tilden 1910, 294, pl. 20, f. 18. — *SB* and *MR.* Upper and mid littoral, Jan. 1947 and 1948. *VB.* Edge of pool, south side of Ellen Point, May 1945.

CHLOROPHYTA

ULOTRICHALES — ULOTRICHACEAE

ULOTHRIX Kützing

ULOTHRIX IMPLEXA Kützing 1849, 349. Setchell and Gardner 1920, 283. Smith 1944, 34. — *AR.* As a green band along the waterline on boats anchored near American River jetty, Aug. 1948. Seasonal occurrence (from local information), March to Nov. These specimens agree well with the above descriptions, but I have not seen authentic material. There seems to be some difference of opinion as to whether the marine species should be known as *U. implexa* or *U. subflaccida* Wille. Setchell and Gardner are followed in referring it to *U. implexa.*

ULVALES — ULVACEAE

ULVA Linnaeus

ULVA LACTUCA Linnaeus. Setchell and Gardner 1920, 265. Smith 1944, 45. Taylor 1937, 75 — *AR.* On tidal flats (low littoral and upper sublittoral), common, all seasons. Sou'-West River mouth, Dec. 1934 (Cleland and Black). *PB*. Less rough parts of the reefs and rear littoral, all seasons. Also found in almost any suitable habitat elsewhere around the island. In *AR* specimens the thallus is 55-70μ thick, with the cells in transverse section 1-1½ times as high as broad. In *PB* specimens the thallus is 40-60μ (-70μ) thick, cells as high (-1½ times) as broad. In size and form the *AR* specimens often approach var. *latissima* De Candolle, while the *PB* specimens are similar to var. *rigida* (C.Ag.) Le Jol. However, the great variation in size and form between specimens in the same and different localities (from expanded plates to elongate undulate ribbons), prevents any valid separation of varieties.

ENTEROMORPHA Link

This genus is notoriously difficult, and only some of the more distinct forms from Kangaroo Island are listed here. I have received opinions on the species from Dr. V. J. Chapman and also from Dr. C. Bliding whose culture experiments in Sweden have shown that some species include a number of forms. Until it is possible to carry out similar culture and copulation experiments with Kangaroo Island *Enteromorpha's*, the limits of some species must remain uncertain.

ENTEROMORPHA ACANTHOPHORA Kützing 1856, t. 34, f. 1. J. Agardh 1883, 158. De Toni 1889, 135. — *PB*. Rear littoral on reefs, all seasons but best developed in winter. These forms are only 1-4 cm, high, but resemble Kützing's figure and New Zealand specimens in form and structure.

ENTEROMORPHA CLATHRATA (Roth) J. Agardh. Bliding 1944, 331. Doty 1947, 16. Kylin 1949, 28. — *AR*. Lower littoral and upper sublittoral throughout the inlet, all seasons. *MR*. Lower littoral pools, Jan. 1946, 1948. *CC*. Rock pools, Jan. 1948. *VB*. On a punt in mouth of Harriet River, Jan. 1946. *AB*. Rock pool, Jan. 1947. *RP*. Mid littoral, Jan. 1945.

The material from American River inlet is very variable and is referred by Dr. Chapman to a number of forms. The variations seem, however, to be ecological in nature, depending on degree of exposure and water movements, and probably nearly all the American River forms are best placed under one species, as Dr. Bliding would do. Culture experiments with these forms are necessary for a full understanding of the problem. The form of Bliding's Types I, II, and III are represented at American River inlet.

ENTEROMORPHA COMPRESSA (L.) Greville. De Toni 1889, 126. Doty 1947, 14. Bliding 1948, 128. Kylin 1949, 22. f. 14, 15. — *AR*. On buoys near American River jetty, Jan. 1946. *BH*. Lower littoral, Oct. 1947.

ENTEROMORPHA INTESTINALIS (L.) Link. Doty 1947, 14. Bliding 1948, 123. Kylin 1949, 22. — *MR*. In lower littoral pools, Jan. 1946.

BLIDINGIA Kylin

BLIDINGIA MINIMA (Kützing) Kylin 1949, 30. *Enteromorpha minima* Kützing 1856, t. 43, III. Bliding 1938, 84. — *AR*. On jetty steps, mid littoral, Sept. 1946, Aug. 1948. *RP*. Mid littoral, amongst *Enteromorpha clathrata*, Jan. 1945. Original det., C. Bliding.

CLADOPHORALES — CLADOPHORACEAE

CLADOPHORA Kützing

CLADOPHORA CERATINA Kützing 1849, 401; 1854, 5, t. 21, f. 1. — *AR*. Epiphytic on *Zostera muelleri* and in tangled masses on the tidal flats near the mouth of the inlet, Feb. 1946, Jan. 1948. *VB*. On punt and stakes at mouth of Harriet River (brackish), Jan. 1946.

CLADOPHORA DELICATULA Montagne. Setchell and Gardner 1920, 220. Smith 1944, 61. De Toni 1889, 326. — *CC*. Drift, Jan. 1947.

CLADOPHORA FASCICULARIS (Mertens) Kützing 1843, 268, 1849, 393. De Toni 1889, 316. Borgesen 1946, 21. — *AR*. Widely, but often sparsely, distributed in the upper sublittoral throughout the inlet, and on the buoys near American River jetty, all seasons. *BH*. Upper sublittoral, Oct. 1947. *PB*. In mid littoral rock pool on western terraced reef, Jan. 1946. The branching of AR specimens is very much looser, and they appear more slender than those from BH and PB. Filament widths, however, are similar in all specimens, and the fasciculate branching is well developed in all.

CLADOPHORA FEREDAYAE Harvey 1858, pl. 47; 1860b, 339. De Toni 1889, 323. — *CW*, Rock pool, south side, Aug. 1948.

CLADOPHORA REPENS (J. Agardh) Harvey 1871, pl. 236. Kützing 1854, t. 70, f. 2. De Toni 1889, 345. — *VB*. Edge of reef (sublittoral fringe), north side of Ellen Point, Jan. 1948. *PB*. Drift, April 1947.

CLADOPHORA VALONIOIDES Sonder 1846, 149. Harvey 1859, pl. 78. De Toni 1889, 308. — *WB*. Drift, Jan. 1946. *CC*. Rock pool, Jan. 1944, drift, Jan. 1947. *VB*. Drift, and on reefs in bay, Jan. 1949. *PB*. On reefs, littoral, all seasons. Specimens cast up from the sublittoral are much looser and larger than those growing in rough conditions on the reefs.

CHAETOMORPHA Kützing

CHAETOMORPHA AEREA (Dillwyn) Kützing 1849, 379; 1853, t. 59. De Toni 1889, 272. Smith 1944, 56. Taylor 1937, 80. — *SB*. Lower littoral, as a mat on boulders, Jan. 1948. *HR*. In rock pools, Jan. 1949. *WB*. Lower littoral on rocks, Jan. 1946. *PB*. In rock pools, Jan. 1944. *CW*. In rock pools, Jan. 1948.

CHAETOMORPHA DARWINI (Hooker) Kützing 1849, 380. De Toni 1889, 271. *Conferva clavata* var. *darwinii* Hooker 1847, 187, pl. 192, f. 1. — *VB*. Sublittoral fringe on reefs in bay. *PB*. Sublittoral fringe on reefs. *CW*. Lower littoral, south side. All seasons. At *PB*, commonly epiphytic on *Zonaria spiralis*, *Halopteris pseudospicata*, *Cystophora paniculata* and *Ballia scoparia*.

CHAETOMORPHA LINUM (Mueller) Kützing. De Toni 1889, 269. Taylor 1937, 80. — *BS*. Upper sublittoral, June 1947.

CHAETOMORPHA VALIDA (Hooker and Harvey) Kützing 1849, 379. De Toni 1889, 274. *Conferva valida* Hooker and Harvey 1847, 416 — *AR*. Upper sublittoral on Rabbit Island and elsewhere in Pelican Lagoon and near Muston, not common, May 1947, Aug. 1948.

This agrees well with a specimen from Tasmania of *Conferva valida* H. & H. in Melbourne National Herbarium. The plant is dark green, forming rather coarse tangled masses, not readily collapsing out of water; filaments 350-450μ thick, cells mostly $1\frac{1}{2}$-$2\frac{1}{2}$ times as long as wide, slightly inflated. It is a distinctly more robust plant than *C. linum*, readily distinguished in the field.

SIPHONOCLADALES — VALONIACEAE

DICTYOSPHAERIA Decaisne

DICTYOSPHAERIA SERICEA Harvey 1860 b, 339, pl. 196 A. J. Agardh 1887, 118; 1896, 61. De Toni 1889, 371. — *MR*. Upper sublittoral, Jan. 1948. *WR*. Drift, Jan. 1946. *VB*. Pools of sublittoral fringe on reefs in bay, Jan. 1947, *PB*. Pools in sublittoral fringe on reefs, all seasons.

Siphonocladiaceae

APJOHNIA Harvey

Apjohnia laetevirens Harvey 1858, pl. 5. J. Agardh 1887, 108. De Toni 1889, 382. — *MR.* Drift, Jan. 1946. *CC.* Drift, Jan. 1948. *VB.* Drift, Jan. 1948, 1949 and in pools of sublittoral fringe on reefs in bay, Jan. 1948. *PB.* Drift, and in pools of sublittoral fringe, Jan. 1944, 1947, 1948. Specimens growing in pools in the sublittoral fringe are usually stunted, often with only the basal part developed.

STRUVEA Sonder

Struvea plumosa Sonder 1846, 151. Harvey 1858, pl. 32. De Toni 1889, 364. A single specimen from "North of Kangaroo Island, 1893." Collector and further details are unknown.

Boodleaceae

MICRODICTYON Decaisne

Microdictyon umbilicatum (Velley) Zanardini. Setchell 1929, 503. *Microdictyon agardhianum,* Harvey 1858, pl. 50. — *AR.* In *Posidonia* beds near Strawbridge Point, May 1945; drift, Dec. 1948. Apparently rare.

Dasycladaceae

ACETABULARIA Lamouroux

Acetabularia peniculus (R. Brown) Solms-Laubach 1895, 27. *Polyphysa peniculus* (R. Br.) Agardh. Harvey 1858, pl. 11. De Toni 1889, 421. — *AR.* Low littoral and upper sublittoral at head of the lagoons (dense in patches) and in Pelican Lagoon, all seasons. *BS.* Lower littoral, June 1947.

SIPHONALES — Bryopsidaceae

BRYOPSIS Lamouroux

Bryopsis baculifera J. Agardh 1887, 21. De Toni 1889, 428. — *VB.* Shaded end of pool 1, south side of Ellen Point, May 1945, Jan. 1949. *PB.* Shaded pool, rear littoral, main reef, Jan. 1948. Rare.

The few specimens collected have been sterile. They agree well in form and structure with cotype specimens of J. B. Wilson's in Melbourne National Herbarium except that the thallus of Wilson's specimens are nearly twice as wide (340-510μ against 120-350μ).

Bryopsis cupressoides Lamouroux. Kützing 1856, t. 79, f. 1. J. Agardh 1887, 29. De Toni 1889, 435 — *AR.* On buoys, Jan., Sept., 1946; upper sublittoral near American River jetty, July 1946. Best developed in winter. Dr. V. J. Chapman considers these plants are referable to *B. cupressoides,* though they seem to be softer plants with longer pinnules than those figured by Kützing.

Bryopsis plumosa (Hudsworth) Agardh. J. Agardh 1887, 24. De Toni 1889, 431. Setchell and Gardner 1920, 161, pl. 14, f. 1, 2. — *VB.* In rock pools, south side of Ellen Point, May 1945, Jan. 1947, 1948.

Derbesiaceae

DERBESIA Solier

Derbesia clavaeformis (J. Agardh) De Toni 1889, 425. *Bryopsis clavaeformis* J. Agardh 1887, 20. — *WB.* Drift, Jan. 1946. *PB.* Shaded pool, rear littoral, main reef, Jan. 1948. Rare. These specimens agree well with those of J. B. Wilson's in Melbourne National Herbarium. The WB specimen is rather thicker, but identical in form and position and size of zoosporangia.

Codiaceae

CODIUM Stackhouse

Codium galeatum J. Agardh 1887, 42, t. 1, f. 1. De Toni 1889, 494. Lucas 1936, 54. — *AR.* Upper sublittoral throughout the inlet, occasional, all seasons. *WB.* Drift, Jan. 1946. *VB.* Drift, Jan. 1946, 1948, 1949. *DB.* Sublittoral fringe on reef, Jan. 1947. *PB.* Drift, and in sublittoral fringe, all seasons. *RP.* Drift, and pools of lower littoral, all seasons. Most of the specimens placed under *C. galeatum* show a distinctly but moderately thickened top to the utricles. Some, such as those from American River, are very slightly thickened. Some specimens from Victor Harbour and other parts of the South Australian coast have extremely heavily thickened tops to the utricles, which tend to be narrower and contracted a short distance below the apex. All these specimens are identical in external form (stout plants, thallus 4-6 mm. wide), and the variation in utricle thickness between young and old parts of one specimen, and between different specimens, is very considerable. Even when most utricles are scarcely thickened at all, an occasional narrower one occurs with heavy apical thickening.

Although the extremes in utricle thickness are very distinct, and such characters have been largely used in segregation of species within the genus, it seems impossible to delimit the extremes as species or even varieties. On the other hand this may be an ecological variation, as plants with heavily thickened utricles seem to occur mainly in deep water on exposed coasts.

A slender dichotomous *Codium*, 2-3 mm. in thickness, and with very slight utricle thickening has been found in the drift at Pennington and Vivonne Bays. This may be another form of *C. galeatum*, or may prove to be a distinct species.

Codium lucasii Setchell in Lucas 1935, 200. Lucas 1936, 50. — *PB.* Rear littoral on an eastern reef, 1944. Rare.

Codium mamillosum Harvey 1854, 505; 1858, pl. 41. J. Agardh 1887, 39. De Toni 1889, 491. Lucas 1936, 52. — *RP.* Drift, June 1947, Aug. 1948. *EB, MR,* and *PB,* all drift, Jan. 1946. Apparently this species occurs only in the deeper sublittoral, sometimes very commonly in sheltered bays. Near Rocky Point enormous numbers of this species, *C. pomoides* and *C. spongiosum,* were cast up after a storm in June 1947.

Codium muelleri Kützing 1856, 34, t. 95, f. 2. J. Agardh 1887, 42. De Toni 1889, 493. *Codium schmidtii* Vouk 1935, 9, pl. 1. — *RP.* Drift, June 1947, Aug. 1948. *K.* Drift, Jan. 1948. This species is distinguished by the presence of hemispherical thickenings on the internal side of the apical membrane of the utricles. This was first recorded in Vouk's *Codium schmidtii* (from Busselton, Western Australia, and Lefevre Peninsula near Adelaide, South Australia, not New Caledonia as given by Vouk), but Setchell (1940, 444) pointed out the type specimen of *C. muelleri* Kützing shows the same feature although Kützing does not figure it. Cotype specimens of *C. muelleri* in Melbourne National Herbarium show the thickenings distinctly. The plants are slender (2-3 mm. wide) and soft, becoming flat and membranous on drying out.

Most specimens in Australian Herbaria named as *C. muelleri* do not show the internal thickening, and are not this species; some are probably forms of *C. galeatum.*

Codium perrinae Lucas 1935, 203, f. 4. — *DB.* Outer reef pools, Jan. 1950.

CODIUM POMOIDES J. Agardh 1894a, 100. Lucas 1936, 53. — *RP*. Drift, Jan. 1944, June 1947. *EB*. Drift, Jan. 1946. *VB*. Upper sublittoral at end of Ellen Point, Jan. 1946. *PB*. In rock crevices of sublittoral fringe on reefs, occasional, all seasons.

CODIUM SPONGIOSUM Harvey 1854, 565; 1858, pl. 55. J. Agardh 1887, 38; 1894a, 99. De Toni 1889, 489. Lucas 1936, 51. — *RP*. Drift, June 1947, Aug. 1948. *AR*. Upper sublittoral in Pelican Lagoon, all seasons, rare. *PB*. Drift, Jan. 1946. *AB*. Drift, Aug. 1948. Common in drift, near *RP* after storms.

RHIPILIOPSIS A. and E. S. Gepp

RHIPILIOPSIS PELTATA (J. Agardh) A. and E. S. Gepp 1911, 45, f. 118-122. *Udotea peltata* J. Agardh 1882, 74. De Toni 1889, 509. — *PB*. In shaded pools, rear littoral, Jan. 1947, 1948, 1949, also in deeper pools of sublittoral fringe, Jan. 1948, 1949. Not common.

CAULERPACEAE

CAULERPA Lamouroux

CAULERPA BROWNII Endlicher. J. Agardh 1872, 28. De Toni 1889, 468. W. v. Bosse 1898, 306. Lucas 1936, 42. — General in the lower littoral and sublittoral fringe within the exposed rocky coast formation (*MR*, west and south coasts to *AB*). Also drift from deeper water. All seasons, but often not common.

CAULERPA CACTOIDES (Turner) Agardh. Harvey 1858, pl. 26. De Toni 1889, 485. W. v. Bosse 1898, 390. Lucas 1936, 48. — *RP*. Drift, June 1947. *VB*. Drift, Jan. 1948. *PB*. Drift, Jan. 1944. Rare.

CAULERPA ETHELAE W. v. Bosse 1898, 384. *Caulerpa simpliciuscula* var. *vesiculifera* Harvey 1859, pl. 65, f. 3, 4. *Caulerpa vesiculifera* Harvey, Lucas 1936, 47. — *MR*. Upper sublittoral, Jan. 1948; drift, Jan. 1946. *WB*. Drift, Jan. 1945, 1946. *PB*. Drift, Jan. 1944, May 1945

This species has been commonly known as *C. vesiculifera*. W. v. Boose showed that Harvey included two algae in his var. *vesiculifera* of *C. simpliciuscula*, one of which is a loose form of that species, while the other has very much larger vesicles; this she renamed *C. ethelae*.

CAULERPA HEDLEYI W. v. Bosse 1910, 1-2. Lucas 1927b, 559; 1936, 43. — This species was "dredged in 8 fathoms off Kangaroo Island by the fisheries' trawler *Endeavour* in 1909." I have not collected it. The pinnate fronds are densely covered with minute, several times dichotomous, ramenta which are similar but slenderer on the surculus.

CAULERPA HYPNOIDES (R. Br.) Agardh. Harvey 1859, pl. 84. De Toni 1889, 470. W. v. Bosse 1898, 342. Lucas 1936, 44. — *AR*. Sublittoral near Muston, July 1947. *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1948. Sou'-West River mouth. Dec. 1934 (Cleland and Black). *VB*. Drift, Jan. 1949. *PB*. Pools on reefs, all seasons. *AB*. Drift, Aug. 1948. *RP*. Drift, June 1947, Aug. 1948.

var. MUELLERI (Sonder) W. v. Bosse 1898, 342. *Caulerpa muelleri* Sonder. Harvey 1858, pl. 2. — *MR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948, 1949. *PB*. Pools of sublittoral fringe, all seasons, but not common. *AB*. Drift, Jan. 1948.

CAULERPA LONGIFOLIA Agardh. J. Agardh 1872, 16. De Toni 1889, 455. *C. harveyi* F. v. Mueller in Harvey 1859, pl. 95. De Toni 1889, 455. Lucas

1936, 41. W. v. Bosse 1898, 299. — *WB.* Drift, Jan. 1946. *CC.* Drift, Jan. 1948. *VB.* Drift, Jan. 1948. *PB.* Drift, Jan. 1944, 1946. Only found in the sublittoral.

var. CRISPATA (Harvey) comb. nov.

C. harveyi var. *crispata* Harvey 1859, pl. 95. W. v. Bosse 1898, 300. *C. longifolia* Agardh in Lucas 1936, 38. *C. curvifolia* J. Agardh in Wilson 1892, 188 (nomen nudum). — *VB.* Under ledge in sublittoral fringe of reef in bay, Jan. 1947; drift, Jan. 1948. *PB.* In pools of sublittoral fringe on reefs, probably all seasons. Usually found in lower littoral or sublittoral fringe rock pools.

Considerable confusion has existed in the position of *C. longifolia* and *C. harveyi.* In Australian herbaria they have usually been regarded as distinct species, as did Lucas (1936). W. v. Bosse (1898, 299) examined the authentic (probably type) specimens of *C. longifolia* of C. Agardh, in the Paris Museum, and found it to be identical with *C. harveyi* F. v. M. W. v. Bosse conserved the name *C. harveyi* as Agardh's original diagnosis was slightly erroneous. There is, however, no provision for this in the Botanical Rules (1935), and the name must therefore revert to the earlier *C. longifolia* C. Agardh.

The var. *crispata* Harvey of *C. harveyi* F. v. M. has been commonly known in Australia as *C. longifolia* Ag. Most specimens are very distinct from typical *C. harveyi;* they are smaller, much less robust, and have the ramenta recurved inwards above and irregularly placed on the stem. Var. *crispata* is an inhabitant of rock pools, while *C. harveyi* (now *C. longifolia*) inhabits deeper water. From W. v. Bosse's description it appears that specimens of both *C. longifolia* and var. *crispata* are present on the type sheet.

Most specimens of var. *crispata* are very distinct from the species, but intermediate forms do occur, and Harvey claimed to have seen connecting stages between the deep water and rock pool forms. Several intermediate specimens occur in the algal collection of the Melbourne National Harbarium.

C. curvifolia J. Agardh from Port Philip (Wilson 1892, 188) is identical with var *crispata,* but is a nomen nudum as no description has ever been published. Several specimens of Wilson's are in the Melbourne National Herbarium.

CAULERPA OBSCURA Sonder 1846, 550. Harvey 1860b, 337. Kützing 1857, t. 17. W. v. Bosse 1898, 301. *C. sonderi* F. v. M. in Sonder 1852, 661. Harvey 1860a, pl. 167. De Toni 1889, 456. — AR. Sublittoral, near Muston, Jan. 1948. *RP.* Drift, June 1947. *WB.* Drift, Jan. 1946. *CC,* Drift, Jan. 1947, 1948. *VB,* Drift, Jan. 1948, 1949. *PB,* Drift, Jan. 1946. Only found in the sublittoral.

CAULERPA REMOTIFOLIA Sonder 1852, 660. Harvey 1859, pl. 107. W. v. Bosse 1898, 286. De Toni 1889, 448. — *AR.* Upper sublittoral throughout lagoons, especially at edge of channel and in deeper holes, all seasons. *K.* Drift, Jan. 1945. *CC.* Drift, Jan. 1948. This species shows great seasonal variation in density of the lateral pinnae along the branches. In summer (Dec.-April) the pinnae are few, sometimes completely absent. In winter more pinnae develop, until in late winter (Aug.-Oct.) they are sufficiently close to just overlap. Harvey's figure shows an intermediate stage. The alga occurs as dense intertwined masses, often 1-2 ft. across.

CAULERPA SCALPELLIFORMIS (R. Brown) C. Agardh. Harvey 1858, pl. 17. De Toni 1889, 449. W. v. Bosse 1898, 286. Lucas 1936, 34. — *CC.* Drift, Jan. 1948. *VB.* Sublittoral fringe of reef in bay, Jan. 1948, 1949. *PB.* Pools of sublittoral fringe, Jan. 1944, 1948.

CAULERPA SEDOIDES (R. Brown) C. Agardh. Harvey 1859, pl. 72. De Toni 1889, 480. W. v. Bosse 1898, 387. Lucas 1936, 47. — *AR*. In Posidonia beds near Strawbridge Point, May 1945. *MR*. and *WR*. Drift, Jan. 1946. *VB*. Sublittoral fringe of reef in bay, Jan. 1947. *PB*. Pools of sublittoral fringe on reefs, Jan. 1944, 1947, 1948.

CAULERPA SIMPLICIUSCULA (Turner) C. Agardh. Harvey 1859, pl. 65, f. 1, 2. De Toni 1889, 482. W. v. Bosse 1898, 377. Lucas 1936, 47. *BS*. (no data). PB. In pools of sublittoral fringe on reefs, all seasons.

var. VESICULIFERA Harvey 1859, descr. of pl. 65. W. v. Bosse 1898, 377. — *AR*. Upper sublittoral in lagoons, especially on edge of channel, all seasons.

Under *C. ethelae* I have commented that Harvey confused two plants under his var. *vesiculifera*. W. v. Bosse renamed one *C. ethelae* and kept a form with more loosely placed vesicles (but of similar size to those of the species) as var. *vesiculifera*.

CAULERPA TRIFARIA Harvey 1863, pl. 261. J. Agardh 1872, 16. De Toni 1889, 454. W. v. Bosse 1898, 299. Lucas 1936, 39. — South coast, collected by J. Cork, winter 1939 (probably drift). *VB*. Shaded end of pool 1, south side of Ellen Point, Jan. 1948 (No. A9469). *PB*. Shaded pools, rear littoral, main reef, Jan. 1948 (No. A7019). The specimens under A9469 and A7019 are 1″-2″ high and show two regular rows of ramenta, never three. They are morphologically identical with *C. sertularioides* (Gm.) Howe. (*C. plumaris* Forsk). However, specimens of *C. trifaria* sometimes have only two rows of ramenta in parts, and this may be a feature of juvenile plants (as the VB and PB specimens probably are). *C. trifaria* also differs from *C. sertularioides* in having spines on the surculus. These are absent in these specimens, but this again may be a feature of young *C. trifaria*. For the present I prefer to leave these specimens under *C. trifaria*, though the possibility of their being *C. sertularioides* cannot be excluded.

In the Herbarium of the University of Adelaide is a specimen (A96) collected by Dr. Englehart at Lacepede Bay in 1897, identified as *Caulerpa plumaris* var. *elegans* (see Reinbold 1897, 44). This is also recorded by Lucas 1936, 35. Underneath the specimen is written: "Examined and identified by Madame Weber van Bosse," probably in Reinbold's writing, as he dealt with Engelhart's collection generally. W. v. Bosse (294) states in a footnote that she made the determination and adds: "Ceci repose sur une erreur, car l'algue de M. Reinbold est le *C. plumaris*, mais un échantillon tres ramifie." The specimen, however, is a typical *C. trifaria*, with three rows of ramenta in most parts.

C. sertularioides is characteristic of tropical waters, and on geographical grounds it would be unlikely to occur along Southern Australia.

PHAEOPHYTA

ISOGENERATAE — ECTOCARPALES — ECTOCARPACEAE

ECTOCARPUS Lynghye

ECTOCARPUS CONFERVOIDES (Roth) Le Jolis. Setchell and Gardner 1925, 412. Taylor 1937, 109. May 1939, 537-554. — *AR*. Common throughout the inlet, growing epiphytically on other algae (especially *Hormosira*) in winter (June-October). *CC*. In a rock pool, Jan. 1944. *PB*. Common in the rear littoral, winter (May-Nov.).

PYLAIELLA Bory

PYLAIELLA FULVESCENS (Schousboe) Bornet 1889, 8, pl. 1, f. 1. De Toni 1895, 536. Borgesen 1920, 431, f. 408, 409. — *BH*. Mid littoral, east side, Jan.

1948. *PB*. Rear littoral, summer (Nov.-April). *CW*. In a rock pool, south side, August 1948. *HB*. In rock pools, Jan. 1944. *RP*. Low littoral, Jan. 1948.

SPHACELARIALES — Sphacelariaceae

SPHACELARIA Reinke

Sphacelaria biradiata Askenasy 1894, 15, pl. 2, f. 12. De Toni 1895, 507. Sauvageau 1914, 163-166. — *SB*. Drift, Jan. 1946. *MR*. Epiphytic on *Sargassum*, drift, Jan. 1946. *VB*. On *Cystophora subfarcinata* and *Cystophyllum muricatum* in littoral pools, south side of Ellen Point, Dec. 1945, Jan. 1946. *PB*. On stems of *Cystophora uvifera* and *Cystophyllum muricatum*, littoral on reefs, Nov. to Feb. (? all seasons).

Sphacelaria furcigera Kützing 1855, 27, t. 90. De Toni 1895, 506. Sauvageau 1914, 145-156. Taylor 1937, 129. — *PB*. On *Cystophora uvifera* and *Cystophyllum muricatum*, littoral, on reefs, all seasons.

Sphacelaria pygmaea Lenormand in Sauvageau 1914, 29-31. — *CC*. On *Carpoglossum confluens*, drift, Jan. 1948.

Sphacelaria tribuloides Meneghini. Kützing 1855, t. 89, f. 2. De Toni 1895, 502. Sauvageau 1914, 123-130. — *VB*. On *Myriodesma latifolia* var. *duriuscula* in littoral pools, south side of Ellen Point, Dec. 1945, Jan. 1946, 1947, 1948. Also in shaded part of pool 1, May 1945, Jan. 1946, 1948. *PB*. In mid littoral pools of western terraced reef, Jan. 1946.

Stypocaulaceae

HALOPTERIS Kützing

Halopteris funicularis Sauvageau 1914, 402-403. Dickinson 1933, 255, f. 2 (for ball forms). *Sphacelaria muelleri* Sonder 1853, 507. — *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1949.

Halopteris pseudospicata Sauvageau 1914, 411. — *BH*. Upper sublittoral, east side, Oct. 1947, Dec. 1948. *SB*. Drift, Jan. 1948. *MR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1947. *VB*. Drift, Jan. 1948, 1949. *PB*. In pools on reefs, upper sublittoral, all seasons. *CW*. Drift, Jan. 1946. *AB*. Upper sublittoral, Jan. 1947.

Halopteris hordacea (Harvey) Sauvageau 1914, 416-433. — *CW*. Drift. Jan. 1946. A single sexual plant.

Halopteris spicigera (Areschoug) Moore in Reports of the 7th Pacific Science Congress, 1950. *Sphacelaria spicigera* Areschoug 1854, 365. Sauvageau 1914, 418-420. — *BH*. Upper sublittoral, east side, Oct. 1947. *PB*. In a low littoral pool, just west of main reef, Dec. 1948, Jan. 1949 (fertile). *CW*. Drift, Jan. 1946.

PHLOEOCAULON Geyler

Phloecaulon spectabile Reinke 1890, 213. De Toni 1895, 520. Sauvageau 1914, 457-463. — *MR*. Drift, Jan. 1946, 1947. *WR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *PB*. Drift, Jan. 1944, May 1945, Jan. 1947, 1948. Also in pools of sublittoral fringe, main reef, Nov. 1947, Jan. 1948.

Cladostephaceae

CLADOSTEPHUS Agardh

Cladostephus verticillatus (Lightfoot) Agardh. De Toni 1895, 513. Lucas

1936, 105. Taylor 1937, 135, pl. 17, f. 9-11. — In the upper sublittoral zone within the Rocky Coast Formation, in well washed but not extremely rough places (often sandy), all seasons. Common at *RP, K, EB, MR, PB, CW, HB.*

CUTLERIALES — Cutleriaceae

CUTLERIA Greville

Cutleria multifida Greville. Kützing 1859, t. 45, f. 1. De Toni 1895, 302. Newton 1931, 197, f. 125. — *AR.* Sublittoral, on edge of channel, especially near Muston, Nov. 1947, Aug. 1948. On cockle bank near Strawbridge Point, Jan. 1949. *RP.* Drift on beach, Aug. 1948. This is mainly a late winter form, rarely seen in January. The thallus is mostly 2-3 mm. wide.

DICTYOTALES — Dictyotaceae

Dictyoteae

DICTYOTA Lamouroux

Dictyota apiculata J. Agardh 1894a, 67. De Toni 1895, 262. *D. dichotoma* Harvey, Alg. Aus. exs., n. 70 in part. — *BH.* Very low littoral, Dec. 1948. *VB.* Shaded part of the large littoral pool, south side of Ellen Point, Jan. 1949.

The terminal segments of *D. apiculata* are acute, not obtuse as in *D. dichotoma.* The VB specimens agree well with specimens of *D. apiculata* in Melbourne National Herbarium; the BH specimens are very similar but show a slight tendency for the tetrasporangia to become aggregated into sori.

Dictyota bifurca J. Agardh 1894a, 79. De Toni 1895, 279. — *RP.* Upper sublittoral, Jan. 1947, 1948. *BH.* Upper sublittoral, east side, Jan. 1947. These specimens agree well with Wilson's (cotypes?) in Melbourne National Herbarium.

Dictyota dichotoma (Huds.) Lamouroux. Harvey 1871, pl. 103, f. 1. J. Agardh 1882, 92; 1894a, 67. Newton 1931, 212, f. 134. Lucas 1936, 91, f. 51 — *BH.* Upper sublittoral, Oct. 1947. *CC.* Sublittoral fringe and lower littoral in the sheltered inlet, Jan. 1948. *CW.* Lower littoral, south side, Jan. 1946.

var. intricata (Agardh) Greville. Harvey 1871, pl. 103, f. 2. Papenfuss 1944, 338. — *AR.* Widely distributed in the upper sublittoral throughout the inlet, all seasons. *PB.* In sandy pool, main reef, Jan. 1945. Although this is a common alga in American River inlet, no fertile plants have yet been collected. It agrees very well, however, with Harvey's figure and specimens from Europe.

Dictyota diemensis Sonder in Kützing 1859, 14, t. 34. De Toni 1895, 266. J. Agardh 1882, 97; 1894a, 69. *D. naevosa*, Harvey 1862, pl. 186. — *BH.* Drift, Dec. 1948. *WR.* Drift, Jan. 1946. *VB.* In shaded part of the large littoral pool, south side of Ellen Point, and drift, Jan. 1949. *PB.* Drift, Jan. 1948.

These specimens agree well with the figures of Kützing and Harvey, although the fronds are narrower. A few specimens have ill-defined sori.

Dictyota furcellata Agardh. J. Agardh 1848, 90; 1894a, 80. De Toni 1895, 280. Not *D. furcellata* Harvey. — *RP.* Upper sublittoral, Jan. 1948. *BH.* Upper sublittoral, Jan. 1948. This species is regularly dichotomous, in contrast to the more lateral branching of *Pachydictyon furcellatum*

(*D. furcellata* of Harvey). Older parts of the thallus are typically *Dictyota* in section. Our specimens agree well with some in Melbourne National Herbarium.

DICTYOTA LATIFOLIA J. Agardh 1894a, 65. De Toni 1895, 261. Lucas 1936, 90. — *WB.* Drift, Jan. 1946. *CC.* Drift, Jan. 1948. *VB.* Drift, Jan. 1946, 1948, 1949. *PB.* Drift, Jan. 1944, May 1945, Jan. 1946, 1947, 1948.

An extensive range of specimens, undoubtedly belonging to the one species, has been examined, and they show considerable variation in characters which are accepted as being of generic significance in the Dictyotaceae.

The thallus width ranges from 1 to 5 cm., the number of dichotomies from 1 to 4 or 5. The small surface proliferations densely cover well developed fronds, but the upper parts and older fronds are often largely or almost completely denuded. The transverse section of the thallus in most specimens is that of *Dictyota*. Old parts of A3299f, however, show two rows of internal cells, though only one in younger parts (c.f., *Dilophus*). The tetrasporangia and sexual sori in most specimens are scattered over the thallus but not on the proliferations. Some specimens (*e.g.*, A3299d) show sporangia on both thallus and proliferations, while in others (A3299a and f) they are only on the proliferations (c.f. *Glossophora*). Similar variations have been observed in specimens of this species in Melbourne National Herbarium. Kützing (1859, 6, t. 12, f. 1) described a *Dictyota latifolia* from the Atlantic which has been relegated to a synonym of *D. dichotoma* (see De Toni). As J. Agardh's *D. latifolia* was described in 1894, his name is invalid, and if the species is to be maintained it must be renamed.

J. Agardh 1882, 94, described *D. nigricans*, which differs from *D. latifolia* J. Ag. mainly in degree of branching. Specimens of these two species in Melbourne National Herbarium (some were probably named by J. Agardh) are very doubtfully distinct. The degree of branching is variable, and specimens under both names show the variation in cellular structure described above. If the two species are to be combined, *D. nigricans* has priority and appears to be a valid name. In showing very few dichotomies, the Kangaroo Island specimens are of the *D. latifolia* form.

Until the type specimens of *D. latifolia* J. Ag. and *D. nigricans* J. Ag. can be re-examined, in light of the above remarks, it seems best to leave the position as it is, rather than renaming *D. latifolia* J. Ag. and adding a name to the literature which may have to be relegated to the synonym of *D. nigricans* later.

DICTYOTA RADICANS Harvey 1854, 536; 1859, pl. 110. Kützing 1859, t. 36, f. 2. J. Agardh 1882, 92; 1894a, 74. De Toni 1895, 273. Lucas 1936, 91. — *WB.* Drift, Jan. 1946. *VB.* Drift, Jan. 1949. *PB.* Drift, Jan. 1944, 1948.

PACHYDICTYON J. Agardh

PACHYDICTYON FURCELLATUM (Harvey) J. Agardh 1894a, 83. De Toni 1895, 282. *Dictyota furcellata*, Harvey 1858, pl. 38 (not *D. furcellata* Ag.). — *EB.* Upper sublittoral, on *Posidonia*, Jan. 1945, 1946. *AB.* Drift, Jan. 1945. Harvey, in describing *D. furcellata*, recognised that some specimens show characters intermediate between this species and *P. paniculatum*. The main distinction lies in the wider and more robust frond of *P. paniculatum*. Most specimens are quite distinct, but some intermediate forms are very difficult to place. Harvey doubted whether his plant was distinct from *Dictyota minus* Sonder, but from specimens of Sonder's in Melbourne National Herbarium *D. minus* is probably identical with *P. paniculatum*.

In his description Harvey referred to, and figured, "spores" which he thought might be antheridia. A specimen of Harvey's No. 67B in Melbourne National Herbarium shows the structures figured by Harvey. They are not reproductive organs but intracellular thickenings. Fig. 1 shows their characteristic form. I have observed similar thickenings in occasional specimens of *Dictyota dichotoma* and *Dilophus fastigiatus* also.

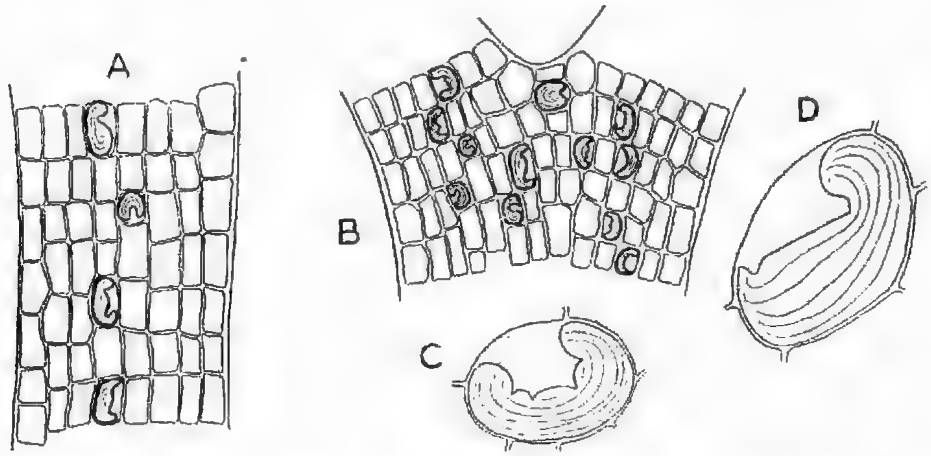

Fig. 1
Intracellular inclusions in some Dictyotaceae, as seen lying in the medullary cells (cortical cells not shown). A. In Harvey's specimen of *Pachydictyon furcellatum*. B. In a specimen of *Dictyota dichotoma*. C and D. Two typical inclusions.

PACHYDICTON PANICULATUM J. Agardh 1894a, 84. De Toni 1895, 283. De Toni and Forti, 1923, 73, pl. 8, f. 8. Levring 1946, 218, f. 3. — *BH*. Upper sublittoral, Jan. 1948, 1949. *EB*. Upper sublittoral, Jan. 1945. *WR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1945, 1946. *CC*. Drift, Jan. 1944, 1947, 1948. *VB*. In the large littoral pool, south side of Ellen Point, and drift, probably all year. *PB*. Pools of sublittoral fringe, all seasons. *CW*. In rock pools, Aug. 1948, and drift, Jan. 1946, 1947. *AB*. Upper sublittoral, Jan. 1947. *RP*. Upper sublittoral, Jan. 1948. Probably present in all seasons in the upper sublittoral and low rock pools within the Rocky Shore Formation.

DILOPHUS J. Agardh

DILOPHUS FASTIGIATUS (Sonder) J. Agardh 1882, 107; 1894a, 92. De Toni 1895, 288. *Dictyota fastigiata* Sonder 1846, 155. Harvey 1859, pl. 82. — *MR*, *WR*, and *WB*, all drift, Jan. 1946. *CW*. In a rock pool, south side, Jan, 1948.

DILOPHUS FOLIOSUS J. Agardh 1894a, 94. De Toni 1895, 290. — *BH*. Drift, Dec, 1948. *MR*. Drift, Jan. 1946. — J. Agardh placed *D. foliosus* in the section Marginatae, with two rows of internal cells in the median part and four at the edges. The BH specimens show one row of internal cells and two at the edges in the youngest parts, with the number of rows increasing in older parts to four rows all through, the margin being very slightly if at all thicker. In the presence of small proliferations, general form and position of sori they closely resemble some of Wilson's specimens of *D. foliosus* in Melbourne National Herbarium. Wilson's specimens also vary in number of rows of internal cells.

DICTYOPTERIS Lamouroux

Dictyopteris nigricans Womersley 1949, 115, f. 1, pl. 22, f. 2. — *WB*. Drift, Jan 1946. *VB*. In pools on reefs in the bay, Jan. 1948, drift, Jan. 1948, 1949. *PB*. In pools of the sublittoral fringe and calmer parts of the reefs, all seasons. (Previously reported in Pt. II as *D. acrostichoides*?)

Dictyopteris muelleri (Sonder) Schmidt 1938, 218. *Haliseris muelleri* Sonder 1852, 665. Harvey 1860a, pl. 180. De Toni 1895, 255. Lucas 1936, 89, f. 49a. — *MR*. Drift, Jan. 1946. *VB*. In shaded parts of large littoral pool south side of Ellen Point, Jan. 1949. *PB*. Drift, Jan. 1944, 1946, 1948. *AB*. Drift, Aug. 1948.

LOBOSPIRA Areschoug

Lobospira bicuspidata Areschoug 1854, 364. Harvey 1858, pl. 34. De Toni 1895, 292. J. Agardh 1894a, 98. Lucas 1936, 93. — *BH*. Upper sublittoral, Dec. 1948. *MR*. Drift, Jan. 1946. *WR*. Drift, Jan. 1946. *HR*. In a low rock pool, Jan. 1949. *WB*. Drift, Jan. 1945, 1946. *VB*. In large littoral pool, south side of Ellen Point, Jan. 1947, 1949; drift, Jan. 1949. *PB*. Pools of sublittoral fringe and drift, all seasons. *CW*. Drift, Jan. 1946.

Zonarieae

CHLANIDOPHORA J. Agardh

Chlanidophora microphylla (Harvey) J. Agardh 1894a, 18, t. 1, f. 3-5. De Toni 1895, 238. Lucas 1936, 87. Levring 1940, 2. *Zonaria microphylla* Harvey 1862, pl. 195. — *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1949. *PB*. Drift, Jan. 1949.

POCOCKIELLA Papenfuss

Pocockiella variegata (Lamouroux) Papenfuss 1943, 467, f. 1-14. *Gymnosorus variegatus* (Lamour). J. Agardh 1894a, 11, pl. 1, f. 1-2. De Toni 1895, 227. — *MR*. Drift, Jan. 1946. *VB*. Shaded end of pool 1, south side of Ellen Point, Jan. 1947. *PB*. In pools of sublittoral fringe on reefs, Jan. 1947, 1948 (as *Gymnosorus* in Pt. II). *RP*. Drift, Jan. 1944, June 1947.

TAONIA J. Agardh

Taonia australasica J. Agardh 1894a, 30. De Toni 1895, 242. Lucas 1936, 87. — *BH*. Upper sublittoral, Oct. 1947, and drift, Dec. 1948. *CC*. Drift, Jan. 1948. These specimens agree very well with Agardh's description, and certainly belong to *Taonia*. In Melbourne National Herbarium there are no specimens of Wilson's under this name, but some labelled *Taonia atomaria* which are identical with the Kangaroo Island specimens. These are probably authentic specimens of *T. australasica*, and had been originally referred to by Agardh to *T. atomaria*. *T. australasica* resembles *T. atomaria* in form, but is a much smaller plant (4-8 cm. high).

Spatoglossum australasicum Kützing 1859, t. 48, which J. Agardh doubtfully refers to his *T. australasica*, is a quite distinct plant. Cotype (and probably type) specimens are in the Melbourne National Herbarium.

ZONARIA Agardh

Zonaria crenata J. Agardh 1872, 48; 1894a, 13. De Toni 1895, 230. Lucas 1936, 86. — *MR*. Drift. Jan. 1948. *VB*. Drift, Jan. 1946. *PB*. Drift, May 1945, Jan. 1947, 1948. *CW*. Drift, Jan. 1947. *AB*. Drift, Aug. 1948.

Zonaria diesingiana J. Agardh 1848, 109; 1872, 46; 1894a, 13. De Toni 1895, 229. Lucas 1936, 86. Levring 1946, 216, f. 1. — *SB*. In littoral pools, Jan. 1948. *PB*. In pools of sublittoral fringe, main reef, Dec. 1948. The SB specimens show concentric zones of long hairs on one surface. Germinating spores had apparently become entangled in the hairs, forming numerous young plants which appeared like proliferations.

Zonaria spiralis (J. Agardh) Papenfuss 1944, 341. *Homoeostrichus spiralis* J. Agardh 1894b, 89. De Toni 1895, 237. Lucas 1936, 86. — *MR*. Drift, Jan. 1948. Rock pools, Jan. 1946. *HR*. In rock pools, Jan. 1949. *VB*. Drift, Jan. 1948, 1949; sublittoral fringe in bay, Jan. 1947. *PB*. In pools of sublittoral fringe on reefs, and drift, all seasons. *CW*. Lower littoral, east side, Jan. 1946.

I am in full agreement with Papenfuss in not recognising *Homoeostrichus* as distinct from *Zonaria*. The "twinning" of cortical cells in both *Z spiralis* and *Z. stuposa* is very variable. Most specimens of *Z. spiralis* are readily distinguished from *Z. subarticulata*, but intermediate specimens with only slight spirality of the upper parts of the thallus occur, and are difficult to place.

Zonaria stuposa R. Brown in Kützing 1849, 564. J. Agardh 1872, 50. *Homoeostrichus stuposus* (R. Br.) J. Agardh 1894a, 15. De Toni 1895, 236. Lucas 1936, 86. — *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1944, 1946, 1947, 1948 (as *Homoeostrichus* in Pt. II, 161).

Zonaria subarticulata (Lamouroux) Papenfuss 1944, 339. *Z. turneriana* J. Agardh 1872, 48; 1894a, 14. De Toni 1895, 232. Lucas 1936, 86. *Z. interrupta*, Harvey 1862, pl. 190. — *MR*. Drift, Jan. 1946, 1948; lower rock pools, Jan. 1946. *VB*. Drift, Jan. 1948, 1949; sublittoral fringe on reefs in bay, Jan. 1947. *PB*. Drift, May 1945, and sublittoral fringe on reefs, all seasons. *AB*. Drift,Jan. 1948, Aug. 1948; low littoral, Jan. 1945, 1947, 1948. Very variable in size, and usually stunted when in the sublittoral fringe. This was reported in Pt. I, as *Z. turneriana*.

HETEROGENERATE — CHORDARIALES — Myrionemataceae

MYRIONEMA Greville

Myrionema strangulans Greville. Kützing 1857, t. 93, f. 1. De Toni 1895, 399. De Toni and Forti 1923, 78. Setchell and Gardner 1925, 471, pl. 40, f. 51. Smith 1944, 106, pl. 15, f. 5. *M. leclancheri*, Harvey 1863, Syn. No. 134. — *AR*. Epiphytic on *Ulva lactuca*, upper sublittoral on Shag Rock in Pelican Lagoon, July 1947. Harvey recorded this species as *M. leclancheri* from Georgetown, Tasmania. De Toni and Forti also refer Harvey's specimens to *M. strangulans*.

Corynophlaeaceae

CORYNOPHLAEA Kützing

Corynophlaea cystophorae J. Agardh 1882, 22, t. 1, f. 1. De Toni 1895, 421. Lucas 1936, 102. — *WR*. On *Cystophora spartioides* in the upper sublittoral, Jan. 1946. *CC*. On *Cystophora intermedia* in sublittoral fringe, Jan. 1945. *PB*. On *Cystophora intermedia* Jan. 1945, 1947, 1948 and *Cyst. siliquosa*, Nov. 1947, in sublittoral fringe. Often very dense on these species of *Cystophora* where aeration is high. Kuckuck (1929, 40) refers this species to *Myriactis* as *M. cystophorae* (J. Ag.) Kuckuck.

CHORDARIACEAE

CLADOSIPHON Kützing

CLADOSIPHON FILUM (Harvey) Kylin 1940, 29. *Mesogloia filum* Harvey 1854, 536. *Bactrophora filum* (Harv.) J. Agardh 1882, 24, t. 1, f. 4. De Toni 1895, 409. — *MR*. Low littoral, west side, Jan. 1947. *VB*. Littoral on reefs in bay, Jan. 1947. *PB*. Littoral on reefs, Jan. 1944, 1946, 1948, Nov. 1947. *AB*. Littoral pools, Jan. 1945.

The thallus is usually simple or sub-simple, with a few branches from a common base. Some MR specimens show numerous lateral "proliferations", but all grades to the simple forms occur in the same area.

CLADOSIPHON VERMICULARIS (J. Agardh) Kylin 1940, 30, t. 5, f. 12. *Bactrophora vermicularis* J. Agardh 1882, 25. De Toni 1895, 409. — *MR*. Drift, Jan. 1946. *CC*. Mid littoral, Jan. 1948. *PB*. Pools on main reef, Jan., Dec. 1947.

MYRIOGLOIA Kuckuck

MYRIOGLOIA SCIURUS (Harvey) Kuckuck 1929, 63, f. 81. Kylin 1940, 12, f. 8A. *Myriocladia sciurus* Harvey 1858, pl. 58. J. Agardh 1882, 19. — *WB*. Littoral on a small reef near beach, Jan. 1946.

POLYCEREA J. Agardh

POLYCEREA NIGRESCENS (Harvey) Kylin 1940, 36, f. 20 A-B, t. 7, f. 16. *Cladosiphon nigrescens* Harvey, Alg. Aus. exs. n. 94. Kützing 1859, t. 1. Kuckuck 1929, 58, f. 73, 74. *Cladosiphon nigricans* Harvey 1860b, 292. *Polycerea ramulosa* J. Agardh 1882, 48, t. 3. f. 3. — *AR*. Upper sublittoral on cockle bank, Jan. 1946. *BH*. Drift, Jan. 1948. *EB*. Drift, Jan. 1946. *WR*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948, 1949, and upper sublittoral in the bay, Jan. 1946. *PB*. Drift, Jan. 1947, 1948.

POLYCEREA ZOSTERICOLA (Harvey) Kylin 1940, 37, t. 7, f. 17. *Cladosiphon zostericola* Harvey 1863, Syn No. 130. Kützing 1859, t. 1. J. Agardh 1882, 43. Kuckuck 1929, 58, f. 75. — *MR*. Drift, Jan. 1946. *VB*. Drift, Jan. 1949. *AB*. Drift, Jan. 1948.

These two species of *Polycerea* are very similar in habit, and both grow on *Posidonia* in similar localities. The figures of Kuckuck illustrate well the differences between them, *P. nigrescens* having large inflated terminal cells on the assimilatory filaments, while *P. zostericola* has not. J. Agardh's figure (1882, t. II, f. 3a) of *P. zostericola* is incorrect in this respect.

TINOCLADIA Kylin

TINOCLADIA AUSTRALIS (Harvey) Kylin 1940, 34, t. 6, f. 14. *Liebmannia australis* Harvey 1860b, 291. Alg. Aus. exs., Nr. 88. *Eudesme australis* J. Agardh 1882, 32. — *VB*, Drift, Jan. 1948.

SPERMATOCHNACEAE

STILOPSIS Kuckuck

STILOPSIS HARVEYANA Kylin 1940, 50, t. 8, f. 22. *Stilophora lyngbyei* Harvey Alg. Aus. exs. Nr. 65; 1863, Syn n. 118 — *AR*. Upper sublittoral in Pelican Lagoon, May 1945, Nov. 1947.

SPLACHNIDIACEAE

SPLACHNIDIUM Greville

SPLACHNIDIUM RUGOSUM (Linn.) Greville. Harvey 1858, pl. 14. Kützing 1860, t. 8. Lucas 1936, 83. Kylin 1940, 55. — *CC* Mid littoral, Jan. 1945, *VB*. Upper littoral, south side of Ellen Point, Jan. 1946. *PB*. Upper littoral, Jan. 1944 (very rare). *CW*. Upper littoral, Jan. 1946, 1947, 1948 (common, on granite rock).

SPOROCHNALES — Sporochnaceae

SPOROCHNUS Agardh

Sporochnus harveyanus J. Agardh 1896, 32. *Sporochnus comosus*, Harvey 1859, pl. 104 (not C. Agardh). — *MR*. Drift. Jan. 1946. *WB*. Drift, Jan. 1946. *PB*. Drift, Jan. 1947, Aug. 1948 (as *Sp. comosus* in Pt. II, 161). Examination of a range of specimens may show *Sp. harveyanus* is not distinct from *Sp. comosus* C. Agardh.

Sporochnus radiciformis (R. Brown) Agardh. Harvey 1862, pl. 225. De Toni 1895, 382. Lucas 1936, 100. — *CC*. Drift, Jan. 1948. *VB*. Shaded part of large littoral pool, south side of Ellen Point, Jan. 1949.

Sporochnus scoparius Harvey 1854, 535; 1862, pl. 226. De Toni 1895, 383. Lucas 1936, 100. — *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1946, 1947. *CW*. Drift, Jan. 1946.

Sporochnus radiciformis and *Sp. scoparius* may well be forms of one species. *Sp. scoparius* is a more robust plant, usually with a prominent main stem; *Sp. radiciformis* is less robust, usually with several slender stems from near the base. Harvey separated them on robustness, angle of branching (wider in *Sp. radiciformis*) and form of receptacles. The slight differences in these features are of doubtful specific distinction, depending on the age of the plant, state of development of receptacles, and habitat.

Kützing's species *Sp. sphaerocephalus*, *Sp. obovatus* and *Sp. cryptocephalus* belong to the *radiciformis-scoparius* complex, and are doubtfully distinct species.

ENCYOTHALIA Harvey

Encyothalia cliftoni Harvey 1859, pl. 62. De Toni 1895, 379. Lucas 1936, 99, f. 55. — *PB*. Drift, Jan. 1944, May 1945, Jan. 1946, 1947.

BELLOTIA Harvey

Bellotia eriophorum Harvey 1859, pl. 69; 1860b, 288, t. 187, f. 1-3. De Toni 1895, 377. Lucas 1936, 97, f. 54. — *MR*. Drift, Jan. 1946. *WR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1947, 1948, 1949. *PB*. Drift, Jan. 1946, 1948, 1949.

PERITHALIA J. Agardh

Perithalia inermis (R. Brown) J. Agardh 1890, 4. De Toni 1895, 378. Lucas 1936, 100. *Carpomitra inermis*, Harvey 1862, pl. 238. — *MR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1947. *VB*. Drift, May 1945, Jan. 1946, 1949. *PB*. Two to three feet over edge of main reef (and probably deeper), all seasons.

NEREIA Zanardini

Nereia australis Harvey 1860b, 289, pl. 187. *Stilophora ? australis* Harvey 1844, 453; Alg. Aus. exs., n. 66. J. Agardh 1848, 86. — *VB*. Drift, Jan. 1948. *PB*. Drift, Jan. 1948.

CARPOMITRA Kützing

Carpomitra costata Batters. Newton 1931, 137, f. 84. *C. cabrerae* Kützing 1849, 569; 1859, t. 89, f. 1. Harvey 1871, pl. 14. — *CW*. Drift, Jan. 1946.

DICTYOSIPHONALES — Punctariaceae

ASPEROCOCCUS Lamouroux

Asperococcus bullosus Lamouroux. De Toni 1895, 493. Newton 1931, 172, f. 107. Lucas 1936, 104. Kylin 1947, 75, t. 11, f. 38. *A. turneri,* Harvey 1871, pl. 11; 1863, Syn. n. 119. — *AR.* In the upper sublittoral throughout the inlet, usually epiphytic on *Posidonia,* all seasons. In summer the plants are 2-5 cm. high, increasing in size in late winter (Aug.-Nov.) to up to 60 cm. high and 10 cm. wide, and then becoming very common in the *Posidonia* beds. *MR.* Drift, Jan. 1946. *AB.* Drift, Jan. 1948.

COLPOMENIA Derbes and Solier

Colpomenia sinuosa (Roth) Derbes and Solier. De Toni 1895, 489. Setchell and Gardner 1925, 539, pl. 45, f. 82-86. Lucas 1936, 103. Smith 1944, 128, pl. 20, f. 1. *A. sinuosus,* Harvey 1863, Syn. N. 120. — *AR.* Upper sublittoral in the lagoons, mainly winter (Aug.-Nov.), with small plants on the buoys most of the year. *EB.* Lower littoral on rocks, Jan. 1945. *MR.* Lower littoral, Jan. 1947. *WR.* Drift, Jan. 1946. *PB.* In the sublittoral fringe and littoral on reefs, Jan., Aug. 1948.

HYDROCLATHRUS Bory

Hydroclathrus clathratus Bory. Setchell and Gardner 1925, 543. *H. cancellatus,* Harvey 1859, pl. 98. De Toni 1895, 490. Lucas 1936, 103. — *AR.* On red buoy, Dec. 1948. *EB.* Drift, Jan. 1946. *MR.* Drift, Jan. 1946. *AB.* Drift, Jan. 1948.

SCYTOSIPHON Agardh

Scytosiphon lomentaria (Lyngbye) J. Agardh. De Toni 1895, 485. Setchell and Gardner 1925, 531, pl. 44, f. 72, 74. Newton 1931, 178, f. 111. Lucas 1936, 103. Smith 1944, 129, pl. 19, f. 1. — *AR.* On *Posidonia,* upper sublittoral, and on the buoys, winter (July-Nov.). *MR.* In rock pools, Jan. 1946. *PB.* In pools and on rock in rear littoral, Jan. 1944, May 1945, Sept. 1946, Nov. 1947.

LAMINARIALES — Lessoniaceae

MACROCYSTIS Agardh

Macrocystis pyrifera (Linn.) Agardh. De Toni 1895, 372. Setchell and Gardner 1925, 627, pl. 64, 65. Lucas 1936, 95, f. 53. Smith 1944, 144, pl. 31, f. 3-4. — *PB.* Drift, Jan. 1944. Several fragments which may have drifted from some distance away. No beds exist along the coast as far as is known.

Alariaceae

ECKLONIA Horneman

Ecklonia radiata (Agardh) J. Agardh. De Toni 1895, 354. Lucas 1936, 95, f. 52. Papenfuss 1944, 341. — *MR.* Upper sublittoral. *CC.* Sublittoral fringe in sheltered inlet and more exposed parts. Sou'-West River mouth. Dec. 1934 (Cleland and Black). *VB.* Drift. *PB.* In the sublittoral fringe on reefs, occasional. *CW.* Upper sublittoral, east side, occasional. *RP.* Upper sublittoral, common. Present in all seasons in all localities.

Papenfuss (1940, 210) considers that *E. biruncinata* (Bory) Pap., (*E. exasperata* (Turner) J. Agardh) and *E. richardiana* J. Ag. are specifically distinct from *E. radiata,* being separated on form and presence of marginal and surface spines. Degree of spininess and form are, however, both very variable features, depending on habitat, and in South Australia all the above species must be combined. At Cape Coudie, in a small inlet (50 metres long by 5-10 metres wide), relatively sheltered at the inner end and exposed at the outside, gradations in spininess and form are found. Sheltered plants are simple, consisting of a main elongate lamina with small marginal outgrowths, but no spines. In rougher parts a few marginal spines appear, and in the rough condtiions at the end of the channel spines densely cover the surface and edges, the plants being dense and stout.

These variations can only be regarded as ecological forms of the one species, and in view of the gradations between them it seems useless to give them even varietal names. Stephenson (1948, 284) has come to a similar belief concerning the South African forms of this species. I suspect that *E. lanciloba* Sonder is only another form of *E. radiata.*

CYCLOSPORAE — FUCALES — NOTHEIACEAE

HORMOSIRA Endlicher

HORMOSIRA BANKSII (Turner) Decaisne. Harvey 1860a, pl. 135. De Toni 1895, 187. Lucas 1936, 80. Osborn 1948, 47-71. — *AR*. Lower littoral throughout the inlet. *BH*. Lower littoral. *MR* and *WR*. Low rock pools. *VB*. Lower littoral on reefs in bay. *PB*. Lower littoral on reefs. *RP*. Lower littoral. Present in all seasons and likely to be found anywhere around the island except in very rough places on steep rock. *H. banksii* shows a variety of ecological forms. On the whole each form is characteristic of a particular habitat, but gradations between them occur in intermediate habitats. The following forms occur around Kangaroo Island.

f. *labillardieri* (Bory) Harvey. American River Inlet.
f. *sieberi* (Bory) Harvey. Pools and reefs on north-west and south coasts.
f. *pumila* Sonder (in Kützing 1860, t. 4, f. 2). Rocky Point and Ballast Head.

NOTHEIA Bailey and Harvey

NOTHEIA ANOMALA Bailey and Harvey. Harvey 1862, pl. 213. De Toni 1895, 224. Lucas 1936, 82, f. 48. — *VB*. On *Hormosira banksii* on reefs in bay. *PB*. On *H. banksii* on reefs. All seasons. *Notheia* is usually parasitic on *Hormosira banksii*, but has only been found on f. *sieberi* on reefs on the south coast, where wave action is strong.

FUCACEAE

MYRIODESMA Decaisne

MYRIODESMA INTEGRIFOLIA Harvey 1860b, 286, pl. 186. J. Agardh 1890, 6; 1894b, 92. De Toni 1895, 191. Lucas 1936, 79, f. 47. — *VB*. Drift, Jan 1948, 1949. *PB*. Drift, Jan. 1948.

MYRIODESMA LATIFOLIA Harvey var. DURIUSCULA J. Agardh. Harvey 1858, pl. 24 (for species). J. Agardh 1894b, 92. De Toni 1895, 192. — *CC*. Drift, Jan. 1948. *VB*. In shaded parts of large rock pools, south side of Ellen Point, Jan. 1945, 1949.

MYRIODESMA QUERCIFOLIUM (Bory) J. Agardh 1848, 192; 1890, 7; 1894b, 93. De Toni 1895, 193. — South-West River mouth. Drift, Jan. 1945. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, 1944, 1946, 1947, Dec. 1948 (as *M. calophyllum* in Pt. II, 161). J. Agardh (1894b, 94) described *M. calophyllum* from Port Phillip (J. B. Wilson), differing from *quercifolium* in having an entire (not spinous) margin. The Kangaroo Island specimens are mostly entire, sometimes with one or two small marginal spines. Most of the specimens in Melbourne National Herbarium under *M. quercifolium* and *M. calophyllum* are entire, some with a few marginal spines. Without examining the type material, together with a range of specimens, it is difficult to judge whether these two species are distinct or not, but I suspect they are not. *M. quercifolium* has been recorded generally in the Southern Australian region, and the type locality is somewhere in this region. Should *M. calophyllum* prove to be distinct from *M. quercifolium*, the Kangaroo Island specimens will probably belong to the former.

SCYTOTHALIA Greville

SCYTOTHALIA DORYCARPA (Turner) Greville. Harvey 1858, pl. 9. De Toni 1895, 132. Lucas 1936, 69, f. 42. — *WR*. Drift, Jan. 1946. Sou'-West River mouth. Drift, Jan. 1945. *VB*. In shaded part of the large littoral pool, south side of Ellen Point, Dec. 1945, Jan. 1948, and drift, May 1945, Jan. 1949. *PB*. Sublittoral fringe on reefs, all seasons.

SEIROCOCCUS Greville

SEIROCOCCUS AXILLARIS (Turner) Greville. Harvey 1858, pl. 4. De Toni 1895, 131. Lucas 1936, 68, f. 41. — *MR*. Drift, Jan. 1946. *PB*. Drift, Jan. 1946, 1948, June 1947. *CW*. Drift, Jan. 1946.

XIPHOPHORA Montagne

XIPHOPHORA CHONDROPHYLLA (R. Brown) Montagne var. MINUS J. Agardh. De Toni 1895, 213. Heine 1932, 558, pl. 17, f. 2, 3. Lucas 1936, 81. — *MR*, *WR*, *CW* and *AB*. Growing in patches in the upper sublittoral, probably all seasons. *PB*. Small patches in the *Cystophora*-coralline association on the main reef, all seasons.

This species was at first confused with *Acrotylus australis* (see correction in Pt. II). It grows to 8 or 12 cm. high, and has rarely been found fertile. Kangaroo Island is probably the extreme west of the geographic range of var. *minus*.

CYSTOSEIRACEAE

CARPOGLOSSUM Kützing

CARPOGLOSSUM CONFLUENS (R. Brown) Kützing. Harvey 1860a, pl. 159. De Toni 1895, 182. Lucas 1936, 78, f. 46. — *MR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *VB*. Drift, May 1945, Jan. 1948, 1949. *PB*. Drift, Jan. 1944, May 1945, Jan. 1948. Only found in the sublittoral.

CYSTOPHORA J. Agardh

Some authors have used the generic name *Blossevillea* Decaisne. *Cystophora* J. Agardh appears in the "Nomina Generica conservanda proposita" of the 1935 edition of the International Rules, and it is to be hoped this well-known name will be adopted at the next Botanical Congress.

CYSTOPHORA BOTRYOCYSTIS Sonder 1852, 670. Harvey 1858, pl. 56. De Toni 1895, 144. Lucas 1936, 72. — *RP*. Drift on beach near AR inlet, Jan. 1944, May 1945, June 1947, Aug. 1948 (probably growing in several meters in Eastern Cove). *EB*. Drift, Jan. 1946.

CYSTOPHORA BROWNII (Turner) J. Agardh. Harvey 1860a, pl. 169. De Toni 1895, 146. Lucas 1936, 73. — *MR*. In littoral pools and upper sublittoral, Jan. 1946, 1948. *VB*. In large littoral pool, south side of Ellen

Point, all seasons. *PB.* In littoral pools on a reef, Jan. 1947, and drift, June 1947

CYSTOPHORA CEPHALORNITHOS (Labilladiere) J. Agardh. Harvey 1859, pl. 116. De Toni 1895, 138. Lucas 1936, 70. — *AR.* Upper sublittoral at head of lagoons, Jan. 1948 (probably all seasons), and drift near American River jetty, June 1947. Not common. *K.* Drift, Jan. 1944, 1945.

CYSTOPHORA DUMOSA (Greville) J. Agardh 1870, 444. De Toni 1895, 142. *Blossevillea dumosa,* Kützing 1860, t. 73, f. 1. — *VB.* Drift, May 1945, Jan. 1946. *PB.* Drift, all seasons.

CYSTOPHORA GREVILLEI (Agardh) J. Agardh. Harvey 1862, pl. 183. De Toni 1895, 144. Lucas 1936, 73. — *MR.* Drift, Jan. 1946. *VB.* Drift, May 1945, Jan. 1946. *PB.* Drift, Jan. 1944, April 1947, Dec. 1948. *RP.* Drift, June 1947.

CYSTOPHORA INTERMEDIA J. Agardh 1897, 102. — In the sublittoral fringe throughout the Exposed Rocky Coast Formation, all seasons (see Pt. I).

CYSTOPHORA MONILIFERA J. Agardh 1848, 241. Harvey 1863, pl. 245. De Toni 1895, 146. Lucas 1936, 73. — *EB, MR, WR, WB, CC, VB, PB, CW, AB,* all drift from sublittoral, all seasons. Widely distributed in the sublittoral around the island. Rarely on rock in the channel at *AR* inlet.

CYSTOPHORA PANICULATA (Turner) J. Agardh. Harvey 1863, pl. 247. De Toni 1895, 149. Lucas 1936, 74. — *WR, MR,* and *CC.* Drift. *VB.* Drift and in the large littoral pool, south side of Ellen Point. *PB.* In the *Cystophora*-coralline and sublittoral fringe associations on reefs, and sublittoral. *CW.* Drift. All seasons in all localities.

CYSTOPHORA PECTINATA (Greville and Agardh) J. Agardh. De Toni 1895, 139. Lucas 1936, 71. *Blossevillea pectinata,* Kützing 1860, t. 74, f. 2. — *WR.* Drift, Jan. 1946. *CC.* Drift, Jan. 1948. *PB.* Drift, May 1945, Jan. 1946, 1948. Restricted to the sublittoral.

CYSTOPHORA PLATYLOBIUM (Mertens) J. Agardh. De Toni 1895, 138. Lucas 1936, 71. *Cystophora lyallii* Harvey 1855, 214, pl. 108. — *MR.* Drift, Jan. 1946, 1948. *CC.* Drift, Jan. 1948. Sou'-West River mouth, Dec. 1934 (Cleland and Black). *VB.* Drift, May 1945, Jan. 1946, 1948, 1949. *PB.* Drift, Jan. 1944, May 1945, April 1947, Jan. 1948. *CW.* Drift, Jan. 1946, 1948. Restricted to sublittoral.

CYSTOPHORA POLYCYSTIDEA Areschoug in J. Agardh 1848, 240. De Toni 1895, 148. Lucas 1936, 74. Widely distributed in the upper sublittoral within the Sheltered Rocky Coast Subformation, all seasons. Also in very sheltered pools at *PB* and *CW,* all seasons.

CYSTOPHORA RACEMOSA Harvey. Alg. Aus. Exs. n. 5. J. Agardh 1870, 441. De Toni 1895, 140. Lucas 1936, 71. *Blossevillea racemosa,* Kützing 1860, t. 85, f. 1. — *PB.* Drift, Sept. 1946, June 1947.

CYSTOPHORA RETORTA (Mertens) J. Agardh 1848, 243; 1870, 443. De Toni 1895, 141. Lucas 1936, 72. — *VB.* Drift, Jan. 1948. *PB.* Drift, May 1945, July 1947, Jan. 1948.

CYSTOPHORA SILIQUOSA J. Agardh 1870, 445. De Toni 1895, 143. Lucas 1936, 72 — In the upper sublittoral and in low, large littoral pools throughout the Rocky Shore Formation. Common on reefs on the south coast. All seasons.

Cystophora spartioides (Turner) J. Agardh. Harvey 1859, pl. 76. De Toni 1895, 145. Lucas 1936, 73. — *EB* and *MR*. Upper sublittoral, Jan. 1946. *VB*. In the large littoral pool, south side of Ellen Point, and sublittoral in bay, Jan. 1946, 1947. *PB*. In pools on the sublittoral fringe, all seasons. *CW*. Upper sublittoral, east side, Jan. 1946, 1947. *AB*. Upper sublittoral, Jan. 1947.

Cystophora subfarcinata (Mertens) J. Agardh 1848, 240. De Toni 1895, 147. Lucas 1936, 74. — Widely distributed in the upper sublittoral and low littoral pools within the Rocky Coast Formation. Very common on south coast reefs. All seasons. The north coast form (MR to AB) bears vesicles.

Cystophora uvifera (Agardh) J. Agardh. Harvey 1860a, pl. 175. De Toni 1895, 137. Lucas 1936, 70. — South'-West River mouth, Dec. 1934 (Cleland and Black). *VB*. Littoral on reefs in bay, all seasons. *PB*. Littoral on reefs and occasionally drift from deeper water, all seasons. The seasonal variation in vesicle formation at PB has been described previously (Pt. II, 154). *AB*. Drift, Aug. 1948. This species probably occurs on all the reefs along the south coast.

CYSTOPHYLLUM J. Agardh

Cystophyllum muricatum (Turner) J. Agardh 1848, 231. De Toni 1895, 154. Lucas 1936, 74. — *AR*. Occasional in the upper sublittoral, mainly near the channel edge. *K*. Drift. *EB*, *WR* and *MR*. Upper sublittoral. *PB*. Littoral pool association on reefs. *RP*. Low littoral. All seasons in all localities. Widely distributed in the Sheltered Rocky Coast Formation.

SARGASSUM

Sargassum biforme Sonder. J. Agardh 1889, 75, pl. 23, f. 3. De Toni 1895, 34. Lucas, 1936, 67. — *AR*. Sublittoral and upper sublittoral on rock along channel, occasional, all seasons. Also cast up (from Eastern Cove), May 1945, Sept 1946.

Sargassum bracteolosum J. Agardh 1889, 67, pl. 4, pl. 19, f. 2. De Toni 1895, 28. Lucas 1936, 66. — *WR*. Upper sublittoral, Jan. 1946. Sou'-West River mouth, Dec. 1934 (Cleland and Black) and drift, Jan. 1945. *VB*. Upper sublittoral at the end of Ellen Point and in the large littoral pool, south side of Ellen Point, Jan. 1946. *DB*. Sublittoral fringe on reefs, Jan. 1947. *PB*. Sublittoral fringe on reefs and sublittoral, all seasons.

Sargassum cristatum J. Agardh 1889, 84, t. 25, f. 5. De Toni 1895, 44. Lucas 1936, 67. — *EB*. Drift, Jan. 1946. *PB*. Drift, Jan. 1944, 1945, April 1947, Dec. 1948.

Sargassum lacerifolium (Turner) Agardh. Harvey 1862, pl. 208. J. Agardh 1889, 74, t. 23, f. 2. De Toni 1895, 34. Lucas 1936, 66. — *PB*. Drift, April 1947, July 1947, Dec. 1948.

Sargassum merrifieldii J. Agardh 1889, 115, pl. 30, f. 4. De Toni 1895, 96. Lucas 1936, 68. — *BH*. Upper sublittoral, Oct. 1947, Dec. 1948. The species is somewhat variable in form but agrees well with J. Agardh's description and figures.

Sargassum muriculatum J. Agardh 1872, 58; 1889, 44, pl. 14, f. 2. De Toni 1895, 10. Lucas 1936, 63. — *MR*. Drift, Jan. 1946. *VB*. In the large littoral pool, south side of Ellen Point, Dec. 1945, Jan. 1949. *PB*. Littoral on reefs, all seasons. (Seasonal variation described in Pt. II, 155.) *CW*. In rock pools, south side, Aug. 1948. *RP*. Drift, June 1947, Aug. 1948.

SARGASSUM SONDERI J. Agardh 1889, 44, pl. 14, f. 1-2. De Toni 1895, 10. Lucas 1936, 63. *Cystophora sonderi*, Harvey 1863, pl, 243. — *PB*. Drift, May 1945.

SARGASSUM TRICHOPHYLLUM J. Agardh 1889, 52, pl. 17. De Toni 1895, 16. Lucas 1936, 64. — *AR*. Drift (probably from Eastern Cove), June 1947. *PB*. Drift, all seasons.

SARGASSUM VARIANS Sonder. J. Agardh 1889, 49, pl. 16, f. 1-8. De Toni 1895, 14. Lucas 1936, 64. — *MR*. Upper sublittoral, Jan. 1946. *PB*. Drift May 1945, Sept. 1946, April, July 1947.

SCABERIA Greville

SCABERIA AGARDHII Greville. Harvey 1860a, pl. 164. De Toni 1895, pl. 179. Lucas 1936, 76. — *EB*. Upper sublittoral. *VB* and *PB*. Drift. *RP*. Upper sublittoral. Common, all seasons. *Scaberia rugulosa* J. Agardh is only a slenderer form of this species.

RHODOPHYTA

BANGIOIDEAE — BANGIALES — BANGIACEAE

BANGIA Lyngbye

BANGIA FUSCOPURPUREA (Dillwyn) Lyngbye. De Toni 1897, 11. Newton 1931, 238, f. 145. Taylor 1937, 218, pl. 28, f. 10-12. Lucas and Perrin 1947, 125. f. 4. — *AR*. On black buoy, Sept. 1946, Jan. 1947. *CW*. At the edge of exposed rock pools, south side, Aug. 1948. This seems to be mainly a winter form, and has usually disappeared at American River by January.

PORPHYRA C. Agardh

PORPHYRA UMBILICALIS (Linnaeus) J. Agardh. Newton 1931, 240, f. 146. Taylor 1937, 221, pl. 30, f. 1-3. Lucas and Perrin 1947, 125, f. 5, 6. *Wildemania umbilicalis* (L.) De Toni 1897, 20. — *AR*. Upper littoral on Shag Rock and Pig Island (probably elsewhere in the lagoons), Sept. 1946, July and Nov. 1947. — *CW*. Upper littoral, south side, Aug 1948. This is a winter form, occurring in American River inlet from June to early November.

FLORIDEAE — NEMALIONALES — ACROCHAETIACEAE

ACROCHAETIUM Naegeli

ACROCHAETIUM BOTRYOCARPUM (Harvey) J. Agardh 1876, 10. Papenfuss 1945, 313. *Callithamnion botryocarpum* Harvey 1854, 563. — *PB*. Drift, on *Polyceria nigrescens*, Jan. 1948.

BONNEMAISONIACEAE

ASPARAGOPSIS Montagne

ASPARAGOPSIS ARMATA Harvey 1854, 544; 1862, pl. 192. De Toni 1900, 772. Feldmann 1942, 82, 102, 109. Lucas and Perrin 1947, 244. — *BH*. Upper sublittoral, Oct. 1947. *WB*. Drift, Jan. 1946. *PB*. Drift, Jan. 1944, May 1945, Jan. 1948.

Feldmann has presented evidence, based on culture experiments and morphology, that *Falkenbergia* (Rhodomelaceae) is the terasporic phase of *Asparagopsis armata*. *Falkenbergia* has not yet been found around Kangaroo Island.

Asparagopsis taxiformis (Delile) Collins and Hervey. Feldmann 1942, 81. *Asparagopsis sanfordiana* Harvey 1858, pl. 6. De Toni 1900, 771. — North coast (no details). This single specimen in the Adelaide University Herbarium agrees with others from Port Willunga, in Gulf St. Vincent, which are referable to *A. sanfordiana* Harvey. Feldman and others consider this species identical with *A. taxiformis*, any differences being due to the habitat.

BONNEMAISONIA C. Agardh

Bonnemaisonia asparagoides (Woodward) Agardh var. hypnoides Reinbold. De Toni 1900, 768. Newton 1931, 269, fig. 164. Reinbold 1899, 47 (for variety). Lucas and Perrin 1947, 243. — *PB*. Drift, Aug. 1948. A single specimen, identical with a cotype of Reinbold's var. *hypnoides* in Adelaide University Herbarium, and which seems to agree closely with figures of *B. asparagoides*.

DELISEA Lamouroux

Delisea hypneoides Harvey 1860a, pl. 134. De Toni 1900, 761. Lucas and Perrin 1947, 241. — *SB*. Drift, Jan. 1948. *WR, MR* and *WB*, all drift, Jan. 1946. *CC*. Drift, Jan. 1947, 1948. *VB*. Drift, Jan. 1944, 1946, 1948, 1949. *PB*. Drift, Jan. 1944, 1946, 1947. These specimens are rather denser than Harvey's figure, and were reported as *D. elegans* in Pt. I, 244.

Delisea pulchra (Greville) Montagne. Harvey 1858, pl. 16. De Toni 1900, 763. Lucas and Perrin 1947, 241. — *WR*. Drift, Jan. 1946. *WB*. Drift Jan. 1945, 1946. *PB*. Drift, Jan. 1947.

Helminthocladiaceae

LIAGORA Lamouroux

Liagora harveyana Zeh 1913, 270. De Toni 1924, 92. Lucas and Perrin 1947, 134. *Liagora viscida*, Harvey Alg. Aus. exs. n. 348B; 1863, Syn n., 477. — *PB*. Littoral and sublittoral fringe on reefs, all seasons but variable in occurrence. *CW*. In a rock pool, south side, Jan. 1948.

Liagora wilsoniana Zeh 1913, 269. De Toni 1924, 94. Lucas and Perrin 1947, 134. — *PB*. Littoral, on sloping rock, Jan. 1948. No authentic specimens are available for comparison, but the specimens agree very well with Zeh's description.

NEMALION Targioni-Tozzetti

Nemalion helminthoides (Velley) Batters. Cotton 1912, 133. Newton 1931, 256. Lucas and Perrin 1947, 131, f. 7. *N. lubricum* Duby. Smith 1944, 186, pl. 41, f. 5. — *AR*. Mid littoral on a post on Strawbridge Point, Jan. 1949. *BH*. Mid and lower littoral, Jan., Dec. 1948. *MR*. Mid littoral, Jan. 1946, 1947, 1948. *PB*. Sublittoral fringe, main reef, rare, Jan. 1947. In form this species ranges from plants with a few simple branches from a common base to ones dichotomously or even proliferously branched many times. (see fig. 2). These latter dichotomous forms are included by most authors under *N. multifidum* (Weber and Mohr) J. Agardh, but such a great variation in degree of branching is found, even in the same situation, that only one species can be maintained around Kangaroo Island. Some of the forms found in one colony at Ballast Head are shown in fig. 2. The Middle River specimens are usually rather simple, those at Pennington Bay with numerous branches. Cotton also found difficulty in separating *N. helminthoides* and *N. multi-*

fidium at Clare Island, Ireland, and suggested they may be forms of the one species. *N. helminthoides* has priority as a specific name over *N. multifidum* if they are to be united.

May 1945, 122, recorded *N. multifidum* from New South Wales, noting that there were few branches in her specimens. I have seen plants of *Nemalion* at Harbord, N.S.W., which show very simple thalli, which are best referred to *N. helminthoides*.

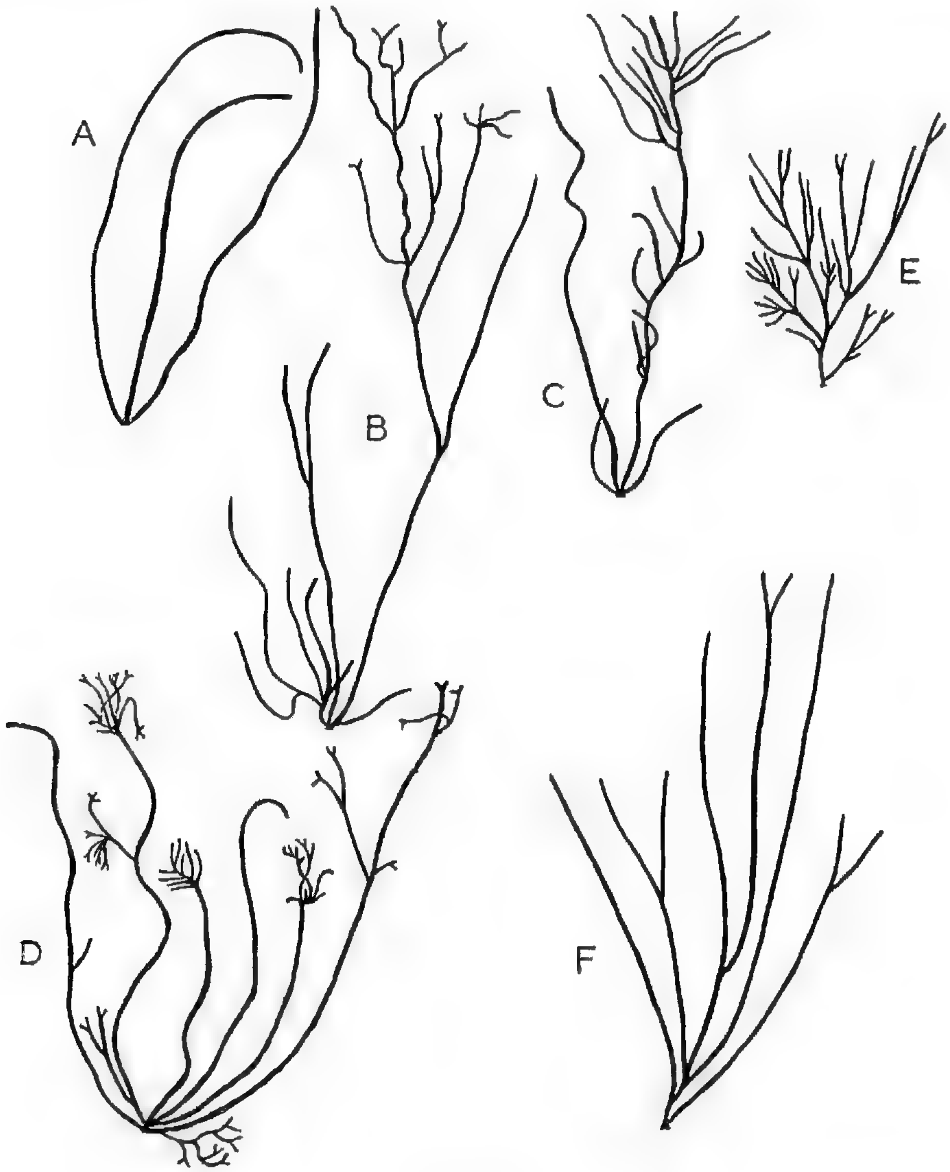

Fig 2

The range of form in *Nemalion helminthoides* on Kangaroo Island. A. A typical specimen from the coast at Middle River. B, C, D, F. Specimens from Ballast Head. The form shown in A also occurs here. E. A specimen from Pennington Bay. Approx. ¼ natural size.

Chaetangiaceae

GLOIOPHLOEA J. Agardh

Gloiophloea scinaioides J. Agardh. De Toni 1897, 107. Setchell 1914a, 112. *Scinaia furcellata*, Harvey 1863, Syn. n. 458; Alg. Aus. Exs. n. 348. — *MR*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948. *PB*. Drift, Dec. 1948.

GALAXAURA Lamouroux

Galaxaura spathulata Kjellman 1900, 74, t. 12, f. 5-12; t. 20, f. 35. De Toni 1924, 132. — *PB*. Drift, Jan. 1946. These specimens agree well with Kjellman's description and figures of *G. spathulata*. The Australian species which Kjellman described need re-examining with abundant material, as Howe (1918, 191) has shown that tetrasporic and sexual individuals of the same species may differ considerably in their anatomy and have been placed in different groups as distinct species by Kjellman. The Kangaroo Island specimens are sterile. In Pt. II, 161, they were reported as *Brachycladia marginata*.

GELIDIALES — Gelidiaceae

GELIDIUM Lamouroux

Gelidium australe J. Agardh 1876, 550. De Toni 1897, 153. Lucas and Perrin 1947, 143. — *MR*. Drift, Jan. 1946. *VB*. In shaded parts of the large littoral pool, south side of Ellen Point, Jan. 1946, 1947, 1948, 1949 and drift, Jan. 1948. *PB*. In the sublittoral fringe and to half a meter over edge of the reef, all seasons.

Gelidium pusillum (Stackhouse) Le Jolis. De Toni 1897, 147. Dawson 1944, 258. *Acrorarpus pusillus*, Kützing 1868, t. 37. — *AR*. Upper littoral in shaded parts of low cliffs, occasionally in the lower littoral, throughout the inlet, all seasons. *EB*. Lower littoral, in a dense mat, all seasons. *MR*. In *Hormosira-Cystophora* pools (sometimes heavily epiphytic on the mollusc *Neothais textiliosa*), Jan. 1946. *WB*. Littoral on reef near beach, Jan. 1945, 1946. *VB*. Lower littoral, north side of Ellen Point, Jan. 1948, and in pool 1, south side of Ellen Point, Jan. 1946. *PB*. Rear littoral, on sloping and vertical rock, all seasons. *CW*. Mid littoral, south side, Jan. 1946. *RP*. Lower littoral, all seasons.

Original determination by Miss V. May. This plant shows considerable ecological variation. At AR and RP it forms dense entangled mats, to 1 cm. thick; at PB it forms a thin mat on shaded rock, but when growing in pools may reach a height of 2 cm., with less branched, rather tufted fronds.

PTEROCLADIA J. Agardh

Pterocladia capillacea (Gmelin) Bornet and Thuret. De Toni 1897, 162. Moore 1945, 336, pl. 45, f. 1-4, pl. 46. — *BH*. Upper sublittoral, Jan. 1948. *CC*. Lower littoral in sheltered inlet, Jan. 1948. *CW*. In a rock pool, south side, Oct. 1948. *RP*. Upper sublittoral, Jan. 1947.

Pterocladia lucida (R. Brown) J. Agardh. De Toni 1897, 162. Moore 1945, 338, pl. 45, f. 5-10; pl. 47, 48, 49. Lucas and Perrin 1947, 144, f. 19. — *VB*. Drift, Jan. 1949. *PB*. Sublittoral fringe, main reef, rare, Jan. 1948. *CW*. Drift, Jan. 1946. *AB*. Drift, Aug. 1948.

CRYPTONEMIALES — Dumontiaceae

DASYPHLOEA Montagne

Dasyphloea tasmanica Harvey 1859, pl. 115. De Toni 1905, 1,629. Lucas and Perrin 1947, 384, f. 193. *Nizzophloea tasmanica* (Harvey) J. Agardh 1876, 256. — *PB*. Drift, Jan. 1948.

Rhizophyllidaceae

RHODOPELTIS Harvey

Rhodopeltis australis (Sonder) Schmitz. Harvey 1863, pl. 264. De Toni 1905, 1,671. *Amphiroa australis* Sonder 1846, 188. Harvey 1859, pl. 77. — *CC.* Drift, Jan. 1947.

The position of this algae is uncertain. Sonder first described it as *Amphiroa australis,* and later Harvey (1863, pl. 264) figured the fertile areas as an epiphyte which he called *Rhodopeltis australis.* W. van Bosse (1904, 104) later renamed it *Litharthron australis* on vegetative features. Yamada (1931b, 75) has described a second species of *Rhodopeltis,* with similar fertile areas (nemathecia) on the thallus segments.

Squamariaceae

ETHELIA W. v. Bosse

Ethelia australis (Sonder) W. v. Bosse. W. v. Bosse 1921, 300. De Toni 1924, 594. *Peyssonnelia australis* Sonder. Harvey 1859, pl. 81. Lucas and Perrin 1947, 388, f. 196. — *WB.* Drift, Jan. 1946. Reported in Pt. II, p. 161, as *Peyssonnelia australis.*

PEYSSONNELIA Decaisne

Peyssonnelia gunniana J. Agardh 1876, 387. De Toni 1905, 1,698. W. v. Bosse 1921, 272. *P. rubra,* Harvey, Alg. Aus. exs. n. 327. — *AR.* Upper sublittoral near Muston, Jan. 1946, July 1947, Jan. 1948. *BH,* Upper sublittoral, Oct. 1947. *PB.* In a shaded pool, rear littoral, Jan. 1947.

Corallinaceae — Corallineae

AMPHIROA Lamouroux

Amphiroa anceps (Lamarck) Decaisne. Harvey 1847, 98, pl. 37. De Toni 1905, 1,815. W. v. Bosse 1904, 93, pl. 16, f. 6-8. — *CC.* Sublittoral fringe, Jan. 1948. South Coast. Winter 1939, coll. J. Cork.

CORALLINA Linnaeus

Corallina cuvieri Lamouroux. Harvey 1847, 106. De Toni 1905, 1,848. Manza 1940, 279. Lucas and Perrin 1947, 399. — *MR, WR, CC* and *VB.* Lower littoral and drift. *PB. Cystophora*-coralline association, sublittoral fringe and deeper pools. *CW* and *AB.* Lower littoral and drift. Present in all seasons, and common, though often stunted in the lower littoral throughout the Rocky Shore Formation.

This is a very variable species, especially in the development of slender lateral ramelli which arise from the main stems. The articulations of the main stem are relatively constant in shape and size and provide a good specific character.

The following forms are included under *C. cuvieri* by De Toni: *Jania granifera* Sonder, *Cor. crispata* Lamx., *Cor. gracilis* Lamx.?, *J. subulata* Sonder. In addition the following are probably only forms of *C. cuvieri*: *Jania rosea* Dcne (Harvey 1847, 105, pl. 40), *Cor. calliptera* Kütz. (1858, t. 72 a-b), *Cor. plumifera* Kütz (1858, t. 71 c-d) and probably *Cor. clavigera* Kütz. (1858, t. 75) and *Cor. trichocarpa* Kütz. (1858, t. 74) (although Levring 1946, 221 considers it distinct). Possibly *Cor. denudata* Sonder in Kütz. 1858, t. 72, is only another denuded form.

Most Kangaroo Island specimens belong to var. *crispata* (Lamx.) Areschoug. This is a short stunted form, due to strong wave action, and grades into other forms in different habitats.

Corallina lenormandiana Grunow. De Toni 1905, 1,851. Lucas and Perrin 1947, 400. *Corallina ? nana* Lenormand, Harvey 1863, Syn. n. 346; Alg. Aus. exs. n. 452. — *VB.* On *Cystophora subfarcinata* in the large littoral pool, south side of Ellen Point, Jan. 1946, 1949. *PB.* On *Cystophora dumosa*, drift, Dec. 1948. These specimens are identical with Harvey's No. 452 in Melbourne National Herbarium.

Corallina officinalis Linnaeus. De Toni 1905, 1,840. Newton 1931, 313. Taylor 1937, 271, pl. 36, f. 1-5. Manza 1940, 275. — *CW.* In a shaded rock pool, south side, Aug. 1948.

Corallina pilifera Lamouroux. Kützing 1858, t. 74 c-d. De Toni 1905, 1,848. Manza 1940, 280. Lucas and Perrin 1947, 400. — *PB.* Drift, Jan. 1948. South Coast. Winter 1939, coll. J. Cork.

JANIA Lamouroux

Jania fastigiata Harvey 1863, pl. 251. De Toni 1905, 1,854. Lucas and Perrin 1947, 397, f. 201. — *WR.* Lower littoral, Jan. 1946. *PB.* Epiphytic on *Cystophora subfarcinata*, *C. paniculata*, occasionally on *C. siliquosa* and on rock in the sublittoral fringe and especially in the *Cystophora*-coralline association, all seasons. *CW.* On *Cystophora subfarcinata* and *Cladostephus verticillatus*, upper sublittoral, Jan. 1946, 1947. *AB.* Low littoral, on *Cystophora subfarcinata*, Jan. 1947.

Jania micrarthrodia Lamouroux. De Toni 1905, 1,855. Lucas and Perrin 1947, 397. *J. tenuissima* Sonder and *J. antennina* Kützing in Sonder 1846, 186. — *AR.* Upper sublittoral, on *Posidonia*, especially near and just outside mouth of the inlet, Aug. 1948. *K.* Drift, Jan. 1948.

Jania natalensis Harvey 1847, 107. Kützing 1858, t. 79, II. De Toni 1905, 1,856. — *RP.* Lower littoral, Jan. 1948. *AR.* Upper sublittoral on Pig Island, occasional, Jan. 1947, Dec. 1948. These specimens agree very well with Kützing's figures and Harvey's description.

METAGONIOLITHON W. v. Bosse

Metagoniolithon charoides (Lamouroux) W. v. Bosse 1904, 102. Manza 1940, 310. *Amphiroa charoides*, Harvey 1847, 96, pl. 39. Lucas and Perrin 1947, 394. — *MR.* Drift, Jan. 1946, 1948. *CC.* Drift, Jan. 1947, and lower littoral, Jan. 1948. *PB.* Sublittoral fringe and deeper pools on reefs, all seasons. *CW.* Upper sublittoral, Jan. 1947. *AB.* Upper sublittoral, Jan. 1945, 1947, Aug. 1948.

Metagoniolithon gracile (Harvey) Yendo. Manza 1940, 311. *Amphiroa gracilis* Harvey 1862, pl. 231. De Toni 1905, 1809. Lucas and Perrin 1947, 394. — *K.* Drift, Jan. 1948.

Metagoniolithon stelligera (Lamarck) W. v. Bosse 1904, 103, pl. 15, f. 9, 13. Manza 1940, 311. *Amphiroa stelligera*, Harvey 1862, pl. 230. Lucas and Perrin 1947, 394, f. 199. — *MR.* Drift, Jan. 1946. *VB.* Drift, Jan. 1947, 1948, 1949. *PB.* Drift, Jan. 1944, 1948.

Mastophoreae

METAMASTOPHORA Setchell

Metamastophora flabellata (Sonder) Setchell 1943, 131. *Mastophora flabellata*, Harvey 1847, 108. *Mastophora lamourouxii*, Harvey 1863, Syn. n. 367. Lucas and Perrin 1947, 391. — *WB.* Drift, Jan. 1946. South Coast. Winter 1939, coll. J. Cork.

Lithothamnieae

A number of species of crustaceous corallines have been collected from Kangaroo Island, but as no authentic material of this group is available in Australian Herbaria for comparison, identification of most has not been possible.

LITHOTHAMNION Philippi

Lithothamnion patena (Hooker and Harvey) Heydrich. De Toni 1924, 622. *Melobesia patena*, Harvey 1847, 111, pl. 40. — *WB*. On *Ballia callitricha*, drift, Jan. 1946. South Coast. On *Ballia callitricha*, winter 1939, coll. J. Cork.

Grateloupiaceae

HALYMENIA C. Agardh

Halymenia harveyana J. Agardh 1892, 55. De Toni 1905, 1,539. Lucas and Perrin 1947, 375, f. 188. *Halymenia floresia*, Harvey 1862, pl. 214. — *PB*. Drift, Jan. 1948.

THAMNOCLONIUM Kützing

Thamnoclonium claviferum J. Agardh 1876, 168. De Toni 1905, 1,614. Lucas and Perrin 1947, 381, f. 192. *Thamnoclonium hirsutum* Harvey 1863, pl. 293. — *VB*. Drift, Jan. 1948. *PB*. Drift, Jan. 1946.

Callymeniaceae

CALLOPHYLLIS Kützing

Callophyllis cervicornis Sonder 1852, 678. De Toni 1897, 276. Lucas and Perrin 1947, 158. — *PB*. Drift, Jan. 1948. These specimens agree well with some of Sonder's in Melbourne National Herbarium.

Callophyllis coccinea Harvey. Hooker and Harvey 1847, 404. Kützing 1867, t. 92. J. Agardh 1876, 234. De Toni 1897, 282. Lucas and Perrin 1947, 159, f. 31.

var. carnea J. Agardh. — *CC*. Drift, Jan. 1947, 1948. *VB*. Drift, Jan. 1948, 1949. *PB*. Sublittoral fringe on main reef, Jan. 1947, 1948.

var. corymbosa J. Agardh. — *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, May 1945, Jan. 1948.

These specimens seem to agree well with J. Agardh's descriptions of the above two varieties.

Callophyllis harveyana J. Agardh 1876, 230. De Toni 1897, 277. Lucas and Perrin 1947, 158. *Callophyllis obtusifolia*, Harvey 1862, pl. 193 (not J. Agardh). — *AB*. Drift, Jan. 1946. *PB*. Drift, Jan. 1947.

Callophyllis lambertii (Turner) Greville. J. Agardh 1876, 233. De Toni 1897, 282. Lucas and Perrin 1947, 159, f. 30. — *CC*. Drift, Jan. 1948. Sou'-West River mouth. Drift, Jan. 1945. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1946, 1948.

CALLYMENIA J. Agardh

Callymenia cribrosa Harvey 1859, pl. 73. J. Agardh 1876, 219. De Toni 1897, 295. Lucas and Perrin 1947, 161, f. 33, 35. — Eastern Cove. On underside of buoys, rare, Jan. 1946, 1948. North Coast (no details). *VB*. Drift, Jan. 1948.

GELINARIA Sonder

Gelinaria ulvoidea Sonder 1846, 172. Harvey 1859, pl. 85. De Toni 1897, 311. Lucas and Perrin 1947, 163, f. 36. — *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1944.

POLYCOELIA J. Agardh

POLYCOELIA LACINIATA J. Agardh 1851, 306; 1876, 228. De Toni 1897, 293. Lucas and Perrin 1947, 161, f. 32. — *VB.* Drift, Jan. 1948. These specimens agree well with Agardh's description, but I have seen no authentic specimens. It is closely related to *P. fastigiata* Harvey from Tasmania and may be conspecific.

GIGARTINALES — NEMASTOMACEAE

NEMASTOMA J. Agardh

NEMASTOMA FEREDAYAE Harvey 1860b, 327, pl. 195A. J. Agardh 1876, 126. De Toni 1905, 1,663. Lucas and Perrin 1947, 386, f. 195. — *CC.* Drift, Jan. 1948. *VB.* Drift, Jan. 1948, 1949. *PB.* Sublittoral fringe on reefs Jan. 1946, 1947, 1948, Dec. 1948. The Pennington Bay specimens growing in the sublittoral fringe are 5 to 10 cm. high and greenish-purple in colour; those cast up from deeper water at Vivonne Bay are up to 20 cm. high and dark red in colour.

GRACILARIACEAE

CURDIEA Harvey

CURDIEA LACINIATA Harvey 1858, pl. 39. Kützing 1869, t. 33 c-d. De Toni 1900, 424. Lucas and Perrin 1947, 184, f. 54. — *VB.* Drift, Jan. 1949.

CURDIEA OBESA (Harvey) Kylin 1932, 61. *Sarcocladia obesa* Harvey 1862, pl. 217. De Toni 1900, 426. — *VB.* Drift, Jan. 1949.

GRACILARIA Greville

GRACILARA CONFERVOIDES (Linn.) Greville. De Toni 1900, 431. Newton 1931, 429, f. 258. Taylor 1937, 293, pl. 38, f. 1. May 1948, 18, f. 1, 2, pl. 1. — *AR.* On the tidal flats throughout the lagoons, scattered but common in some areas between American River jetty and Muston, all seasons.

GRACILARIA FURCELLATA Harvey 1863, pl. 286 (excl. syn.). De Toni 1900, 441. May 1948, 53, f. 9. — *BH.* Lower littoral, Oct. 1947. *WB.* Littoral, Jan. 1945. *VB.* Shaded end of pool 1, south side of Ellen Point, Jan. 1948, and drift, Jan. 1949. *DB.* Littoral, Jan. 1947. *PB.* Littoral on well washed rock, Jan. 1948, 1949 and drift, May 1945, Jan. 1946, 1947.

May refers this form to f. *furcellata* (Harvey) May. The thickening towards the base which is characteristic of this form is dependent to some extent on habitat.

MELANTHALIA Montagne

MELANTHALIA CONCINNA (R. Brown) J. Agardh 1876, 404. De Toni 1900, 421. Kylin 1932, 58. Lucas and Perrin 1947, 184, f. 52. — *VB.* Drift, Jan. 1949. South Coast. Winter 1939, coll. J. Cork.

MELANTHALIA OBTUSATA (Labillardiere) J. Agardh. Harvey 1858, pl. 25. De Toni 1900, 422. Kylin 1932, 58. Lucas and Perrin 1947, 183, f. 51. — *PB.* Upper sublittoral under east edge of main reef, Jan. 1948.

TYLOTUS J. Agardh

TYLOTUS OBTUSATUS (Sonder) J. Agardh 1876, 429. De Toni 1900, 463. Lucas and Perrin 1947, 189. *Curdiea obtusata* Sonder. Harvey 1962, pl. 210. — *WB.* Drift, Jan. 1945. *VB.* Drift, Jan. 1949.

Plocamiaceae

PLOCAMIUM Lamouroux

Plocamium costatum (J. Agardh) Hooker and Harvey. Kützing 1866, t. 52 d-e. J. Agardh 1876, 344. De Toni 1900, 597. Lucas and Perrin 1947, 212, f. 77. — *WB*. Drift, Jan. 1945. *VB*. Drift, Jan. 1949. *PB*. Sublittoral fringe, on rocks off east edge of main reef, Dec. 1948, and drift, Jan. 1946, 1948. The laciniae are usually strongly serrate, but this is a very variable character.

Plocamium gracile J. Agardh 1876, 345. De Toni 1900, 598. Lucas and Perrin 1947, 213, f. 78. *Plocamium augustatum* Kützing 1866, t. 48 c-e. — *BH*. Upper sublittoral, Dec. 1948. *MR, WR* and *WB*. All drift, Jan. 1946. *CC*. Drift, Jan. 1948. *VB*. Drift, Jan. 1948, 1949. *PB*. Sublittoral fringe. Jan. 1944, 1946, 1948, Dec. 1948.

These specimens, although all sterile, agree well on vegetative features with a specimen of J. Agardh's of *P. gracile* from Tasmania ("Algae Muellerianae"), in Melbourne National Herbarium. *P. gracile* is closely related to *P. augustum* (J. Ag.) H. and H., the Australian specimens of which are included by Yendo (1915, 111) under *P. telfairiae* Harvey. These may all prove to be the same species when a large range of specimens is examined. The PB specimens were recorded in Pt. II as *P. angustum*.

Plocamium leptophyllum Kützing 1866, t. 45 a-c. J. Agardh 1876, 338. De Toni 1900, 589. Yendo 1915, 113. Lucas and Perrin 1947, 210, f. 74. — *BH*. Upper sublittoral, Oct. 1947. *VB*. Drift, Jan. 1949. *PB*. Drift, May 1945. *AB*. Drift, Aug. 1948.

Plocamium mertensii (Greville) Harvey 1847, 122; 1863 syn. n. 491 a. J. Agardh 1876, 346. De Toni 1900, 599. Lucas and Perrin 1947, 215, f. 80. — *PB*. Drift, May 1945.

P. mertensii differs from *P. procerum* (J. Agardh) Harvey in having serrate laciniae; otherwise the two species are identical. A range of specimens, however, shows considerable variation in degree of serration of the laciniae, even on the one plant, and these two species cannot be separated satisfactorily. *P. costatum* also varies greatly in serrations on the laciniae. Although this has been used as a specific character in these species, it is of little use when large numbers of specimens are examined. *P. nidificum* has been kept separate here, but may well be only a form of *P. mertensii*. It differs in forming clusters of multifid dichotomous ramelli in the branch axils, but these are often developed only to a slight extent at the base of the plant, and would not appear on juvenile specimens. Harvey (1863 syn. n. 491) included *P. nidificum* and *P. mertensii* as forms of *P. procerum*, but *P. mertensii* is the earliest name.

Plocamium nidificum (Harvey) J. Agardh 1876, 346. De Toni 1900, 599. Lucas and Perrin 1947, 213. *P. procerum* var. *nidificum* Harvey 1863, syn. n. 491 b. *Thamnophora mertensii*, Kützing 1866, t. 55 d-h. — *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1947, 1948. *VB*. Drift, Jan. 1948, 1949 and upper sublittoral at the end of Ellen Point, Jan. 1946. *PB*. Drift, all seasons. See notes under *P. mertensii*.

Plocamium preissianum Sonder 1846, 192. Harvey 1859, pl. 63. J. Agardh 1876, 342. De Toni 1900, 594. Lucas and Perrin 1947, 211, f. 75. — *MR*. Drift, Jan. 1946. *WB*. Drift, Jan 1946. Sou'-West River mouth, Dec. 1934 (Cleland and Black). *VB*. Drift, Jan. 1948. *PB*. Drift, all seasons.

PHACELOCARPUS Endlicher and Diesing

PHACELOCARPUS LABILLARDIERI (Mertens) J. Agardh. Harvey 1860 a, pl. 163 De Toni 1900, 391. Kylin 1932, 52, f. 14 D. Lucas and Perrin 1947, 181, f. 49. — *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1947, 1948. Sou'-West River mouth. Drift, Jan. 1945. *VB*. Drift, May 1945, Jan. 1948, 1949. *PB*. Drift, Jan. 1944, 1946, 1948; in a shaded pool, Jan. 1944; about 2-3 feet below east ledge of main reef, Jan. 1947, 1948. *CW*. Drift, Jan. 1946.

Rather variable in stoutness, depending on habitat. *P. apodus* J. Agardh (1876, 400) is probably only a form of *P. labillardieri*. Kylin (1932, 52) states it is very close to *P. labillardieri*, and specimens of J. Agardh's in Melbourne National Herbarium are not distinct.

PHACELOCARPUS SESSILIS Harvey in J. Agardh 1876, 400. De Toni 1900, 392. Kylin 1932, 52, t. 19, f. 46. Lucas and Perrin 1947, 181. — *CC*. Drift, Jan. 1948. *VB*. Drift, Jan. 1947, 1948, 1949. *PB*. Drift, Jan. 1946, 1948.

STENOCLADIA J. Agardh

STENOCLADIA CONFERTA (Harvey) J. Agardh. Kylin 1932, 50, f. 13. *Areschougia conferta* Harvey 1860 a, pl. 166. — *VB*. Drift, May 1945, Jan. 1946, 1948, 1949. *PB*. Drift, Jan. 1944. South Coast. Winter 1939, coll. J. Cork.

J. Agardh (1876, 440-441) described four species of *Stenocladia* (*St. corymbosa*, *St. cliftoni*, *St. harveyana*, *St. sonderiana*) on specimens previously placed under *St. conferta*, but dropped *St. conferta* as a species name. Kyin (1932, 50), however, considers these are only forms, and places them all under *St. conferta*. The Kangaroo Island specimens are of the same form as shown in Harvey's plate.

SARCODIACEAE

NIZYMENIA Sonder

NIZYMENIA AUSTRALIS Sonder. Harvey 1860 a, pl. 165. De Toni 1900, 408. Kylin 1932, 57. Lucas and Perrin 1947, 182, f. 50 — Sou'-West River mouth. Dec. 1934. Recorded by Cleland and Black (1941, 248).

SOLIERIACEAE

SOLIERIA J. Agardh

SOLIERIA ROBUSTA (Greville) Kylin 1932, 18. Lucas and Perrin 1947, 174, f. 44. *Solieria australis* Harvey 1860 a, pl. 149. *Rhabdonia robusta* J. Agardh 1852, 355.

F. FLAGELLIFORMIS J. Agardh 1876, 592. Kylin 1932, 18, t. 5, f. 9. — *AR*. Sublittoral, Nov. 1947, Jan. 1948, 1949. *K*. Drift, Jan. 1948. *MR*. Drift, Jan. 1946. *PB*. Drift, Jan. 1947.

THYSANOCLADIA Endlicher

THYSANOCLADIA LAXA Sonder 1852, 689. Kützing 1869, t. 30. De Toni 1897, 383. (Not Harvey 1862, pl. 211.) — *WB*. Drift, Jan. 1946. *PB*. Upper sublittoral east side of main reef, Jan. 1948 and drift, Jan. 1946.

THYSANOCLADIA OPPOSITIFOLIA (Agardh) J. Agardh 1851, 617. Harvey 1862, pl. 187. De Toni 1897, 383. Lucas and Perrin 1947, 176, f. 46. — *VB*. Drift, Jan. 1949.

RHABDONIACEAE

ARESCHOUGIA Harvey

Kylin 1947, 49, has resurrected *Areschougia* Meneghini 1844 for a brown algal species previously well known as *Elachista stellaris* Areschoug. This genus antedates *Areschougia* Harvey 1855, and if *Areschougia* Menegh. is to be retained, the red algal genus must be renamed. However, the Australian *Areschougia* Harvey is a well-known genus of about five species, and to change this name would cause needless confusion. It would seem far better to retain *Areschougia* Harvey as a nomen conservandum, rejecting *Areschougia* Menegh., and it is proposed this should be done.

Areschougia australis Harvey 1854, 554; 1858, pl. 13. Kylin 1932, 37. *Areschougia ligulata* J. Agardh 1876, 282. De Toni 1897, 377. Lucas and Perrin 1947, 174, f. 45. — *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1947. *VB*. Drift, Jan. 1949.

Areschougia laurencia (Hooker and Harvey) Harvey 1854, 554; 1860 b, 321. De Toni 1897, 376. Kylin 1932, 37. Lucas and Perrin 1947, 174. — *VB*. Drift, May 1945, Jan. 1948, 1949. *PB*. Drift, Jan. 1944, May 1945, Jan. 1946, 1948.

ERYTHROCLONIUM Sonder

Erythroclonium angustatum Sonder 1852, 692. Kützing 1869, t. 37. De Toni 1897, 354. Kylin 1932, 36. Lucas and Perrin 1947, 169. — *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1948.

Erythroclonium muelleri Sonder 1852, 692. Harvey 1863, pl. 298. De Toni 1897, 355. Kylin 1932, 36, f. 8 A-B. Lucas and Perrin 1947, 170, f. 41. — *AR*. Upper sublittoral on Pig Island, December 1948 (rare). *MR*. Drift, Jan. 1946. *WR*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, occasional, all seasons, and in pool of sublittoral fringe, Nov. 1947. *AB*. Drift, Jan. 1948.

Erythroclonium sonderi Harvey 1859, pl. 86. De Toni 1897, 354. Kylin 1932, 36. Lucas and Perrin 1947, 169. — *VB*. Drift, Jan. 1948.

RHABDONIA Harvey

Rhabdonia coccinea Harvey 1858, pl. 54. De Toni 1897, 358. Lucas and Perrin 1947, 171, f. 42. — *MR*. Drift, Jan. 1946.

Rhabdonia clavigera J. Agardh 1876, 594. Kylin 1932, 36, t. 14, f. 45. — *VB*. Drift, Jan. 1948, 1950.

Rhabdonia verticillata Harvey 1863, pl. 299. De Toni 1897, 359. Lucas and Perrin 1947, 172, f. 43. — *PB*. Drift, Jan. 1944, May 1945.

Rhodophyllidaceae

GRUNOWIELLA Schmitz

Grunowiella barkeriae (Harvey) Schmitz, Engler and Prantl 1897, 375. Kylin 1932, 43. *Rhodophyllis barkeriae* Harvey 1863, pl. 276. *Gloiophyllis barkeriae* J. Agardh, 1890, 29. De Toni 1897, 338. Lucas and Perrin 1947, 164. — *VB*. Drift, Jan. 1948. *PB*. Drift, Jan. 1946, 1947, 1948. The habit of these specimens is rather variable, but close to Harvey's figure.

RHODOPHYLLIS Kützing

Rhodophyllis multipartita Harvey 1860 b, 318. De Toni 1897, 346. Kylin 1932, 42, t. 16, f. 39. — *VB*. Drift, Jan. 1949.

Rhodophyllis tenuifolia (Harvey) J. Agardh 1876, 367. De Toni 1897, 347. Kylin 1932, 43, t. 17, f. 42. Lucas and Perrin 1947, 167. *Callophyllis tenuifolia* Harvey 1863, syn. n. 549. — *PB*. Drift, Jan. 1946, 1948.

Hypneaceae

HYPNEA Lamouroux

Hypnea episcopalis Hooker and Harvey. Harvey 1858, pl. 23. De Toni 1900, 473. Lucas and Perrin 1947, 191, f. 58. — *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1944. *VB*. Drift, Jan. 1949. *PB*. Drift, Jan. 1944, 1946, 1948.

Hypnea musciformis (Wulfen) Lamouroux. Kützing 1868, t. 19. De Toni 1900, 472. Taylor 1937, 291, pl. 37, f. 2. — *AR*. In the upper sublittoral throughout the lagoons, often common, all seasons.

A variety of forms of *Hypnea* occur in American River inlet, most of which are probably referable to *H. musciformis*. The crozier tips to the branches are not developed in these forms.

RHODODACTYLIS J. Agardh

Rhododactylis rubra (Harvey) J. Agardh 1876, 568. De Toni 1900, 486. *Chondria rubra* Harvey 1863, pl. 280. — *PB*. Drift, Jan. 1946. A single specimen which agrees well with Harvey's figure. Kylin (1932, 48) suggests *Rhododactylis* is doubtfully distinct from *Hypnea*.

Mychodeaceae

MYCHODEA Harvey

Mychodea carnosa Harvey 1860 a, pl. 142. De Toni 1897, 263. Kylin 1932, 64. Lucas and Perrin 1947, 156, f. 27. — *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1944, 1946, 1947, 1948.

Mychodea compressa Harvey 1862, pl. 201. De Toni 1897, 265. — *MR*. Drift, Jan. 1946. *VB*. Drift, Jan. 1946, 1948, 1949. *PB*. Drift, Jan. 1946, 1947, 1948 and sublittoral fringe, main reef, Jan. 1946, 1948 (these reef specimens are very stunted).

Mychodia fastigiata (Harvey) J. Agardh 1876, 570. De Toni 1897, 264. Kylin 1932, 64, t. 26, f. 65. *Hypnea fastigiata* Harvey 1863, syn. no. 457. — *VB*. Drift, Jan. 1948, 1949. These are small and rather compact specimens which approach *M. pusilla* (Harvey) J. Agardh. The branches are slenderer and more densely covered with lateral spinous branchlets than in *M. pusilla*.

Mychodea foliosa (Harvey) J. Agardh 1876, 573. De Toni 1897, 266 *Gymnogongrus foliosus* Harvey 1862, pl. 194. — *VB*. Drift, Jan. 1948 *PB*. Sublittoral fringe on reefs, Jan. 1945, 1946, 1947, 1948 (often epiphytic on the stems of *Cystophora paniculata*).

Mychodea hamata Harvey 1860 b, 323. De Toni 1897, 264. Kylin 1932, 64. *Acanthococcus ewingii* Harvey 1860 a, pl. 141. — *VB*. Drift, Jan. 1949.

Mychodea terminalis Harvey 1860 b, 323; 1862, pl. 200. De Toni 1897, 262. — *VB*. Drift, Jan. 1948.

Dicranemaceae

DICRANEMA Sonder

Dicranema grevillei Sonder 1846, 173. Harvey 1859, pl. 120. De Toni 1897, 269. Lucas and Perrin 1947, 157, f. 29. — *VB*. Drift, Jan. 1946, 1948, 1949

Dicranema revolutum (Agardh) J. Agardh 1876, 435. Harvey 1859, pl. 74. De Toni 1897, 269. — *VB*. On *Cymodocea*, upper sublittoral near jetty in bay, Jan. 1947.

ACROTYLACEAE

ACROTYLUS J. Agardh

ACROTYLUS AUSTRALIS J. Agardh. Harvey 1859, pl. 99. De Toni 1897, 170. Kylin 1932, 68, fig. 20 A, B, 21 B. Lucas and Perrin 1947, 147, f. 20. — *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1944, 1946, 1948.

GIGARTINACEAE

GIGARTINA Stackhouse

GIGARTINA BRACHIATA Harvey 1860 b, 325. J. Agardh 1876, 191. De Toni 1897, 200. — *AR*. Upper sublittoral on Pig Island, Dec. 1948. *BH*. Lower littoral, Oct. 1947. The specimens are sterile, but agree well with Harvey's specimen from Georgetown, Tasmania, and other specimens from there.

GIGARTINA DISTICHA Sonder 1846, 175. Harvey 1863, pl. 297. De Toni 1897, 208. Lucas and Perrin 1947, 150, f. 22. — *MR*. Drift, Jan. 1948 *VB*. Drift, Jan, 1948, 1949. *PB*. Drift, Jan. 1946.

RHODOGLOSSUM J. Agardh

RHODOGLOSSUM PROLIFERUM J. Agardh 1884, 27. *Iridaea prolifera* (J. Agardh) De Toni 1897, 190. Levring 1946, 222, f. 5. — *VB*. Low littoral, north side of Ellen Point, Jan. 1946, 1948. *PB*. Pools in the sublittoral fringe, rare, Jan. 1944, 1948, 1949. (as *Iridaea prolifera* in Pt. II).

RHODYMENIALES — RHODYMENIACEAE — FAUCHEAE

BINDERA Harvey

BINDERA KALIFORMIS J. Agardh 1896, 75. De Toni 1900, 549. Kylin 1931, 7, t. 1, f. 1. Lucas and Perrin 1947, 204. — *WR*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948, 1949.

GLOIODERMA J. Agardh

GLOIODERMA AUSTRALIS J. Agardh 1851, 244. De Toni 1900, 496. *Horea polycarpa* Harvey 1860 b, 329, pl. 194 B. — *VB*. Drift, Jan. 1948, 1949.

GLOIDERMA HALYMENIOIDES (Harvey) De Toni 1900, 497. Lucas and Perrin 1947, 194, f. 61. *Horea halymenioides* Harvey 1854, 555; 1859, pl. 67. — *AR*. On red and outer buoys, Jan. 1946, 1948, and on anchor of red buoy, Jan. 1948.

GLOIODERMA SPECIOSA (Harvey) nov. comb.
Horea speciosa Harvey 1860 b, 328, pl. 194 A. J. Agardh 1876, 292. *Gloioderma tasmanica* Zanardini 1874, 503. De Toni 1900, 497. Kylin 1931, 7. Lucas and Perrin 1947, 194, f. 62. — *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1944, 1946, 1948. This species has usually been called *G. tasmanicum*, and was reported as such in Pt. II, 162, of this series. *G. speciosa*, however, has priority.

GLOIODERMA WILSONIS (J. Agardh) De Toni 1900, 496. Kylin 1931, 7, t. 1, f. 2. *Horea wilsonis* J. Agardh 1884, 38. — *PB*. Drift, Jan. 1946. A single tetrasporic specimen which agrees well with Kylin's figure of the type, and with Wilson's specimens in Melbourne National Herbarium.

RHODYMENIEAE

BOTRYOCLADIA Kylin

BOTRYOCLADIA OBOVATA (Sonder) Kylin 1931 18. *Chrysymenia obovata* Sonder 1846, 176. Harvey 1858, pl. 10. De Toni 1900, 544. Lucas and Perrin

1947, 203, f. 67. — *AR*. Drift, near American River jetty, Sept. 1946, Aug. 1947. *K*. Drift, Jan. 1948. *MR*. Drift, Jan. 1946. *VB*. Upper Sublittoral on reef in the bay, Jan. 1947, and drift, Jan. 1948, 1949. *AB*. Drift, Aug. 1948. *RP*. Drift, Aug. 1948.

COELARTHRUM Borgesen

Coelarthrum muelleri (Sonder) Borgesen 1931, 9. Kylin 1931, 15. *Chylocladia muelleri* Harvey 1860 a, pl. 138. *Erythrocolon muelleri*, J. Agardh 1896, 91. De Toni 1900, 585. Lucas and Perrin 1947, 208, f. 73. — *K*. Drift, Jan. 1948. *PB*. Drift, Jan. 1948.

ERYTHRYMENIA Schmitz

Erythrymenia minuta Kylin 1931, 13, t. 4, f. 10. — *PB*. Sublittoral fringe of main reef, Jan. 1944, 1946, 1947, 1948 and drift, Jan. 1946.

In Pt. II, 159, this species was recorded as the juvenile state of *Hymenocladia conspersa* (Harvey) J. Agardh (c.f., Harvey 1862, pl. 237, juvenile plant). The specimens, however, agree very well with Kylin's description and figure of *Erythrymenia minuta*. In Melbourne National Herbarium are specimens of *Chrysymenia meridithiana* J. Agardh (= *Erythrymenia meridithiana* (J. Ag.) Kylin) which appear identical with the Pennington Bay specimens. They were collected by Wilson at Port Phillip, and on the sheet the name has been changed to *Hymenocladia conspersa* by Wilson. The adult of *H. conspersa* is very different in form (see Harvey 1862, pl. 237) to *E. minuta*. Kylin described *E. minuta* from specimens recorded by J. Agardh as juveniles of *E. meridithiana*. Tetrasporangia are not known, and these species clearly need a thorough investigation.

GLOIOSACCION Harvey

Gloiosaccion brownii Harvey 1859, pl. 83. Kylin 1931, 19. Lucas and Perrin 1947, 202, f. 66. *Chrysymenia brownii*, De Toni 1900, 545. — *AR*. Sublittoral near Muston, Jan. 1948 and on buoys, Jan. 1946, 1948. *MR*, *WR* and *WB*. All drift, Jan. 1946. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1946, 1947.

The American River specimens are smaller, with thinner and softer membranes than those from rough coasts. The former were referred to var. *α membranaceum* by Harvey, the latter to var. *β firmum*. These are only ecological variations.

RHODYMENIA Greville

Rhodymenia foliifera Harvey 1863, syn. n. 508. J. Agardh 1876, 331. De Toni 1900, 517. Kylin 1931, 21, t. 7, f. 17. — *AR*. Upper sublittoral near Muston, Nov. 1947. *BH*. Dredged in 2-3 fathoms, Jan. 1946. *VB*. Drift, Jan. 1949. *PB*. Sublittoral fringe on reefs, Jan. 1944, 1946, 1947, Dec. 1948. *RP*. Drift, June 1947.

This is a variable species, closely related to *Rhodymenia australis* Sonder. In the type and other authentic specimens of *R. australis* in Melbourne National Herbarium, the segments taper from about the centre to the tips. In *R. foliifera* the terminal parts of the thallus are usually as wide or even wider than the lower parts, and spread at a wide angle. Many variations occur, however, and tips of specimens from the Pennington Bay reefs which I have referred to *R. foliifera* are sometimes narrow and almost laciniate. A range of specimens from different habitats may show that these species are not distinct.

HYMENOCLADIA J. Agardh

HYMENOCLADIA POLYMORPHA (Harvey) J. Agardh 1876, 315. De Toni 1900, 504. Lucas and Perrin 1947, 198, f. 64. *Rhodymenia polymorpha* Harvey 1860 a, pl. 157. — *WB.* On *Codium galeatum,* drift, Jan. 1946. *CC.* Drift, Jan. 1947. *VB.* Drift, Jan. 1946, 1948, 1949, and on the base of *Myriodesma latifolia* var. *duriuscula* in a low littoral pool, south side of Ellen Point, Jan. 1946. *PB.* Drift, Jan. 1944, 1946, 1947 and in sublittoral fringe (stunted), all seasons.

HYMENOCLADIA USNEA (R. Brown) J. Agardh 1863, 772. Harvey 1859, pl. 118. De Toni 1900, 502. Kylin 1931, 24. Lucas and Perrin 1947, 197, f. 63. — *VB.* Drift, Jan. 1946, 1948, 1949. *PB.* Drift, Jan. 1946.

CHAMPIACEAE — LOMENTARIEAE

LOMENTARIA Lyngbye

LOMENTARIA AUSTRALIS (Kützing) Levring 1946, 223. *Chondrothamnion australis* Kützing 1865, 29, pl. 82. — *AR.* On buoys near American River jetty, Jan. 1948, and in upper sublittoral on *Zostera* on the cockle bank and near Muston, Jan. 1948.

These specimens agree very well with Kützing's figures. Levring considers it distinct from *L. clavellosa,* to which De Toni referred it.

CHAMPIEAE

CHAMPIA Desveau

CHAMPIA AFFINIS (Hooker and Harvey) J. Agardh 1876, 304. De Toni 1900, 559. Lucas and Perrin 1947, 206, f. 71. *Chylocladia affinis,* Harvey 1847, 79, pl. 29. — *AR.* Upper sublittoral on flats near mouth, Nov. 1947, Aug. 1948. *WR.* Drift, Jan. 1946. *CC.* Drift, Jan. 1948. *PB.* Drift, Jan. 1948. *CW.* Drift, Jan. 1946. *AB.* Drift, Aug. 1948. *RP.* Drift, June 1947, Aug. 1948.

CHAMPIA OBSOLETA Harvey 1860 b, 307. J. Agardh 1876, 304. De Toni 1900, 559. Kylin 1931, 28, t. 15, f. 35. Lucas and Perrin 1947, 206. — *AR.* On the buoys, Jan. 1946, Sept. 1946, Jan. 1948, and upper sublittoral on cockle bank and near Muston, Jan. and Aug. 1948, and drift, May 1945. *WB.* Drift, Jan. 1946. *CC.* Drift, Jan. 1948. *PB.* Littoral and sublittoral fringe on reefs, all seasons, but variable. *AB.* Drift, Aug. 1948. *RP.* Drift, Aug. 1948.

Kylin doubts whether this species is distinct from *C. affinis.* Most specimens can be separated readily on the much heavier and more extensive thickening of the stem and branches in *C. obsoleta,* thus obscuring the diaphragms. A few specimens, however, show intermediate characters.

CHAMPIA TASMANICA Harvey 1844, 407, pl. 19. De Toni 1900, 563. Lucas and Perrin 1947, 207, f. 72. — *MR.* Drift, Jan. 1946. *PB.* Drift, Jan. 1948.

CERAMIALES — CERAMIACEAE — GRIFFITHSIAE

GRIFFITHSIA C. Agardh

GRIFFITHSIA ANTARCTICA Hooker and Harvey. J. Agardh 1851, 87; 1876, 68. Kützing 1862, t. 23 a-b. Laing 1905, 390, pl. 25, f. 2. *Bornetia antarctica,* De Toni 1903, 1,297. — *AR.* Sublittoral near Muston, Nov. 1847, Jan. 1948. *K.* Drift, Jan 1948. *VB.* Shaded end of pool 1, south side of Ellen Point, May 1945, Jan. 1946, 1947, 1948 (as *Bornetia* sp. in Pt. I). *PB.* Sublittoral fringe on main reef, Jan. 1947, 1948, Dec. 1948 and drift, Jan. 1944, 1948. *RP.* Drift, June 1947, Aug. 1948, Jan. 1949.

Griffithsia flabelliformis Harvey 1844, 450. J. Agardh 1876, 61. De Toni 1903, 1,278. Lucas and Perrin 1947, 326. — *AR*. Upper sublittoral between Muston and the mouth of the inlet, May 1945, June, Oct., Nov. 1947, Jan. and Aug. 1948. *RP*. Drift, Aug. 1948. This is chiefly a winter form and is rarely found in January.

Griffithsia monilis Harvey 1854, 559; 1860 b, 332, pl. 195 B. De Toni 1903, 1,283. Lucas and Perrin 1947, 326. — *PB*. In the sublittoral fringe and *Cystophora*-coralline association, May 1945, Jan. 1947, Aug. and Dec. 1948.

Griffithsia ovalis Harvey 1854, 559; 1862, pl. 203. De Toni 1903, 1,277. Lucas and Perrin 1947, 325, f. 156. — *AR*. Sublittoral near Muston, Nov. 1947.

Monosporeae

NEOMONOSPORA Setchell and Gardner

Setchell and Gardner (1937, 86) have pointed out that *Monospora* Solier is antedated by *Monospora* Hochstetter, a genus of Angiosperms, and have renamed the algal genus *Neomonospora*. The following species were reported as *Monospora* in Pt. I and II, and they are now transferred to *Neomonospora*.

Neomonospora elongata (Harvey) nov. comb.
Callithamnion elongatum Harvey 1860 b, 336. *Monospora elongata*, De Toni 1903, 1,302. Lucas and Perrin 1947, 331. — *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1947. *VB*. Drift, May 1945. *PB*. Sublittoral fringe and *Cystophora*-coralline associations (often epiphytic on larger algae), May 1945, Jan., Nov. 1947, Dec. 1948, and drift, May 1945, Jan. 1946, 1948. The sublittoral fringe plants are stunted and more compact than those cast up from deeper water.

Neomonospora griffithsioides (Sonder) nov. comb.
Callithamnion griffithsioides Harvey 1860 a, pl. 160. *Monospora griffithsioides*, De Toni 1903, 1,302. Lucas and Perrin 1947, 331. — *VB*. Drift, Jan. 1948, 1949. *CW*. Drift, Jan. 1946.

Neomonospora licmophora (Harvey) nov. comb.
Callithamnion licmophora Harvey 1859, pl. 90. *Monospora licmophora* De Toni 1903, 1,301. Lucas and Perrin 1947, 329, f. 160. — *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1947.

Callithamnieae

CALLITHAMNION Lyngbye

Callithamnion laricinum Harvey 1854, 562; 1862, pl. 218. De Toni 1903, 1,330. Lucas and Perrin 1947, 332, f. 161. — *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1948. *VB*. On *Perithalia inermis* and *Laurencia elata*, drift, Jan. 1948, 1949. *PB*. On *Laurencia elata* and other algae in the sublittoral fringe, all seasons. *AB*. Drift, Aug. 1948.

Spongoclonieae

HALOPLEGMA Montagne

Haloplegma preissii Sonder 1846, 171. Harvey 1859, pl. 79. De Toni 1903, 1,366. Lucas and Perrin 1947, 336, f. 163. — *MR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948, 1949 and sublittoral fringe on a reef in the bay, Jan. 1947. *PB*. Sublittoral fringe on reefs, Jan. 1946, 1947, 1948, in a shaded littoral pool, Jan. 1944, and drift, Jan. 1946, 1948. *AB*. Drift, Aug. 1948.

SPONGOCLONIUM Sonder

SPONGOCLONIUM BROUNIANUM (Harvey) J. Agardh 1892, 41. De Toni 1903, 1,358. Lucas 1927 a, 464, pl. 28, 29. Lucas and Perrin 1947, 334. *Callithamnion brounianum* Harvey 1854, 561. — *PB*. Drift, Jan. 1948.

SPONGOCLONIUM FASCICULATUM J. Agardh 1894 a, 118. De Toni 1903, 1,358. Lucas 1927 a, 464, pl. 27. — *MR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948. *PB*. Drift, Jan. 1947, 1948.

These specimens agree well with J. B. Wilson's specimen in Melbourne National Herbarium (Lucas, pl. 27). The type species of the genus, *S. conspicuum* Sonder is poorly known, and the differences between it and *S. fasciculatum* need careful study.

PTILOTEAE

EUPTILOTA Kützing

EUPTILOTA ARTICULATA (J. Agardh) Schmitz. De Toni 1903, 1,370. Levring 1946, 224, f. 6. Lucas and Perrin 1947, 338, f. 164. *Ptilota articulata* J. Agardh 1876, 78. — *WB*. Drift, Jan. 1946. *VB*. Drift, Jan, 1946, 1948, 1949. *PB*. Drift, Jan. 1946, 1947, 1948.

EUPTILOTA CORALLOIDEA (J. Agardh) Kützing 1849, 672. De Toni 1903, 1,371. Lucas and Perrin 1947, 338. *Ptilota coralloidea* J. Agardh 1876, 78. — South coast. Winter 1939, coll. J. Cork.

PERISCHELIA J. Agardh

PERISCHELIA GLOMERULIFERA J. Agardh 1897, 34. De Toni 1924, 530. *Thamnocarpus ? glomeruliferus* J. Agardh 1885, 6. Lucas and Perrin 1947, 372. — *VB*. Drift, Jan. 1948, 1949.

DASYPHILEAE

DASYPHILA Sonder

DASYPHILA PREISSII Sonder 1846, 169. Harvey 1859, pl. 66. De Toni 1903, 1,387. Lucas and Perrin 1947, 342, f. 169. — *MR*. Drift, Jan. 1946. *VB*. Drift, Jan. 1949. *PB*. Drift, Jan. 1944, May 1945, Jan. 1946, 1948. *AB*. Drift, Aug. 1948.

MUELLERENA Schmitz

MUELLERENA INSIGNIS (Harvey) De Toni 1903, 1,389. Lucas and Perrin 1947, 346, f. 171. *Crouania insignis* Harvey 1860 b, 331, t. 193 B. J. Agardh 1876, 87. — *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1944, 1946, 1947, 1948 and in the sublittoral fringe, main reef (often on *Phacelocarpus labillardieri*), Jan. 1946, Jan., Nov. 1947, Jan., Dec. 1948. Specimens growing on the reefs are much more compact and stouter than those from deeper water.

GULSONIA Harvey

GULSONIA ANNULATA Harvey 1860 b, 320, pl. 193 A. J. Agardh 1894 a, 122, t. 2, f. 13; 1897, 56. De Toni 1897, 66. — *VB*. Drift, Jan. 1949. *PB*. Drift, Jan. 1948.

The position of this genus is uncertain and needs thorough investigation.

CROUANIEAE

ANTITHAMNION Naegeli

ANTITHAMNION DISPAR (Harvey) J. Agardh 1892, 20. De Toni 1903, 1,405. Lucas and Perrin 1947, 353, f. 176. *Callithamnion dispar* Harvey 1862, pl. 227. — *PB*. Drift, May, 1945.

ANTITHAMNION HANOWIOIDES (Sonder) De Toni 1903, 1,398. Lucas and Perrin 1947, 352. *Callithamnion hanowioides* Sonder 1852, 674. J. Agardh 1876, 55. — *MR*. Drift, Jan. 1946. *WB*. On *Laurencia elata*, drift, Jan. 1946. *PB*. On *Laurencia heteroclada, L. elata, Gelidium australe, Rhodymenia, Caulerpa brownii* and other species in the sublittoral fringe, all seasons.

ANTITHAMNION MUCRONATUM (J. Agardh) Naegeli. De Toni 1903, 1,410. Lucas and Perrin 1947, 355. *Callithamnion mucronatum* J. Agardh 1851, 29; 1876, 19. Harvey 1863, syn. n. 688. — *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1948. *VB*. Drift, Jan. 1948. *PB*. Drift, Jan. 1944, May 1945, Jan. 1946, 1947, 1948.

ANTITHAMNION NODIFERUM J. Agardh 1892, 20. De Toni 1903, 1,404. Lucas and Perrin 1947, 353. *Callithamnion nodiferum* J. Agardh 1876, 25. *Callithamnion simile* Harvey 1862, pl. 207 (excl. syn.). — *WB*. Drift, Jan. 1946. *PB*. Drift, Jan. 1948.

BALLIA Harvey

BALLIA CALLITRICHA (Agardh) Montagne. J. Agardh 1851, 75. Kützing 1862, t. 37. Harvey 1863, syn. n. 656. De Toni 1903, 1,393. Lucas and Perrin 1947, 350, f. 174. — *WR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1948. Sou'-West River mouth, Dec. 1934 (Cleland and Black) and drift, Jan. 1945. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift Jan. 1944, 1946, 1948.

BALLIA ROBERTIANA Harvey 1858, pl. 36. J. Agardh 1876, 588. De Toni 1903, 1,394. Lucas and Perrin 1947, 349, f. 173. — *CC*. Drift, Jan. 1945.

BALLIA SCOPARIA Harvey 1860 a, pl. 168. De Toni 1903, 1,395. Lucas and Perrin 1947, 351, f. 175. — *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1949. *PB*. Drift, Jan. 1946, Jan., Aug. 1948 and in the sublittoral fringe on reefs, all seasons (stunted).

CROUANIA J. Agardh

CROUANIA AUSTRALIS (Harvey) J. Agardh 1876, 85. De Toni 1903, 1,418. Lucas and Perrin 1947, 355. *Crouania attenuata* var. *australis* Harvey 1863 syn. n. 635. — *AR*. No details. This specimen agrees well with Harvey's 485 B in Melbourne National Herbarium. Specimens from the upper sublittoral near the mouth of the inlet, Aug. 1948, are probably a form of this species.

CROUANIA MUELLERI Harvey 1863, syn. n. 638. J. Agardh 1876, 85. De Toni 1903, 1,419. Lucas and Perrin 1947, 356. — *VB*. Drift, Jan. 1948. *PB*. On *Cystophora intermedia, C. siliquosa* and *C. spartioides* in the sublittoral fringe, Jan. and Nov. 1947, Jan. and Dec. 1948.

CROUANIA VESTITA Harvey 1860 a, pl. 140. J. Agardh 1876, 86. De Toni 1903, 1,419. Lucas and Perrin 1947, 356, f. 177. — *CC*. Drift, Jan. 1946. *AB*. Drift, Aug. 1948.

LASIOTHALIA Harvey

LASIOTHALIA FORMOSA (Harvey) De Toni 1903, 1,421. Lucas and Perrin 1947, 357. *Callithamnion formosum* Harvey 1863, pl. 281. — *VB*. Drift, Jan. 1948. *PB*. Drift Jan. 1944, 1946, 1947, 1948.

PTILOCLADIA Sonder

PTILOCLADIA PULCHRA Sonder 1846, 170. Harvey 1862, pl. 209. De Toni 1903, 1,424. Lucas and Perrin 1947, 360, f. 180. — *WB*. Drift Jan. 1946. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1946, 1947, 1948.

Spyridieae

SPYRIDIA Harvey

Spyridia biannulata J. Agardh 1876, 267; 1897, 13. De Toni 1903, 1,426. Lucas and Perrin 1947, 363. — *AR.* Upper sublittoral throughout the inlet, all seasons. *K.* Drift, Jan. 1944. *BS.* Upper sublittoral, June 1947. *VB.* Shaded end of pool 1, south side of Ellen Point, Jan. 1946, 1947. *RP.* Low littoral pools, Jan. 1944, 1945, 1948, and drift, Jan. 1944, 1948.

Spyridia opposita Harvey 1860 a, pl. 158. J. Agardh 1876, 270. De Toni 1903, 1,431. Lucas and Perrin 1947, 363, f. 182. — *WB.* Drift, Jan. 1946. *VB.* Drift, Jan. 1948, 1949. *DB.* Sublittoral fringe on reefs, Jan. 1947. *PB.* in pools of the sublittoral fringe, Jan. 1944, 1946, 1948, Dec. 1948. *CW.* Drift, Jan. 1946.

Ceramieae

CENTROCERAS Kützing

Centroceras clavulatum (Agardh) Montagne. J. Agardh 1876, 108. Smith 1944, 328, pl. 84, f. 5-6. *Ceramium clavulatum,* De Toni 1903, 1,491. — *AR.* Upper sublittoral throughout the inlet, often epiphytic on larger algae, all seasons; in late winter (July-Nov.) forming dense red-brown tufts to 12 cm. high on pebbles along the shore (mid-littoral) near American River jetty. *CC.* In rock pools, Jan. 1944 and lower littoral, Jan. 1948. *VB.* Mid littoral at the end of Ellen Point, Jan. 1946, and in rock pools, Jan. 1946. PB. Rear littoral, May 1945. Also found amongst other algae almost anywhere around the island.

CERAMIUM Wiggers

Ceramium isogonum Harvey 1854, 55; 1862, pl. 206 B. J. Agardh 1876, 96. De Toni 1903, 1,469. Lucas and Perrin 1947, 369, f. 186. — *PB.* Drift, May 1945.

Ceramium miniatum Suhr. Harvey 1862, pl. 206 A. De Toni 1903, 1,454. Lucas and Perrin 1947, 367, f. 185. — *AR.* On black buoy, Jan., Sept. 1946, Jan. 1947, 1948. *MR.* On *Corallina,* lower littoral, Jan. 1947. *VB.* On *Laurencia heteroclada* in rock pools, south side of Ellen Point, May 1945. *PB.* On *Laurencia heteroclada* in the littoral and drift, May 1945. *AB.* On molluscs in the mid littoral, Jan. 1947. The Australian species which passes under this name needs careful checking with authentic material from Peru, the type locality.

Ceramium nobile J. Agardh 1894 b, 41. De Toni 1903, 1,480. Lucas and Perrin 1947, 369. — *VB.* Drift, Jan. 1948. *PB.* On *Spyridia opposita, Laurencia heteroclada* and other algae in the sublittoral fringe, all seasons.

Ceramium puberulum Sonder 1946, 167. J. Agardh 1876, 102. De Toni 1903, 1,452. Lucas and Perrin 1947, 367. — *AR.* On *Posidonia,* upper sublittoral, all seasons. *EB.* Drift, Jan. 1946. *WR.* Drift, Jan. 1946. *PB.* On *Posidonia,* drift, May 1945, Jan. 1946, 1948. *RP.* On *Posidonia,* drift, June 1947, Aug. 1948

Wrangelieae

WRANGELIA Agardh

Wrangelia clavigera Harvey 1863, pl. 287. J. Agardh 1876, 621. De Toni 1897, 132. Lucas and Perrin 1947, 140, f. 13. — *PB.* Sublittoral fringe (mainly 1-2 ft. down side of main reef), all seasons.

WRANGELIA CRASSA Hooker and Harvey. Harvey 1860 b, 308. J. Agardh 1876, 620. De Toni 1897, 131. Lucas and Perrin 1947, 138. — *CC*. Drift, Jan. 1947. *VB*. Drift, Jan. 1949. *PB*. Drift, Jan. 1946, 1948, and in a shaded pool, Jan. 1944. Orig. Det., V. May.

WRANGELIA HALURUS Harvey 1859, pl. 170. J. Agardh, 1876, 619. De Toni 1897, 130. Lucas and Perrin 1947, 138. — *WB*. Drift, Jan. 1946. *VB*. Drift. Jan. 1948.

WRANGELIA MYRIOPHYLLOIDES Harvey 1854, 564; 1862, pl. 224. J. Agardh 1876, 617. De Toni 1897, 128. Lucas and Perrin 1947, 136. — *MR*. Drift, Jan. 1946. *PB*. Drift, Jan. 1944; Jan., Aug. 1948.

WRANGELIA PLUMOSA Harvey 1844, 450. J. Agardh 1876, 624. De Toni 1897, 136. Lucas and Perrin 1947, 143, f. 16. — *AR*. On black buoy, Sept. 1946, and upper sublittoral along channel near buoys, Nov. 1947. — *MR*. Lower littoral, Jan. 1947. *WR*. Lower littoral, Jan. 1946. *HR*. In a low rock pool, Jan. 1948. *PB*. Sublittoral fringe and littoral pools on reefs, all seasons, but variable. *AB*. Lower littoral, Jan. 1947.

WRANGELIA PRINCEPS Harvey 1862, pl. 234; J. Agardh 1876, 624. De Toni 1897, 136. Lucas and Perrin 1947, 143. — *PB*. Drift, Jan. 1946 (on *Codium galeatum*) and Jan. 1949.

WRANGELIA PROTENSA Harvey 1860 b, 308. J. Agardh 1876, 619. De Toni 1897, 130. Lucas and Perrin 1947, 137, f. 10. — *AR*. Upper sublittoral along channel from Muston to American River, Nov. 1947, Aug. 1948.

WRANGELIA VELUTINA Harvey 1854, 546; 1858, pl. 46. J. Agardh 1876, 617. De Toni 1897, 128. Lucas and Perrin 1947, 136, f. 9. — *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948. *PB*. Drift, Jan. 1948 and in a shaded pool, Jan. 1944.

WRANGELIA VERTICILLATA Harvey 1863, syn. n. 332. J. Agardh 1876, 619. De Toni 1897, 130. Lucas and Perrin 1947, 138, f. 11. — *WB*. Drift, Jan. 1946. *PB*. In a littoral pool, Jan. 1944.

WRANGELIA WATTSII Harvey 1862, pl. 233. J. Agardh 1876, 620. De Toni 1897, 131. Lucas and Perrin 1947, 138, f. 12. — *WB*. Drift, Jan. 1946.

DASYACEAE

DASYA C. Agardh

DASYA CAPILLARIS Hooker and Harvey. Harvey 1847, 60, pl. 19; 1860 b, 302. Kützing 1865, t. 73. De Toni 1903, 1,200. Lucas and Perrin 1947, 313. — *AR*. Sublittoral near Muston, Nov. 1947.

DASYA FEREDAYAE Harvey 1860 a, pl. 173, f. 1, 3. De Toni 1903, 1,211. — *WB*. Drift, Jan. 1946.

DASYA HAFFIAE Harvey 1860 b, 303; 1860 a, pl. 143. De Toni 1903, 1,193. Lucas and Perrin 1947, 311. — *VB*. Drift, Jan. 1948. *PB*. Drift, Jan. 1946, 1948.

DASYA NACCARIOIDES Harvey 1844, 432; 1847, 63, pl. 22. J. Agardh 1863, 1,217. De Toni 1903, 1,198. Lucas and Perrin 1947, 313. — *WB*. Drift, Jan. 1946. *PB*. Drift, Jan. 1944, May 1945, Jan. 1946 and in a deep pool on main reef, Nov. 1947.

DASYA SCOPULIFERA Harvey 1863, pl. 271. De Toni 1903, 1,185. — *PB*. Drift, Jan. 1946. A single specimen which agrees well with Harvey's figure.

DASYA URCEOLATA Harvey, Alg. Aus. exs. n. 217. J. Agardh 1863, 1,208. De Toni 1903, 1,209. Lucas and Perrin 1947, 314 — *PB*. On *Cystophora intermedia* and occasionally on *C. subfarcinata* in sublittoral fringe on main reef, May 1945, Nov. 1947, Aug., Dec. 1948. Checked with one of Harvey's specimens from Point Fairy.

DASYA VILLOSA Harvey 1847, 61, pl. 20. J. Agardh 1863, 1,215. De Toni 1903, 1,203. Lucas and Perrin 1947, 314. — *AR*. 5-6 feet below low water near Picnic Point, Jan. 1948. *MR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *VB*. Drift, Jan. 1947, 1948, 1949. *PB*. Drift, Jan. 1944, 1946, 1948.

DASYOPSIS Zanardini

DASYOPSIS CLAVIGERA Womersley 1946 b, 137, f. 1, 2, pl. 27. — *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1947, 1948. *VB*. Lower littoral, south side of Ellen Point, May 1945, Dec. 1945. *PB*. Sub-littoral fringe on reefs, all seasons.

HALODICTYON Zanardini

HALODICTYON ARACHNOIDEUM Harvey 1858, pl. 37 A. De Toni 1903, 1,246. Lucas and Perrin 1947, 322. — *AR*. Sublittoral near Muston, Nov. 1947, Jan. 1948. *RP*. Drift, Aug. 1948.

HALODICTYON ROBUSTUM Harvey 1858, pl. 37 B. De Toni 1903, 1,245. Lucas and Perrin 1947, 322. — *PB*. Drift, Jan. 1948.

HETEROSIPHONIA Montagne

HETEROSIPHONIA CURDIEANA (Harvey) Falkenberg 1901, 716. De Toni 1903, 1,236. Lucas and Perrin 1947, 318. *Dasya curdieana* Harvey in J. Agardh 1863, 1,189; 1890, 87. — *VB*. Drift, Jan. 1949. *PB*. Drift, Jan. 1948.

HETEROSIPHONIA GUNNIANA (Harvey) Falkenberg 1901, 651. De Toni 1903, 1,231. Lucas and Perrin 1947, 316, f. 153. *Dasya gunniana* Harvey 1847, 59, pl. 17; 1860 b, 301. — *AR*. Upper sublittoral, Jan. 1949. *MR*. Drift, Jan. 1946. *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1947. *PB*. Sublittoral fringe and outer pools on reefs, all seasons.

HETEROSIPHONIA MICROCLADIOIDES (J. Agardh) Falkenberg 1901, 637, t. 19, f. 5. De Toni 1903, 1,224. Lucas and Perrin 1947, 316. *Dasya microcladioides* J. Agardh 1890, 83. *Dasya pellucida* Harvey 1854, 543. — *VB*. Shaded end of pool 1, south side of Ellen Point, Jan. 1947. A few specimens which agree well with Harvey's *D. pellucida* from King George's Sound (in Melbourne National Herbarium.

HETEROSIPHONIA MUELLERI (Sonder) De Toni 1903, 1,237. Lucas and Perrin 1947, 319, f. 154. *Dasya muelleri* Sonder in Harvey 1858, pl. 31 (partim). J. Agardh 1890, 84, t. III, f. 1. — *VB*. Sublittoral fringe on reefs in the bay, Jan. 1949. *DB*. Sublittoral fringe, Jan. 1947. *PB*. Sublittoral fringe on main reef, Jan. 1947, and drift, Jan. 1946, 1948. *AB*. Drift, Aug. 1948. Eastern Cove. On sinker of buoy (12-15 feet below low water), Jan. 1948. None of these specimens is cystocarpic, so it is possible some may be *H. struthiopenna* (J. Agardh) De Toni, which has terminal cystocarps instead of the lateral, sessile ones of *H. muelleri*.

THURETIA Decaisne

THURETIA QUERCIFOLIA Decaisne. Harvey 1858, pl. 40. Falkenberg 1901, 668, t. 17, f. 1-9. De Toni 1903, 1,175. Lucas and Perrin 1947, 308, f. 147. — *WB*. Drift, Jan. 1946. *CC*. Drift, Jan. 1948. *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, Jan. 1944, 1945, 1946, 1947, 1948. *CW*. Drift. Jan. 1946.

THURETIA TERES Harvey 1862, pl. 191. Falkenberg 1901, 674. De Toni 1903, 1,176. Lucas and Perrin 1947, 309. — *CC.* Drift, Jan. 1948. *PB.* In *Cystophora*-coralline and sublittoral fringe associations (on *Cystophora subfarcinata* and *C. paniculata*), all seasons but rare.

DELESSERIACEAE — DELESSERIEAE

APOGLOSSUM J. Agardh

APOGLOSSUM TASMANICUM (F. v. Mueller) J. Agardh. De Toni 1900, 702. Kylin 1924, 23. Lucas and Perrin 1947, 231, f. 94. *Delesseria tasmanica* F. v. Mueller in Harvey 1860 b, 311, t. 190 B. J. Agardh 1876, 494. — *VB.* shaded end of pool 1, south side of Ellen Point, Jan. 1948. A few small sterile plants only.

CHAUVINIA

CHAUVINIA CORIIFOLIA Harvey 1863, syn. n. 376. Kylin 1924, 13. Lucas and Perrin 1947, 230, f. 93. *Delesseria coriifolia* Harvey 1860 a, pl. 150. — *VB.* Drift, Jan. 1948, 1949.

CLAUDEA Lamouroux

CLAUDEA ELEGANS Lamouroux. Harvey 1858, pl. 1. De Toni 1900, 748. Lucas and Perrin 1947, 237, f. 101. — *PB.* Drift, Jan. 1948 (rare).

HEMINEURA Harvey

HEMINEURA FRONDOSA (Hooker and Harvey) Harvey 1847, 116, pl. 45. Kylin 1924, 6. Lucas and Perrin 1947, 232, f. 95. *Delesseria frondosa,* Harvey 1860 a, pl. 179. — *WB.* Drift, Jan. 1946. *VB.* Drift, Jan. 1946, 1948.

HYPOGLOSSUM Kützing

HYPOGLOSSUM REVOLUTUM (Harvey) J. Agardh. De Toni 1900, 692. Lucas and Perrin 1947, 228, f. 91. *Delesseria revoluta* Harvey 1860 a, pl. 170. — *AR.* Sublittoral near Muston, Nov. 1947, and near mouth of inlet, Aug. 1948, Jan. 1949.

HYPOGLOSSUM SPATHULATUM (Kützing) J. Agardh. De Toni 1900, 689. Lucas and Perrin 1947, 227. *Delesseria spathulata* Kützing 1869, t. 12 c-e. *Delesseria hypoglossoides* Harvey 1859, pl. 87. — *AR.* Sublittoral near Muston, Nov. 1947, and near mouth of inlet, Aug. 1948.

PHITYMOPHORA J. Agardh

PHITYMOPHORA IMBRICATA (Areschoug) J. Agardh. Kylin 1924, 13. Kuehne 1946, 35, pl. 2. Lucas and Perrin 1947, 230. *Chauvinea imbricata* Harvey 1862, pl. 240. — *WB.* Drift, Jan. 1946. *CC.* Drift, Jan. 1948. *VB.* Drift, Jan. 1948, 1949. *PB.* Sublittoral fringe, main reef, Jan. 1947, 1948.

SARCOMENIA Sonder

SARCOMENIA DASYOIDES Harvey. J. Agardh 1863, 1,263; 1896, 134. De Toni 1900, 738. Lucas and Perrin 1947, 234, f. 96. — *WB.* Drift, Jan. 1946. *VB.* Drift, Jan. 1946, 1948. *PB.* In pools of the sublittoral fringe, Jan. 1946, 1947, Jan., Dec. 1948, Jan. 1949.

SARCOMENIA DELESSERIOIDES Sonder. Harvey 1860 a, pl. 121. J. Agardh 1896, 137. De Toni 1900, 742. Lucas and Perrin 1947, 236, f. 100. — *CC.* Drift, Jan. 1948. *VB.* Drift, Jan. 1949. *PB.* Drift, May 1945, Jan. 1946.

SARCOMENIA MUTABILIS (Harvey) J. Agardh 1896, 134. De Toni 1900, 736. Lucas and Perrin 1947, 234. — *AR.* Upper sublittoral along channel, July, Nov. 1947, Aug. 1948 (probably a winter form).

SARCOMENIA TENERA (Harvey) J. Agardh 1896, 136. De Toni 1900, 740. *Polysiphonia tenera* Harvey 1863, pl. 257. Lucas and Perrin 1947, 234, pl. 99. — *AR.* Upper sublittoral near the mouth, May 1945, July, Nov. 1947, Aug. 1948 (probably a winter form).

NITOPHYLLEAE

CRYPTOPLEURA Kützing

CRYPTOPLEURA ENDIVIAEFOLIA (Hooker and Harvey) Kylin 1924, 91. *Delesseria endiviaefolia* Hooker and Harvey 1847, 403. Kützing 1869, t. 11. *Nitophyllum endiviaefolium* J. Agardh 1876, 461. De Toni 1900, 637. — *WB.* Drift, Jan. 1945, 1946. *CC.* Drift, Jan. 1947, 1948.

HYMENEMA Greville

HYMENEMA CURDIEANA (Harvey) Kylin 1924, 79. *Nitophyllum curdieanum* Harvey 1860 a, pl. 151. J. Agardh 1876, 458. De Toni 1900, 658. Lucas and Perrin 1947, 223, f. 89, 90. — *WB.* Drift, Jan. 1946. *CC.* Drift, Jan. 1944, 1948. *VB.* Drift, Jan. 1946, 1949.

MYRIOGRAMME Kylin

MYRIOGRAMME EROSA (Harvey) Kylin 1924, 61. *Nitophyllum erosum* Harvey 1859, pl. 94. J. Agardh 1876, 460. De Toni 1900, 639. — *WB.* Drift, Jan. 1946. *CC.* Drift, Jan. 1947. *VB.* Drift, Jan. 1949.

MYRIOGRAMME PRISTOIDEA (Harvey) Kylin 1924, 61. *Nitophyllum pristoideum* Harvey 1862, pl. 229. J. Agardh 1876, 460. De Toni 1900, 640. Lucas and Perrin 1947, 222, f. 86. — *WB.* Drift, Jan. 1946. *CC.* Drift, Jan. 1947. *VB.* Drift, Jan. 1949.

RHODOMELACEAE — POLYSIPHONIEAE

CHIRACANTHIA Falkenberg

CHIRACANTHIA ARBOREA (Harvey) Falkenberg 1901, 179, t. 19, f. 18-23. De Toni 1903, 971. *Acanthophora arborea* Harvey 1860 b, 296; 1860 a, pl. 132. — *AR.* Sublittoral near and outside the mouth of the inlet, all seasons.

LOPHURELLA Schmitz

LOPHURELLA PERICLADOS (Sonder) Schmitz. Falkenberg 1901, 154, t. 19, f. 24-26. De Toni 1903, 855. *Rhodomela periclados,* Harvey 1858, pl. 28. — *PB.* Sublittoral fringe, main reef, Jan. 1947 (rare).

POLYSIPHONIA Greville

POLYSIPHONIA ABSCISSA Hooker and Harvey. Hooker 1847, 480, pl. 183, f. 2. De Toni 1903, 879. Lucas and Perrin 1947, 267. — *PB.* In rear littoral pools, all seasons. *CW.* In low rock pools, Jan. 1948.

POLYSIPHONIA CANCELLATA Harvey 1847, 51, pl. 15. De Toni 1903, 928. Lucas and Perrin 1947, 273. — *AR.* Sublittoral along channel, often on *Posidonia,* all seasons. *AB.* (no details).

POLYSIPHONIA DASYOIDES Zanardini 1874, 489. De Toni 1903, 954. Lucas and Perrin 1947, 266. — *CC.* In rock pools, Jan. 1944. *VB.* Upper littoral (splash area), south side of Ellen Point, Jan. 1946. *PB.* In littoral pools, Jan. 1944, Nov. 1947, and sublittoral fringe, May 1945, Jan. 1946, April 1947, (often epiphytic on larger algae).

No authentic specimens of this species are available in Australia, but agreement with Zanardini's description is very good.

POLYSIPHONIA DAVYAE Reinbold 1899, 49. De Toni 1903, 913. Lucas and Perrin 1947, 265. — *AR.* On *Posidonia* in upper sublittoral, all seasons but not common. *PB.* Drift, Jan. 1946. *RP.* Drift, Aug. 1948.

POLYSIPHONIA FRUTEX Harvey 1847. 52; 1860 b. 301. Kützing 1863, t. 66 d-e. De Toni 1903, 925. Lucas and Perrin 1947, 273, f. 122. — *VB.* Mid littoral on reef in bay, Jan. 1946. *DB.* Lower littoral on reefs, Jan. 1947. *PB.* Littoral, and in pools, all seasons. *AB.* Lower littoral, Jan. 1947.

POLYSIPHONIA FUSCESCENS Harvey 1847, 52; 1860 b, 301. Kützing 1863, t. 67 a-d. De Toni 1903, 925. Lucas and Perrin 1947, 273. — *AR.* Sublittoral and upper sublittoral along channel and throughout lagoons, all seasons. *RP.* Drift, Aug. 1948. This species is very closely related to *P. frutex*, and possibly only an extreme ecological form. *P. fuscescens* is more loosely and distantly branched, and a slenderer plant than *P. frutex,* and grows in much calmer conditions around Kangaroo Island.

POLYSIPHONIA HOOKERI Harvey 1847, 40, pl. 12; 1860 b, 299. Kützing 1864, t. 17. De Toni 1903, 905. Lucas and Perrin 1947, 263, f. 119. — *AR.* Sublittoral near Muston, Nov. 1947. *PB.* Drift, Jan. 1947.

POLYSIPHONIA HYSTRIX Hooker and Harvey. Harvey 1847, 41, pl. 14; 1860 b, 299. Kützing 1864, t. 18 a-c. De Toni 1903, 906. Lucas and Perrin 1947, 265, f. 120. — *MR.* Drift, Jan. 1946.

POLYSIPHONIA MALLARDIAE Harvey 1847, 40, pl. 13; 1860 b, 299. Kützing 1864, t. 22 c-e. De Toni 1903, 908. Lucas and Perrin 1947, 265, f. 121. — *AR.* Sublittoral near Muston, Nov. 1947, Jan. 1948. *MR.* Drift, Jan. 1946. *WB.* Drift, Jan. 1946. *VB.* Drift, Jan. 1948. *PB.* Drift, Jan. 1948, and in a shaded pool, Jan. 1944.

POLYSIPHONIA NIGRITA Sonder 1846, 181. Harvey 1847, 51. Kützing 1863, t. 67 e-h. Lucas and Perrin 1947, 274. — *WB.* Drift, Jan. 1946. CC. Drift, Jan. 1944, 1947, 1948. *PB.* Sublittoral fringe, all seasons (epiphytic on other algae). *CW.* Lower littoral, Jan. 1946.

P. nigrita differs from *P. cancellata* in not having the pericentral cells arranged in distinct rows, as seen in face view.

POLYSIPHONIA PATERSONIS Sonder. Kützing 1864, t. 18 d-f. *Polysiphonia spinosissima* Harvey 1860 a, pl. 155. *Brongniartella spinosissima,* Falkenberg 1901, 548, t. 19, f. 11-12. Lucas and Perrin 1947, 283. — *AR.* Lower littoral on the tidal flats, all seasons. The trichoblasts in this species are confined to the ends of the branches as in *Polysiphonia.*

POLYSIPHONIA SUCCULENTA Harvey 1860 b, 300. J. Agardh 1863, 969. De Toni 1903, 879. Lucas and Perrin 1947, 267. — *AR.* On *Posidonia* in the upper sublittoral throughout the lagoons, all seasons, common. *RP.* Drift, Aug. 1948.

LOPHOTHALIEAE

BRONGNIARTELLA Bory

BRONGNIARTELLA AUSTRALIS (Agardh) Schmitz. Falkenberg 1901, 546, t. 19, f. 6-7. De Toni 1903, 1,010. Lucas and Perrin 1947, 283, f. 130. *Polysiphonia cladostephus* Harvey 1860 a, pl. 154. — *AR.* Sublittoral along channel, all seasons but commonest in winter. *VB.* Mid littoral on well-washed rock in bay, Jan. 1946, 1948. *DB.* Drift, Jan. 1947. *PB.* Drift, all seasons. *RP.* Drift, Aug. 1948. The American River form is a larger, looser and softer plant than those from the south coast.

BRONGNIARTELLA FEREDAYAE (J. Agardh) Schmitz. De Toni 1903, 1,014. *Dasya feredayae* J. Agardh 1863, 1,235. Harvey 1860 b, 303. — *VB.* Lower littoral, north side of Ellen Point, Jan. 1948, and drift, Jan. 1948, 1949. *PB.* Sublittoral fringe on a western reef, Dec. 1948, and drift, Jan. 1946, 1948.

BRONGNIARTELLA SARCOCAULON (Harvey) Schmitz. De Toni 1903, 1,013. Lucas and Perrin 1947, 285. *Dasya sarcocaulon* Harvey 1863, pl. 278. — *PB.* Drift, Jan. 1946. *CW.* In an exposed pool, south side, Aug. 1948.

DOXODASYA Schmitz

DOXODASYA BULBOCHAETE (Harvey) Falkenberg 1901, 538, t. 13, f. 21-22. De Toni 1903, 1,021. Lucas and Perrin 1947, 286, f. 131. *Dasya bulbochaete* Harvey 1847, 65, pl. 25. — *VB.* Drift, Jan. 1948. *PB.* Drift, Jan. 1944, 1946.

LOPHOCLADIA Schmitz

LOPHOCLADIA HARVEYI (Kützing) Schmitz. Falkenberg 1901, 553. De Toni 1903, 1,016. *Dasya harveyi* Kützing 1864, 26, t. 71 e-f. *Dasya lallemandi,* Harvey 1854, 543. — *AR.* Upper sublittoral on Pig Island, April 1947, and on the cockle bank near the mouth, Jan. 1948, and drift, May 1945.

BOSTRYCHIEAE

BOSTRYCHIA Montagne

BOSTRYCHIA MIXTA Hooker and Harvey. Harvey 1860 a, pl. 176 A. De Toni 1903 1,150. — *AR.* Upper littoral on shaded rock throughout the inlet, mixed in small amount with *B. simpliciuscula,* all seasons. *PB.* On shaded rock in rear littoral, main reef, Aug. 1948, Jan. 1949. *RP.* Upper littoral, all seasons.

BOSTRYCHIA SIMPLICIUSCULA Harvey. J. Agardh 1863, 854. Falkenberg 1901, 152. De Toni 1903, 1,155. Lucas and Perrin 1947, 306. *Bostrychia rivularis,* Harvey 1860 a, pl. 176 B. — *AR.* Upper littoral on shaded rock throughout the inlet, all seasons. *PB.* On shaded rock, rear littoral main reef, May 1945 (rare). *AB.* Upper littoral, Jan. 1945. *RP.* Upper littoral, all seasons.

CHONDRIEAE

CHONDRIA C. Agardh

CHONDRIA DASYPHYLLA (Woodward) C. Agardh. De Toni 1903, 842. Newton 1931, 342, f. 211. Taylor 1937, 359. — *AR.* Upper sublittoral on tidal flats, Feb. 1946, April 1947.

J. Agardh (1892, 148-160) described a number of species of *Chondria* from southern Australia, some of which had previously been placed under *Ch. dasyphylla.* At least three species of *Chondria* occur at American River, and one species in the sublittoral fringe at Pennington Bay, but without examining authentic specimens of J. Agardh's it is difficult to place these. The specimens determined as *Ch. dasyphylla* agree well with Newton's figure.

CLADURUS Falkenberg

CLADURUS ELATUS (Sonder) Falkenberg 1901, 223, pl. 22, f. 1. De Toni 1903, 814. Lucas and Perrin 1947, 251, f. 111. *Rytiphloea elata,* Harvey 1862, pl. 236. — *MR.* Drift, Jan. 1946. *VB.* Drift, Jan. 1948, 1949. *PB.* Drift, Jan. 1946.

COELOCLONIUM J. Agardh

COELOCLONIUM OPUNTIOIDES (Harvey) J. Agardh 1876, 640. Falkenberg 1901, 211, t. 22, f. 32-34. De Toni 1903, 825. Lucas and Perrin 1947, 256. *Chondria opuntioides* Harvey 1860 b, 297, pl. 189. — AR. Upper sublittoral along channel, especially near the mouth, May to Nov. (a winter form). *VB*. Drift, Jan. 1946. *PB*. Drift, May 1945, Jan. 1947. *AB*. Drift, Aug. 1948. *RP*. Drift, Aug. 1948.

LAURENCIEAE

JANCZEWSKIA Solms

JANCZEWSKIA TASMANICA Falkenberg. Engler and Prantl 1897, 432, t. 243 C. Falkenberg 1901, 257, t. 24, f. 18-19. De Toni 1903, 812. Setchell 1914 b, 16. Lucas and Perrin 1947, 250. — *PB*. On *Laurencia elata* in the sublittoral fringe, Jan. 1948, Dec. 1948, and on *Laurencia heteroclada* in the rear littoral, Sept. 1946. *CW*. On *L. heteroclada*, lower littoral, Jan. 1946. Reinbold (1899, 47) lists a *J. australis* Falkenberg from Investigator Strait. De Toni lists this nomen nudum with a query under *J. tasmanica*, and Setchell (p. 18) comments that it may be distinct from *J. tasmanica*. The Kangaroo Island specimens seem to agree well with *J. tasmanica*, and *J. australis* is probably the same species.

LAURENCIA Lamouroux

LAURENCIA BOTRYODES (Turner) Gaillon. Harvey 1862, pl. 182. De Toni 1903, 802. Yamada 1931 a, 230. — *BH*. Very low littoral, Oct. 1947. *CC*. Lower littoral, Jan. 1948. *PB*. Sublittoral fringe and *Cystophora*-coralline associations on reefs, all seasons. *CW*. Rock pools, south side, Aug. 1948.

L. botryoides is very variable in size and stoutness, but fertile specimens are distinctive in the peculiar wart-like, crowded, tetrasporic receptacles. The PB specimens were reported in Pt. II, 159, under the m.s. name of *L. robusta;* fertile specimens show that they are only a stunted form (2-5 cm. high) of *L. botryoides*. The BS specimens are robust plants, to 20 cm. high, with the tetrasporic receptacles almost completely covering the branches.

LAURENCIA CLAVATA Sonder 1852, 694. Yamada 1931 a, 228. *Chondria clavata* Harvey 1860 a, pl. 189. *Corynecladia clavata*, De Toni 1903, 810. — *AR*. Sublittoral near Muston, Jan. 1948. *K*. Drift, Jan. 1945. *RP*. Drift, June 1947.

LAURENCIA ELATA (Agardh) Harvey 1847, 81, pl. 33. De Toni 1903, 803. Yamada 1931 a, 241, pl. 26 a, b. Lucas and Perrin 1947, 249, f. 110. — *HR*. Low pools, Jan. 1949. *PB*. Sublittoral fringe and to 3 feet down the sides of reefs, all seasons.

LAURENCIA GRACILIS Hooker and Harvey. Harvey 1847, 84. De Toni 1903, 780. Yamada 1931 a, 212, pl. 12 b. — *AR*. Low littoral on Pig Island, Dec. 1948; upper sublittoral on Wallaby Island, July 1947, and on cockle bank, Jan. 1948. *BS*. Sublittoral on *Posidonia*, June 1947. *EB*. Upper sublittoral on *Posidonia*, Jan. 1945.

LAURENCIA HETEROCLADA Harvey 1860 a, pl. 148. De Toni 1903, 782. Yamada 1931 a, 238. Lucas and Perrin 1947, 247. — *WR*. Lower littoral and pools, Jan. 1946. *CC*. Rock pools, Jan. 1944. *VB*. Rock pools, south side of Ellen Point, Jan. 1948. *PB*. Littoral on reefs, all seasons. *CW* and *AB*. Lower littoral, Jan. 1947. *L. heteroclada* probably occurs throughout the

Exposed Rocky Coast Subformation, in the littoral and low rock pools. It is a variable species, and the relations between it and *L. filiformis* and *L. forsteri* need careful examination.

LAURENCIA MAJUSCULA (Harvey) Lucas 1935, 223. *Laurencia obtusa* var. *majuscula* Harvey 1863, syn. n. 309 b. Yamada 1931 a, 223, pl. 16 C. — *AR*. Upper sublittoral on Pig Island, Jan. 1947, Dec. 1948.

LAURENCIA TASMANICA Hooker and Harvey. Harvey 1847, 84. J. Agardh 1876, 654. De Toni 1903, 795. Yamada 1931 a, 234, pl. 21. Lucas and Perrin 1947, 249. — *AR*. Upper sublittoral behind Wallaby Island, Aug. 1948. *BH*. Lowest littoral, Oct. 1947. These specimens agree well with Yamada's plate of an authentic specimen, and with Harvey's from Tasmania.

PTEROSIPHONIEAE

DICTYMENIA Greville

DICTYMENIA HARVEYANA Sonder 1852, 698. Harvey 1860 b, 296. Kützing 1864, t. 95 a-b. Falkenberg 1901, 283, t. 19, f. 17. De Toni 1903, 983. Lucas and Perrin 1947, 282, f. 129. *Dictymenia tridens* Harvey 1847, 28, t. 7. — *AR*. Upper sublittoral between Muston and the mouth, May 1945, Nov. 1947, Jan. and Aug. 1948. *VB*. Drift, Jan. 1949. *RP*. Drift, June 1947, Aug. 1948.

DICTYMENIA TRIDENS (Mertens) Greville. Kützing 1864, t. 94 f-g. Falkenberg 1901, 287. De Toni 1903, 985. Lucas and Perrin 1947, 281, f. 128. — *VB*. Drift, Jan. 1948, 1949.

JEANNERETTIA Hooker and Harvey

JEANNERETTIA LOBATA Hooker and Harvey. Harvey 1847, 20, pl. 4; 1858, pl. 33. Papenfuss 1942, 448. *Pollexfenia lobata*, Falkenberg 1901, 295. De Toni 1903, 979. Lucas and Perrin 1947, 278. — *VB*. Drift, Jan. 1948. *PB*. Drift Jan. 1946, 1948, and in the sublittoral fringe, main reef, Jan. 1948.

JEANNERETTIA PEDICELLATA (Harvey) Papenfuss 1942, 448. *Pollexfenia pedicellata* Harvey 1847, 22, pl. 5. Falkenberg 1901, 291, t. 4, f. 14-19. De Toni 1903, 979. Lucas and Perrin 1947, 278. — *AR*. Upper sublittoral throughout the inlet, June to Nov. *AB*. Drift, Aug. 1948. *RP*. Drift, June 1947, Aug. 1948. This seems to be mainly a winter form, and is extremely variable in thallus width (from 4 to 15 mm.).

LOPHOSIPHONIEAE

LOPHOSIPHONIA Falkenberg

LOPHOSIPHONIA SCOPULORUM (Harvey) comb. nov.
Polysiphonia scopulorum Harvey 1854, 540; Alg. Aus. Exs. n. 186. J. Agardh 1863, 940. Kützing 1864, t. 37 a-c. De Toni 1903, 1,065. — *PB*. Forming brownish red patches on rock in the rear littoral on reefs, all seasons.

This material is identical with Harvey's 186 a from Fremantle of *P. scopulorum* (in Melbourne National Herbarium), but the species is clearly a *Lophosiphonia*.

POLYZONIEAE

CLIFTONAEA Harvey

CLIFTONAEA PECTINATA Harvey 1859, pl. 100. Falkenberg 1901, 375, t. 5, f. 17-25; t. 10, f. 1-4; t. 24, f. 3. De Toni 1903, 1,039. Lucas and Perrin 1947, 289, f. 135. — *WR*. Drift, Jan. 1946. *VB*. Drift, Jan. 1948. *CW*. Drift Jan, 1948.

EUZONIELLA Falkenberg

EUZONIELLA FLACCIDA (Harvey) Falkenberg 1901, 365, t. 5, f. 10. De Toni 1903, 1,029. Lucas and Perrin 1947, 288, f. 134. *Polyzonia flaccida* Harvey 1858, pl. 42 B. — *PB*. Drift, Dec. 1948. A single cystocarpic specimen which agrees well with Harvey's figure.

EUZONIELLA INCISA (J. Agardh) Falkenberg 1901, 361, t. 5, f. 2-8, 11; t. 14, f. 28-32. De Toni 1903, 1,028. Lucas and Perrin 1947, 287, f. 133. *Polyzonia incisa*, Harvey 1858, pl. 42 A. — *WB*. Drift, Jan. 1946.

AMANSIEAE

AMANSIA Lamouroux

AMANSIA KUETZINGIOIDES Harvey 1858, pl. 51. Falkenberg 1901, 420, t. 7, f. 5. De Toni 1903, 1,085. Lucas and Perrin 1947, 296, f. 140. — *PB*. Drift, Jan. 1946, 1948.

AMANSIA PINNATIFIDA Harvey 1862, pl. 222. Falkenberg 1901, 419. De Toni 1903, 1,090. Lucas and Perrin 1947, 296. — *VB*. Drift, Jan. 1949. *PB*. Drift, Jan. 1944, May 1945, Jan. 1946, 1947, 1948. *CW*. Drift, Jan. 1946.

ANEURIA (J. Agardh) W. v. Bosse

ANEURIA LATIFOLIA (Harvey) J. Agardh 1892, 169. De Toni 1924, 429. *Lenormandia latifolia* Harvey 1847, 19. — *VB*. Drift, Jan. 1948, 1949. *PB*. Drift, all seasons.

Previously (Pt. I, 244) this species was recorded as *Lenormandia spectabilis*. Harvey considered this and *L. latifolia* to be forms of one species, but they appear to be quite distinct.

LENORMANDIA Sonder

LENORMANDIA MUELLERI Sonder. Harvey 1858, pl. 45. Falkenberg 1901, 467, t. 8, f. 13-16. De Toni 1903, 1,116. Lucas and Perrin 1947, 300, f. 142. — *WB*. Drift, Jan. 1946. *VB*. Drift, Jan 1948. *PB*. Drift, Jan. 1946, 1948.

LENORMANDIA SMITHIAE (Hooker and Harvey) Falkenberg 1901, 464, t. 8, f. 18-21. De Toni 1903, 1,120. Lucas and Perrin 1947, 303, f. 143. *Polyphacum smithiae*, Harvey 1847, 17, pl. 3. — *VB*. Drift, Jan. 1949. *PB*. Drift, Jan. 1944, May 1945, Jan. 1946, 1948.

LENORMANDIA SPECTABILIS Sonder. Harvey 1862, pl. 181. De Toni 1903, 1,117. — *VB*. Drift, Jan. 1946, 1949. A large range of specimens may show that this species is not distinct from *L. muelleri*.

OSMUNDARIA Lamouroux

OSMUNDARIA PROLIFERA Lamouroux. Falkenberg 1901, 469, t. 8, f. 24-26. De Toni 1903, 1,109. Lucas and Perrin 1947, 299, f. 141. *Polyphacum proliferum*, Harvey 1862, pl. 188. — *PB*. Drift, Jan. 1946, 1947, 1948.

PROTOKUETZINGIA Falkenberg

PROTOKUETZINGIA AUSTRALASICA (Montagne) Falkenberg 1901, 475, t. 9, f. 6 and f. 8 B. De Toni 1903, 1,076. Lucas and Perrin 1947, 295. *Rytiphloea australasica*, Harvey 1858, pl. 27. — *VB*. Drift, Jan. 1949. *DB*. Sublittoral fringe of western terraced reef, Dec. 1948, and drift, Jan. 1948. *RP*. Drift June 1947.

VIDALIA Lamouroux

VIDALIA SPIRALIS Lamouroux. Falkenberg 1901, 428. De Toni 1903, 1,106. Lucas and Perrin 1947, 298. *Epineuron spirale,* Harvey 1847, 25, pl. 9. — *VB*. Drift, Jan. 1948, 1949.

HETEROCLADIEAE

TRIGENIA Sonder

TRIGENIA UMBELLATA J. Agardh 1890, 116; 1899, 122, t. 2, f. 1-6. Falkenberg 1901, 583, t. 12, f. 14-15. De Toni 1903, 1,125. Lucas and Perrin 1947, 305, f. 145. — *CC*. Drift, Jan. 1948. *PB*. Drift, Jan. 1944, 1946.

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REFERENCES

AGARDH, J. G. **1848**, Species, Genera et Ordines Algarum **1**; **1851**, *Ibid*, **2**, pt. 1; **1852**, *Ibid*, **2**, pt. 2. **1863**, *Ibid*, **2**, pt. 3. **1870**, "Om Chatham — Oarnes Alger." K. Vet. Akad. Forhandl. No. 5, 435-456; **1872**, Till Algernes Systematik I, II, III." Lund Univ. Arsskr. Bd 9; **1876**, Species, Genera et Ordines Algarum **3**, pt. I. ("Epicrisis"); **1880**, *Ibid*, **3**, pt 2; **1882**, "Till Algernes Systematik IV, V." Lund Univ. Arskr. Bd. 17 **1883**, "Till Alg. Syst. VI," *Ibid*, Bd. 19; **1885**, "Till Alg. Syst. VII." *Ibid*, Bd. 21; **1887**, "Till Alg. Syst. VIII. *Ibid*, Bd. 23; **1889**, "Species Sargassorum Australiae." K. Svensk. Vet. Akad. Handl., Bd. 23, N. 3; **1890**, "Till Alg. Syst. IX, X, XI." Lund. Univ. Arskr., Bd. 26; **1892**, "Analecta Algologica," *Ibid*, Bd. 28; **1894a**, Anal. Alg. Cont. I, *Ibid*, Bd. 29. **1894b**, Anal. Alg. Cont. II, *Ibid*, Bd. 30; **1896**, Anal. Alg. Cont. III, Act. Reg. Soc. Physiogr. Lund., Bd. 7; **1897**, Anal. Alg. Cont. IV, *Ibid*, Bd. 8; **1899**, Anal. Alg. Cont. V, Lund. Univ. Arsskr. Bd. 35.

ARESCHOUG, J. E. **1854**, "Phyceae Novae et Minus Cognitae in Maribus Extraeuropaeis Collectae." Act. Reg. Soc. Scient. (Upssala) Ser. III, V. I, 329-372.

ASKENASY, E. **1894**, "Uber einige australische Meeres-algen." Flora V. 78, 1-18.

BLIDING, C. **1938**, "Studien uber Entwicklung und Systematik in der Gattung Enteromorpha. I." Bot. Notiser. 1938, 93-90; **1944**, "Zur Systematik der schwedischen Enteromorphen." Bot. Notiser. 1944, 331-356; **1948**, "Uber Enteromorpha intestinalis und compressa." Bot. Notiser 1948, 123-136.

BORGESEN, F. 1920, "The Marine Algae of the Danish West Indies," 2, Rhodophyceae, pt. 6;" **1931**, "Some Indian Rhodophyceae especially from the Shores of the Presidency of Bombay." Bull. of Miscell. Inform. Kew 1931, 1-24; **1946**, "Some Marine Algae from Mauritius An Additional List of Species to pt. I. Chlorophyceae." K. Danske Vid. Selskab. Biol. Med. Bd. 20, Nr. 6.

BORNET, E. **1889**, "Note sur l'Ectocarpus (Pilayella) fulvescens Thuret." Rev. Gen. de Botanique, 1889, 8, t. 1.

BORNET, E., and FLAHAULT, C. **1886**, "Revision des Nostocacees Heterocystees." Ann. des Sci. Nat. 7 Ser. Bot. (Pt. I), **3**, 323-380; (Pt. II), **4**, 343-373.

BORNET, E., and THURET, G. **1880**, "Notes Algoglogique II."

CLELAND, J. B., and BLACK, J. M. 1941, "An Enumeration of the Vascular Plants of Kangaroo Island. Additions and Corrections." Trans. Roy. Soc. S. Aust. **65**, 244-248.

COTTON, A. D. 1912, "Clare Island Survey. 15. Marine Algae." Proc. Royal Irish Acad. 31.

DAWSON, E. Y. **1944**, "The Marine Algae of the Gulf of California." Allan Hancock Pacific Expeditions. **3**, N. 10. Univ. Southern Calif. Press.

DE TONI, G. B. **1889-1924**, "Sylloge Algarum"; **1889**, 1, Chlorophyceae; **1895**, 3, Fucoideae; **1897**, 4 (1), Florideae, 1-388; **1900**, 4 (2), 387-776; **1903**, 4 (3), 775-1525; **1905**, 4 (4), 1523-1973; **1924**, 6, Florideae.

DE TONI, G. B., and FORTI, A. **1923**, "Alghe di Australia, Tasmania e Nuova Zelandia." Mem. del Reale Instit. Veneto di Scienze, Lettere de Arti. **29**, No. 3.

DOTY, M. S. **1947**, "The Marine Algae of Oregon, Pt. I. Chlorophyta and Phaeophyta." Farlowia 3, 1-65.

DROUET, F., and DAILY, W. A. **1948**, "Nomenclatural Transfers among Coccoid Algae." Lloydia **11**, 77.

ENGLER, A., and PRANTL, K. **1897**, "Die Naturlichen Pflanzenfamilien" 1. Teil, Abt. 2.

FALKENBERG, P. **1901**, "Die Rhodomelaceen des Golfes von Neapel." Monograph. 25 of "Fauna und Flora des Golfes von "Neapel."

FELDMANN, J. ET G. **1942**, "Recherches sur les Bonnemaisoniacees et leur Alternance de Generations." Ann. Science Naturelles Bot., T. 3, 75-175.

FRITSCH, F. E. **1942**, "The Interrelations and Classification of the Myxophyceae (Cyanophyceae)" New Phytologist, **41**, 134-138; **1945**, "The Structure and Reproduction of the Algae. 2."

GEPP, A. and E. S. **1911**, "The Codiaceae of the Siboga Expedition." Siboga-Expeditie Monographie LXII.

GOMONT, M. **1892**, "Monographie des Oscillariees," Ann. des Sci. Nat. 7 ser Bot. (pt. 1), **15**, 263-368, pl. 6-14, (pt. 11), **16**, 91-264, pl. 1-7; **1899**, "Sur quelques Oscillaries Nouvelles." Bull. Soc. Bot., France, **46**, 25.

HARVEY, W. H. **1844**, "Champia Tasmanica; a new Australian Alga," and "Algae of Tasmania." London Journ. of Botany, **3**, 407, pl. 19, and 428-454 resp.; **1847**, "Nereis Australis"; **1854**, "Some account of the Marine Botany of the Colony of Western Australia." Tr. Roy. Irish Acad., **22**, 525-566. **1855**, "Algae" in Hooker's "Flora Novae-Zelandiae," **2**, 211-266. **1858**, Phycologia Australica, **1**, pl. 1-60; **1859**, *Ibid*, **2**, pl. 61-120; **1860a**, *Ibid*, **3**, pl. 121-180; **1860b**, "Algae" in Hooker's "Flora Tasmanica," 282-343, pl. 185-196; **1862**, Phycologia Australica **4**, pl. 181-240; **1863**, *Ibid*. **5**, pl. 241-300; **1871**, Phycologia Britannica, I-IV. Our copy is a new edition. Setechell and Gardner 1920, p. 313 give the original dates of publication of these plates.

HEINE, E. M. **1932**, "The New Zealand species of Xiphophora with some account of the development of the oogonium." Ann. Bot. **46**, 557-569.

HOOKER, J. D. **1847**, "The Botany of the Antarctic Voyage I." Flora Antarctica, pt 2, Algae, 454-502.

HOOKER, J. D., and HARVEY, W. H. **1847**, "Algae Tasmanicae." London Journ. Bot., **6**, 397-417.

HOWE, M. A. **1918**, "Further Notes on the Structural Dimorphism of Sexual and Tetrasporic Plants in the genus Galaxaura." Brooklyn Bot. Gardens Memoirs, **1**, 191-196.

KJELLMAN, F. R. **1900**, "Om Floride — Slägtet Galaxaura." K. Svenska Vetenskaps Akad. Handl. Bd. 33, 1-109, pl. 1-20.

KUCKUCK, P. **1929**, "Fragmente einer Monographie der Phaeosporeen." Wissenshaftliche Meeresuntersuchungen, Bd. 17, N. 4.

KUEHNE, P. E. **1946**, "Four Marine Algae from Australia and New Zealand." Lloydia, **9**, 31-44.

KÜTZING, F. T. 1843, "Phycologia Generalis"; 1849, "Species Algarum"; 1845-1865, "Tabulae Phycologicae."

1845-49	1	1858	8	1865	15
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KYLIN, H. 1924, "Studien über die Delesseriaceen." Lund. Univ. Arsskr. N. F. Avd. 2 Bd. 20 N. 6; 1931, "Die Florideenordnung Rhodymeniales." *Ibid*, N. F. Avd. 2. Bd. 27. Nr. 11; 1932, "Die Florideenordnung Gigartinales." *Ibid*, N. F. Avd. 2. Bd. 28, N. 8; 1940, "Die Phaeophyceenordnung Chordariales." *Ibid*, N. F. Avd. 2. Bd. 36, N. 9; 1947, "Die Phaeophyceen der Schwedischen Westkuste," *Ibid*, N. F. Avd. 2 Bd. 43, Nr. 4; 1949, "Die Chlorophyceen der Schwedischen Westkuste," *Ibid*, N. F. Avd. 2 Bd. 45, Nr. 4.

LAING, R. M. 1905, "On the New Zealand Species of Ceramiaceae." Trans. New Zealand Institute 37, 384-408, pl. 24-31.

LEVRING, T. 1940, "Die Phaeophyceengattungen Chlanidophora, Distromium und Syringoderma." Kungl. Fysigrafiska Sallsk. i Lund Forhandl, Bd. 10 Nr. 20; 1946, "A list of Marine Algae from Australia and Tasmania." Göteborgs Bot. Trädgard. 6, 215-227.

LUCAS, A. H. S. 1927a, "Notes on Australian Marine Algae IV. The Australian species of the Genus Spongoclonium." Proc. Linn. Soc. N.S.W., 52, 460-470, pl. 27-35; 1927b, "Notes on Australian Marine Algae V." Linn. Soc. N.S.W., 52, 555-562; 1935, "The Marine Algae of Lord Howe Island." Linn. Soc. N.S.W., 60, 194-232; 1936, "The Seaweeds of South Australia," Pt. I. Govt. Printer, Adelaide.

LUCAS, A. H. S., and PERRIN, F. 1947, "The Seaweeds of South Australia," Pt. II. Govt. Printer, Adelaide.

MANZA, A. V. 1940, "A Revision of the Genera of Articulated Corallines." Philippine Journal of Science 71, 239-316, pl. 1-20.

MAY, V. 1939, "Ectocarpus confervoides (Roth) Le Jol." Linn. Soc. N.S.W., 64, 537-554; 1945, "Studies on Australia Marine Algae II." Proc. Linn. Soc. N.S.W., 70, 121-124; 1948, "The Algal Genus Gracilaria in Australia." C.S.I.R. Bull. No. 235.

MOORE, L. B. 1945, "The Genus Pterocladia in New Zealand." Tr. Royal Soc. of N. Zealand, 74, 332-342.

NEWTON, L. 1931, "A Handbook of British Seaweeds." British Museum, London.

OSBORN, J. E. M. 1948, "The Structure and life history of Hormosira banksii (Turn.) Dcne." Tr. Roy. Soc. N. Zealand, 77, 47-71.

PAPENFUSS, G. F. 1940 "Notes on South African Marine Algae I." Bot. Notiser, 1940, 200-226; 1942, "Notes on Algal Nomenclature I. Pollexfenia, Jeannerettia and Mesotrema." Proc. Nat. Acad. of Sciences, 28, 446-451; 1943, "Notes on Algal Nomenclature II. Gymnosorus J.Ag." Am. Journ. Bot. 30, 463-468; 1944, "Notes on Algal Nomenclature III. Miscellaneous species of Chlorophyceae, Phaeophyceae and Rhodophyceae." Farlowia, 1, 337-346; 1945, "Review of the Acrochaetium-Rhodochorton Complex of the Red Algae." Univ.

Calif. Publ. in Bot., **18**, 229-334; **1947a**, "Extension of the brown algal order Dictyosiphonales to include the Punctariales." Bull. Torrey Bot. Club, **74**, 398-402; **1947b**, "Generic Names of Algae Proposed for Conservation I." Madrono, 9, 8-17.

RABENHORST, L. **1932**, "Kryptogamen-Flora." Bd. 14. Cyanophyceae by L. Geiter.

REINBOLD, T. **1897**, "Die Algen der Lacepede und Guichen Bay I." Nuova Notarisia. Ser. **8**, 51-62; **1898**, Pt. II, *Ibid*, Ser. **9**, 33-54; **1899**, "Meeresalgen von Investigator Street (Sud-Australien)" Hedwigia, Bd. 38, 39-51.

REINKE, J. **1890**, "Ubersicht der bisher bekannten Sphacelariaceen." Ber. Deutsch. Bot. Gesellsch, **8**, 201-215.

SAUVAGEAU, C. **1914**, "Remarques sur les Sphacelariacees," 1-628.

SCHMIDT, O. C. **1938**, "Beiträge zur Systematik der Phaeophyten." Hedwigia, **77**, 213-230.

SETCHELL, W. A. **1914a**, "The Scinaia Assembladge." Univ. Calif. Publ. in Bot., **6**, 79-152, pl. 10-16; **1914b**, "Parasitic Florideae I." *Ibid*, **6**, 1-34, pl. 1-6; **1929**, "The Genus Microdictyon." *Ibid*, **14**, 453-588; **1940**, "Some Trabeculate Codiums (including two new species)." Proc. Nat. Acad. Sciences, **26**, 443-448; **1943**, "Mastophora and the Mastophoreae. Genus and Sub-family of Corallinaceae." Proc. Nat. Acad. of Sciences, **29**, 127-135.

SETCHELL, W. A., and GARDNER, N. L. **1919-1925**, "The Marine Algae of the Pacific Coast of North America; **1919**, Pt. I. "Myxophyceae." Univ. Calif. Publ. in Bot. **8**, 1-138; **1920**, Pt. II. "Chlorophyceae." *Ibid*, 139-374; **1925**, Pt. II. "Melanophyceae. *Ibid*, 383-898; **1937**, "The Templeton Crocker Expedition of the California Academy of Sciences, 1932. No. 31, a preliminary report on the Algae." Proc. Calif. Acad. Sciences, **22**, 65-98.

SMITH, G. M. **1938**, "Cryptogamic Botany, I."; **1944**, "Marine Algae of the Monterey Peninsula, California." Stanford Univ. Press.

SONDER, O. **1846**, "Algae" in Lehmann's "Plantae Preissianae," **2**, 148-195; **1852**, "Plantae Muellerianae." Linnaea, **25**, 657-709; **1853**, "Algae annis 1852 et 1853 Collectae." Linnaea, **26**, 506-528.

SOLMS LAUBACH, H. **1895**, "Monograph of the Acetabulariecae." Tr. Linn. Soc. London Bot., **5**, 1-39, pl. 1-4.

STEPHENSON, T. A. **1948**, "The Constitution of the Intertidal Fauna and Flora of South Africa, Pt. III." Ann. Natal Museum, **11**, 207-324.

TAYLOR, W. R. **1937**, "Marine Algae of the North-eastern Coast of North America." Univ. of Michigan Press; **1945**, "Pacific Marine Algae of the Allan Hancock Expeditions to the Galapagos Islands." Univ. Southern Calif. Press.

THURET, G. **1875**, "Essai de classification des Nostochinees." Ann. des Sci. Nat. 6 ser. Bot., **1**, 372.

TILDEN, J. E. **1910**, "Minnesota Algae, Vol. I."

TURNER, D. **1808-1819**, "Historia Fucorum." 1808 Vol. 1.; **1809**, **2**; **1811**, **3**; **1819**, **4**.

van Bosse, W. **1898,** "Monographie des Caulerpes." Ann. Bot. Jard. Buitenzorg, **15,** 243-401, pl. 1-34; **1904,** "The Corallinaceae of the Siboga Expedition Pt. 2." Siboga Expeditie Monogr. LXI.; **1910,** Annales de l'Institut Oceanographique, **2,** p. 1; **1921,** "Liste des Algues du Siboga. II., Rhodophyceae Pt. I." Siboga-Expeditie. Monogr. LIXb.

Vouk, V. **1935,** "A New Codium from Australia." Acta Bot. Inst. Bot. Univ. Zagreb, **10,** 9-12.

Wilson, J. B. **1892,** "Catalogue of Algae Collected at or near Port Phillip Heads and Western Port." Proc. Roy. Soc. Vic., **4,** 157-190.

Womersley, H. B. S. **1946a,** "Studies on the Marine Algae of Southern Australia. No. I. The Genera Isactis and Rivularia." Trans. Roy. S. Aus., **70,** 127-136; **1946b,** *Ibid,* No. II. A New Species of Dasyopsis from Kangaroo Island." *Ibid,* **70,** 137-144, pl. 27; **1947,** "The Marine Algae of Kangaroo Island I. A General Account of the Algal Ecology." *Ibid,* **71,** 228-252, pl. 9-13; **1948,** "The Marine Algae of Kangaroo Island II. The Pennington Bay Region." *Ibid,* **72,** 143-166, pl. 10-15; **1949,** "Studies on the Marine Algae of Southern Australia, No. 3. Notes on Dictyopteris Lamouroux." *Ibid,* **73,** 113-116, pl. 22.

Yamada, Y. **1931a,** "Notes on Laurencia, with special reference to the Japanese species." Univ. Calif. Publ. in Bot., **16,** 185-310, pl. 1-30; **1931b,** "Notes on Some Japanese Algae II." Journ. Fac. Science, Hokkaido Imp. Univ. Ser. V., **1,** 65-76.

Yendo, K. **1915,** "Notes on Algae New to Japan III." Bot. Mag. Tokyo, 29, 99-117.

Zanardini, J. **1874,** "Phyceae Australicae novae vel minus cognitae." Flora, 57, 486-490, 497-505.

Zeh, W. 1913, "Neue Arten der Gattung Liagora." Notizbl. Bot. Gard. Berlin, 5, 268-273.

EVAPORATION STUDIES USING SOME SOUTH AUSTRALIAN DATA

BY C. W. BONYTHON

Summary

The most common instrument for measuring evaporation – the tank evaporimeter – may give erroneous readings as the effect of several different causes. The feasibility of such readings being supplanted by calculated evaporation data based on the readings of several more-readily standardized instruments presents itself, whereupon an equation of calculating evaporation is quoted, and its derivation is given.

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By C. W. Bonython *

[Read 13 April 1950]

SUMMARY

The most common instrument for measuring evaporation—the tank evaporimeter—may give erroneous readings as the effect of several different causes. The feasibility of such readings being supplanted by calculated evaporation data based on the readings of several more-readily standardized instruments presents itself, whereupon an equation for calculating evaporation is quoted, and its derivation is given.

This equation is tested experimentally, using some South Australian data, first against two evaporimeters at Dry Creek for a period of six months, and next for shorter periods in comparing evaporimeters at three different sites near Adelaide. Good correlation between the curves for measured and calculated evaporation is shown, but there are differences between the respective absolute values. It is suspected that there are irregularities due to differences in exposure, etc., of the evaporimeters, and it is concluded that comparisons of the evaporation characteristics of different localities can possibly be more reliably made by using the equation and its relevant data rather than evaporimeters.

Comments are made on how the mean values of the basic data should be used in the evaporation equation, and on the apparent lag in phase in one instance of measured behind calculated evaporation.

Finally there is a discussion upon whether there is a likelihood of variation in the assumed fixed relationship between the coefficients of heat and mass transfer in the air film above the evaporating surface—the basis of the evaporation equation—and how such a variation will affect the accuracy of evaporation calculated by means of the equation.

INTRODUCTION

The tank evaporimeter is still the most widely-used instrument for the measurement of the potential evaporation of a locality, although it is receiving increasing criticism. The definition of evaporation varies according to the field in which the evaporation data are to be used. From the point of view of the physical meteorologist it is the mean rate at which water vapour is actually being carried into the atmosphere from what may be a wide and heterogeneous area of country. To him this will be the only definition. The bio-climatologist, however, may recognize more than one definition, terming the foregoing the water loss due to "evapo-transpiration." From another viewpoint evaporation is the rate at which water would be lost from the surface of a hypothetical—and perhaps large—sheet of water centred upon the site of an evaporimeter to the reading of which it is supposed to bear some relation. The bio-climatologist would term this "evaporation from a free water surface."

Sheppard has stated (18) the requirements of an ideal evaporimeter, viz. "... the necessary condition to be satisfied by the surface of the evaporimeter is that it shall be flush with the surrounding land (or water) surface, that its roughness parameter should be identical with that of the surroundings, and that the vapour pressure at the surface shall be maintained the same as at the surrounding surface." He adds, "Such requirements are excessively difficult to meet."

* I.C.I. Alkali (Australia) Pty. Ltd.

Priestley (14) has cited some figures to show that the total natural evaporation of the Australian continent cannot be greater than one-fifth of that indicated by Foley's (9) map of evaporation based on tank measurements.

Sutton (21) has shown theoretically that the rate of evaporation from an exposed water surface should vary with the dimensions of the surface.

The experimental work of Sleight (20) and Rohwer (17) has shown considerable apparent change in evaporation rate with the size of the evaporimeter in which it is measured. (However, this statement will be qualified further on). Other work, including that of Field and Symons (7) at as early a date as 1869, has shown that exposure markedly influences evaporimeter readings.

It can be seen from the foregoing that since there may be different definitions of evaporation an evaporimeter will not (except in very special cases) yield a measure of it appropriate to all the definitions. All that can be expected of an evaporimeter is generally a rough indication of one of these evaporation rates, and specifically a precise measurement of the evaporation rate for an identical vessel of water identically exposed. Even the second expectation may be difficult to realise in practice: part of the purpose of this paper is to show up difficulties in the reproducing of evaporation conditions.

STANDARDIZING EVAPORIMETERS

The shortcomings of evaporimeter measurements for predicting large scale natural evaporation have been enlarged upon by Sutton (22), Sheppard (18) and others, and these are admitted by the author. However, the tank evaporimeter has yet to be supplanted in practice for the purpose of comparing the evaporation of different localities, countries, etc., so no further excuse is offered for it in this paper which deals with obtaining improved practical data based on evaporation losses from small, specified areas of exposed water surface.

It is undesirable to add to the existing mass of empirical data on the effect of variables like dimensions, radiation absorbing power and exposure upon the rate of evaporation from evaporimeters, when these data are to be used to convert such evaporation rates into so-called "true evaporation." Many of the early investigations were concerned with this aspect. The empirical data presented in this paper are here only for the purpose of revealing the failings of evaporimeters.

Evaporimeters are usually small tanks of water set in, on or above the ground and exposed to sun and air. There are many designs, but the simplest and most common one is a small, circular metal tank, with depth roughly equal to diameter, buried in the ground almost to the rim. Different designs often yield different results when similarly exposed. Consequently, standardization is important. In choosing a suitable design, the following points should be borne in mind:—

(a) There should be the minimum interference with the normal horizontal wind movement over the surface, and the wind direction should not affect the rate of evaporation. Hence a tank set more or less flush with the ground and of circular shape would appear suitable.

(b) The size should not be so great that difficulty in supplying sufficient make-up water is met in dry localities, nor so small that accidental depletion of water by animals and birds can amount to an appreciable part of the normal evaporation loss.

(c) The supply of radiant heat has a controlling influence on tank evaporimeters exposed in the open. Therefore a design minimizing variations in radiation absorption should be sought. A surface of low reflecting power is desirable, and since the characteristics of such an absorbing surface are hard to standardize, an evaporimeter holding a reasonable depth of water and of such shape that it at least approximates to a cavity absorber should be chosen. A black evaporimeter with depth equal to width would meet these requirements. (There is, however, evidence against the use of a surface of low reflecting power on parts of the tank, since the projecting rim may absorb an unduly large amount of radiation relative to that entering through the water surface).

(d) Gain or loss of sensible heat through the sides and bottom should be minimized. While insulation may be impracticable, a buried tank of dimensions giving minimum outside area relative to holding capacity should be chosen.

(e) An evaporimeter must function also as a rain gauge, since total (or "gross"[1]) evaporation must be derived in practice from changes in water level and from gaugings in a nearby rain gauge. Evidence has been produced (2) showing that an evaporimeter may not be a reliable rain gauge. The statement "more water splashes out than splashes in" briefly explains how an evaporimeter may behave in rain. The larger the evaporimeter is the better is the likely approximation to a perfect rain gauge.

The Australian Standard evaporimeter (1) consists of a cylindrical sheet-metal tank, 3 ft. in diameter and 3 ft. deep, set inside a similar tank 4 ft. in diameter sunk in the ground with its rim level with the surface. The rim of the inner tank is 2 in. above that of the outer one. The inner tank is filled with water to within 3 in. of the top, and the outer annular space is filled to the top. It would appear to meet most of the requirements set out. The outer jacket is thought to act as a "guard ring" to the inner vessel in which evaporation is measured, producing uniform conditions over the surface of the latter, and tending to bear the brunt of water depletion caused by animals and birds.

While most Australian Standard evaporimeters are made of galvanized iron sheet, normally left unpainted, the addition of a coat of black paint might be considered an improvement under heading (c), although there is also the disadvantage referred to, and while it might seem that this latter objection could be met by painting the tank black below water level and the rim above it white, this would introduce the uncertainty of the destination of radiation reflected from the white part. In general it is easier to prepare and maintain a surface reasonably good as an absorber than as a reflector. Perhaps, then, weathered galvanized iron, having a short-wave radiation absorption coefficient of the order of 0.9 (4), will be as satisfactory in practice as any other material for evaporimeters.

An example of a design permitting a wide variation in total energy-absorbing power is the U.S. Weather Bureau Class A Land Plan. This is circular, 4 ft. in diameter and 10 in. deep, and set on wooden supports a little above the ground. The author has experimented with one of these at Dry Creek, South Australia, and he has found the following variations in evaporation rate with different surface treatments of the metal:—

[1] Evaporation in this paper is defined as measured fall in water level plus rain gauged during the same period. This is sometimes termed "gross" evaporation.

TABLE I

Surface Treatment	Relative Evaporation Rate
Plain galvanized iron	100
Painted "flat white"	85
Painted "lead grey"	104
Painted black	109

The comparisons were carried out in summer over periods ranging from 9 to 90 days.

Young (24) in the U.S.A. has reported similar results from not-dissimilar tanks painted several colours.

The author has experimented with evaporimeters of the Australian Standard pattern to obain these results:

TABLE II

Construction and Finish	Relative Evaporation Rate
Plain galvanized iron sheet (16 g.)	100
Black-painted steel plate ($\frac{1}{4}$ in.)	103-104

Such results are likely to vary with season and exposure, but the above should hold for the neighbourhood of Adelaide in summer.

It is felt that the radiation absorptive power of the projecting metal rims of the Australian Standard evaporimeter may influence its readings. Reference will be made to this further on.

An important factor not so far dealt with is the working level of the water surface. The distance that this is below the rim has an appreciable effect upon evaporation rate. The author experimented at Dry Creek, South Australia, during the 1948-9 and 1949-50 summers with two identical Australian Standard evaporimeters (of plain galvanized iron), employing different working levels in the one relative to the other. (The roles of reference and subject tank were reversed regularly to eliminate any effects of unequal exposure or construction). The following results were obtained:—

TABLE III

Mean working level below rim		Evaporation rate of subject,
Reference	Subject	taking reference = 100.
1.5 in.	2.5 in.	96
1.5 in.	3.5 in.	85

Another interesting fact is that the use on the Dry Creek evaporimeter of a bird screen made of 1-inch mesh wire netting caused a reduction in evaporation of approximately 6½%.

These results are quite empirical, but they can probably be related to the respective coefficients for diffusion of water vapour to the air.

Impurities on the water surface may affect evaporimeter performance. Dust, and other foreign matter often oily in nature, usually accumulates in quite a short time. Heymann and his associates (10), (11) have shown that, while theoretically (and also in practice in the laboratory) the presence of a thin oil film on the surface can cause a greatly increased resistance to evaporation, such a film is probably unstable under conditions like those of outdoor exposure. The present author experimented by adding a drop or two per day of one of Heymann's oil compositions to the surface of an evaporimeter, keeping an oil-free evaporimeter for reference. The results were erratic and inconclusive, the relative windiness possibly having some influence. On some days a reduction in evaporation of up to 10% was found.

Foley (9) lists some other factors affecting evaporation from evaporimeters.

Many sources of variation in results from evaporimeters have thus been made apparent.

THE CALCULATION OF EVAPORATION

Since evaporimeters are hard to standardize, it appears possible that calculated evaporation, based on readings of meteorological variables taken from several more-readily standardized instruments, could be used for the same purpose with better effect. If these variables are ones already measured in normal meteorological practice, it will be possible to calculate evaporation for localities where such observations are or have been taken but where no evaporimeter exists.

The calculation of evaporation from open water surfaces has been attempted by Cummings and Richardson (6) on the basis of energy balance. Other approaches have followed the lines of "sink strength"—the diffusion of water vapour considered as a driving force versus a resistance—a combination of sink strength and energy balance, and aerodynamical treatment. (These have been summarized by Penman (13)).

A version of the combined sink strength and energy balance method will be considered here. Four meteorological variables are used:—

(i) Net gain of radiant energy.
(ii) Air temperature.
(iii) Humidity.
(iv) Wind speed near the ground.

Penman (13) gives the general form of such an equation, but the one used here is that developed theoretically in England in 1945 by Ferguson[2], based partly on the chemical engineering concept of the inter-relation between heat and mass transfer through a common gas film. The equation has not previously been published[3], so its derivation will be described briefly.

Nett gain of radiant energy is defined as the total short wave solar radiation, both direct and diffuse, penetrating the water surface (which may be regarded as being in an evaporimeter), less the nett loss of long wave radiation by the water. The first can be measured by solarimeter, and allowance made for reflection from the water surface. The second can be calculated with sufficient accuracy from air temperature, humidity and relative hours of bright sunshine. (As a first approximation it is assumed that the temperature of the radiating water surface is the same as that of the air).

Air temperature is dry bulb temperature "near" the evaporating surface.

Humidity is the partial pressure of water vapour in the air "near" the surface.

Wind speed is the horizontal speed "near" the surface. It can be measured by anemometer.

Now in the conditions considered there is a nett inward flow of radiant energy to the water and an outward flow of water vapour (taking away energy as latent heat of vaporization), while there may be a flow of sensible heat from water to air or vice versa.

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[2] Dr. J. Ferguson, then Director of Research, I.C.I. Ltd., Alkali Division, Northwich, Cheshire.

[3] It is now probable that Ferguson will publish this work during 1950.

The sink strength basis is the Dalton equation, which, in appropriate terms, is

$$w = k\ (p_w - p_a) \tag{1}$$

where w = wt. water evaporated per unit time from unit area of surface
k = diffusion coefficient of water vapour to air
p_w = vapour pressure of water at the evaporating surface
p_a = partial pressure of water vapour in the air "near" the surface

Next, from the energy balance aspect, the latent heat used in evaporating water of weight, w, is

$$L\ k\ (p_w - p_a)$$

where L = latent heat of vaporization.

Sensible heat exchange in unit time between unit area of water surface and air is

$$h\ (\theta_w - \theta_a)$$

where h = heat transfer coefficient
θ_w = water surface temperature
θ_a = air temperature

It is further assumed that no rise or fall in water temperature is taking place — that θ_w is constant —, and that there is no flow of heat between the water and its surroundings (other than through the air-water interface).

Hence the nett gain in radiant energy (Q) should equal the sum of these two heat flows, viz:

$$Q = L\ k\ (p_w - p_a) + h\ (\theta_w - \theta_a) \tag{2}$$

This may be simplified by introducing the relationship between mass and heat transfer taking place through the same air film. Such a relationship is treated in the theory of the wet bulb thermometer: regardless of changes in the film resistance the coefficients k and h remain in a fixed relation to one another. Walker, Lewis and McAdams (23) give the relation for water as being

$$\frac{h}{L\ k} = 0{,}50 \tag{3}$$

where temperatures are in deg. C., vapour pressures are in mm. of mercury, and the units of mass and energy are gm. and cal. respectively.

Using (3) to eliminate k in (2) converts the latter to

$$Q = 2\ h\ (p_w - p_a) + h\ (\theta w - \theta_a) \tag{4}$$

where the variables may now be defined specifically as

Q = cal./cm²/hr.
h = cal./cm²/hr./deg. C.
k = gm./cm²/hr./mm. of Hg.
p_w, p_a = mm. of Hg.
θ_w, θ_a = deg. C.

Since p_w, the vapour pressure of water, is a known function of θ_w, the temperature, the equation can be solved for θ_w. Re-arranging (4) gives

$$2\ p_w + \theta_w = \frac{Q}{h} + 2\ p_a + \theta_a \tag{5}$$

For water the values of $(2\ p_w + \theta_w)$ for different values of θ_w (or of p_w), can be obtained from vapour pressure vs. temperature tables.

Since p_w is fixed for a given value of $(2\ p_w + \theta_w)$ we may write

$$p_w = f\ (2\ p_w + \theta_w) \tag{6a}$$

$$= f\ (\frac{Q}{h} + 2\ p_a + \theta_a) \tag{6b}$$

where f is a functional sign.

Evaporation per unit area per unit time is given by w in (1). When w is in gm./cm²/hr. it is numerically equal to E, where E is cm./hr. water evaporated. Hence

$$E = k\ (p_w - p_a) \tag{7a}$$

$$= \frac{2h}{L}\ (p_w - p_a) \tag{7b}$$

when relation (3) is brought in.

Finally, combining (6b) and (7b) we obtain

$$E = \frac{2h}{L} \left\{ f\ (\frac{Q}{h} + 2\ p_a + \theta_a) - p_a \right\} \tag{8}$$

From (8) evaporation may be calculated without θ_w being known in advance. It is, however, necessary to know h. Published data on heat transfer between moving air and flat planes are available, and k (which is, of course, interchangeable with h) can be measured over, for instance, an evaporimeter. Penman (13) gives figures showing the relationship between k and horizontal wind speed, V, and Raman (16) has measured the h — V relationship for certain conditions.

After deriving (8) Ferguson points out that it is based on steady state conditions, and that it cannot necessarily be used with average values of the variables when the latter do not remain constant. Q, θ_a and h at least are continually changing with time, some in a periodic manner. However, after a study involving the solution of differential equations in the Manchester University differential analyser, Ferguson concludes that, provided the water is of reasonable depth—say 6 in. or more—and provided moderate periods of time are taken—say at least 2 or 3 days—equation (8) can be used with the average values of variables.

Ferguson later introduces a minor modification to correct for the fact that the return long wave radiation from the water to the air is controlled by the unknown temperature, θ_w, and not, as assumed for simplicity, by the known temperature, θ_a. He shows mathematically that the correction can be introduced into the sensible heat change quantity in (4) by substituting for the coefficient of heat transfer, h, a fictitious one, h′. (4) now becomes

$$Q = 2\ h\ (p_w - p_a) - h'\ (\theta_w - \theta_a) \tag{9}$$

where h′ is the value substituted for h, so making allowance in the calculated sensible heat change for an error in the calculated return long-wave radiation.

He then re-writes (5) as

$$2\ p_w + \theta_w\ (1 + \frac{r}{h}) = \frac{Q}{h} + 2p_a + \theta_a\ (1 + \frac{r}{h}) \tag{10}$$

where $h' = h + r$, (11)
in which $r = 4 \times 3600\, \sigma\, T_a^3$ (12)
where in turn σ = Stefan-Boltzmann Constant,
and T_a = air temperature, deg. K.
(The mathematical derivation and proof of (12) will not be given here).

In solving the modified evaporation equation, p_w is found graphically by plotting the straight line connecting p_w and θ_w in (10) and reading off its intersection with the known curve for water of p_w vs. θ_w. The derived p_w is used in (7b) to determine evaporation.

It is to be noted that only that value of h related to sensible heat exchange is altered to h′. The h used as the denominator for Q in (10), and that used in (7b) finally to calculate evaporation is not so altered.

This correction somewhat complicates the simple method of equation (8) for calculating evaporation, and in many cases it is negligible. However, the correction involving r has been used in the calculations given subsequently in this paper.

PRACTICAL TESTING OF THE THEORY

The Ferguson equation has been checked experimentally by the author at Dry Creek, South Australia, where there is a meteorological station attached to the solar saltfields of I.C.I. Alkali (Australia) Pty. Ltd.

The first check was carried out in 1947, and while a brief reference to it has been made (3) details were not published. The details differed slightly from those now to be given, mainly concerning the derivation of h. The results were, however, very similar to those found in 1949.

In the latter check solar radiation was measured by a Kipp & Zonen solarimetric thermopile with recorder, and hours of bright sunshine by a Campbell-Stokes recorder. These records, together with those of temperature and humidity, enabled nett loss of long wave radiation to be calculated. (This involved a modified form of the Baur & Phillips formula (5) together with a relationship like that given by Penman (13) connecting relative hours of bright sunshine with radiation loss from skies of different cloudiness). A loss of short-wave radiation by reflection at the air-water interface of 4% was allowed. From the above the nett gain of radiant energy was found.

Air temperature and humidity (expressed as partial pressure of water vapour) were measured at normal Stevenson screen height by an aspirated wet and dry bulb thermograph.

Horizontal wind speed was measured at 3 ft. above the ground by cup anemometer. From wind it was necessary to derive h, the heat transfer coefficient. The simplest and most appropriate way seemed to be via the measured diffusion coefficient, k, for the evaporimeter concerned.

Three feet seems a suitable height for wind measurement, although 1 or 1.25 m. would comply with international standards. It is sufficiently near to the ground (or evaporimeter) level to avoid large errors due to failure of the 1/7 power law of variation of wind with height when extrapolating down wind speeds measured at a meteorological station height like 10 m., but yet not closer to the ground than the characteristics of the anemometer justify. It would seem that an anemometer should be set at a height of at least several cup diameters. The procedure adopted by Rohwer (17) of mounting an anemometer in a small pit with its cup bottoms close to ground level in order to measure "ground wind" is misleading, since the cups are rigid while the air layer at this level is undergoing considerable shear.

In measuring diffusion coefficients for evaporimeters, p_a at screen height provided one of the two partial pressures whose difference constitutes the driving force of the process. The other pressure, p_w, was that at the water surface, and it was found from the surface mean temperature assumed to be the same as the mean temperature measured at 3 in. below the surface. The assumption must have been approximately true, as a number of measurements at different depths using a thermometer with a fine bulb failed to show differences between the surface and the 3 in. level of more than 0.5°C. at the most. Diffusion coefficients were determined from p_w, p_a and measured E, using (7a). Periods of single day's and single month's duration were considered, using the figures from two evaporimeters.

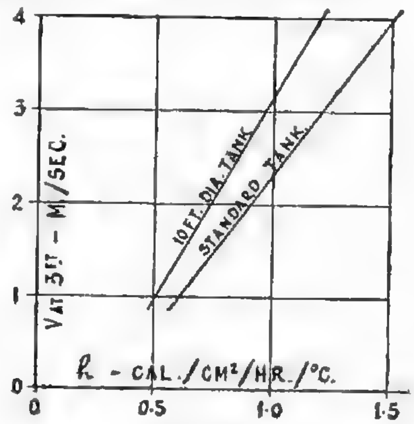

Fig. 1
h vs. V for the Dry Creek evaporimeters.

The plots of k vs. mean wind speed showed considerable scatter, even though results for rainy days were excluded since these were known to be erratic. Penman (13) reports a similar scatter. The best straight lines were drawn through the plotted points. The scatter of k values and the limited range of wind speeds covered were such that no curvature—such as would occur if k varied with $V^{0.78}$ (see Sutton (21)) was delectable.

The best lines for two evaporimeters are shown in fig. 1.

The two evaporimeters will now be described. The first was the "standard" evaporimeter of this site, which, while having the dimensions—the only clearly defined details—of the Australian Standard, was made of ¼ in. mild steel plate and painted black. The outer jacket stood a little over 2 in. above ground level, and was encircled by a shaped annulus of concrete a few inches wide. The surrounding earth was covered with coarse stone screenings. The inner tank stood 2 in. higher than the outer one. The second was a circular, black-painted mild steel tank 10 ft. in diameter by 3 ft. deep, buried in the ground with its rim projecting 4 in. above the surface. They are shown in plate 1 fig. 1.

Measurements of evaporation from these two evaporimeters and of the four basic variables were taken for the calendar months of January to June, 1949, and used to check the Ferguson equation. The latter was used in the form

$$E_1 = 2.30\ h\ (p_w - p_a) \qquad (13)$$

where E_1 = cm./28 days.
to calculate evaporation, after having found p_w using (10).
(Values of h appropriate to each evaporimeter were read from fig. 1).

Table IV

Measured and Calculated Evaporation for Dry Creek

(a) Standard Evaporimeter

Period	Q cal./cm²/hr.	θ_a °C	p_a mm. of Hg.	V m./sec.	h cal./cm²/hr./°C	Deriv. p_w mm. of Hg.	Deriv. θ_w °C	Calc. Evap. cm./28 days	Meas. Evap. cm./28 days	Meas. θ_w °C
Jan., 1949 -	21.8	20.9	9.2	2.85	1.16	18.6	20.9	25.0	30.4	21.7
Feb., " -	15.8	19.0	9.4	2.95	1.19	16.2	18.7	18.6	21.75	20.4
Mar., " -	14.5	17.9	8.6	2.45	1.04	15.5	18.0	16.5	21.15	20.0
Apr., " -	8.5	15.4	7.5	2.25	0.98	12.5	14.6	11.3	14.4	16.5
May " -	4.3	12.9	8.1	1.75	0.83	11.0	12.6	5.5	7.1	13.7
June " -	3.5	9.0	6.7	1.7	0.81	8.7	9.2	3.7	5.65	10.8

(b) 10-ft. Diameter Evaporimeter

Period	Q cal./cm²/hr.	θ_a °C	p_a mm. of Hg.	V m./sec.	h cal./cm²/hr./°C	Deriv. p_w mm. of Hg.	Deriv. θ_w °C	Calc. Evap. cm./28 days	Meas. Evap. cm./28 days	Meas. θ_w °C
Jan., 1949 -	21.8	20.9	9.2	2.85	0.93	20.0	22.1	23.1	22.8	21.5
Feb., " -	15.8	19.0	9.4	2.95	0.95	17.2	19.7	17.1	17.65	20.2
Mar., " -	14.5	17.9	8.6	2.45	0.84	16.4	18.9	15.1	17.25	20.2
Apr., " -	8.5	15.4	7.5	2.25	0.79	13.0	15.3	10.0	11.2	16.3
May " -	4.3	12.9	8.1	1.75	0.68	11.2	13.0	4.9	5.85	13.4
June " -	3.5	9.0	6.7	1.7	0.67	8.9	9.5	3.4	4.1	10.3

The measured and calculated evaporation rates are given in Table IV and plotted in fig. 2. While the two rates do not agree closely for the standard evaporimeter, they agree better for the 10 ft. tank, and in both cases the correlation between the curves over the six-month period is very good. That there is such good correlation over a wide range of meteorological conditions is distinctly encouraging.

The calculated values are low by 20% and 6.5% for the standard and 10 ft. evaporimeter respectively, but it cannot be concluded that it is the calculated figures that are wrong. It could well be that the calculated figures are on a sounder basis than the measured ones. Now according to Ferguson's treatment, it is possible to calculate the mean water temperature, θ_w, as this is directly related to the vapour pressure, p_w. Values of θ_w corresponding to p_w have been shown with the other January to June, 1949, figures in Table IV, as also have measured values of θ_w for 3 in. below the surface. (Suspended maximum and minimum meteorological thermometers fitted with radiation shields were used. $\dfrac{\text{max.} + \text{min.}}{2}$ means were reduced to the basis of true means using a small correction determined practically).

If measured and calculated θ_w are not the same, it is fair to assume that either the equation is wrong or the data used in it are wrong. Of the latter, h and Q are those most likely to contain errors. In the case of the standard evaporimeter, if a value of h is taken to make calculated E_1 the same as measured E_1—this calls for an increase of h—then derived θ_W will be lower, increasing the discrepancy between derived and measured θ_W. If h is taken to make measured and calculated θ_W the same—this calls for a decrease in h—then the disparity between measured and calculated E_1 is increased. (An all round increase in the values of h by 0.6 cals./cm²/hr./°C. will bring cal-

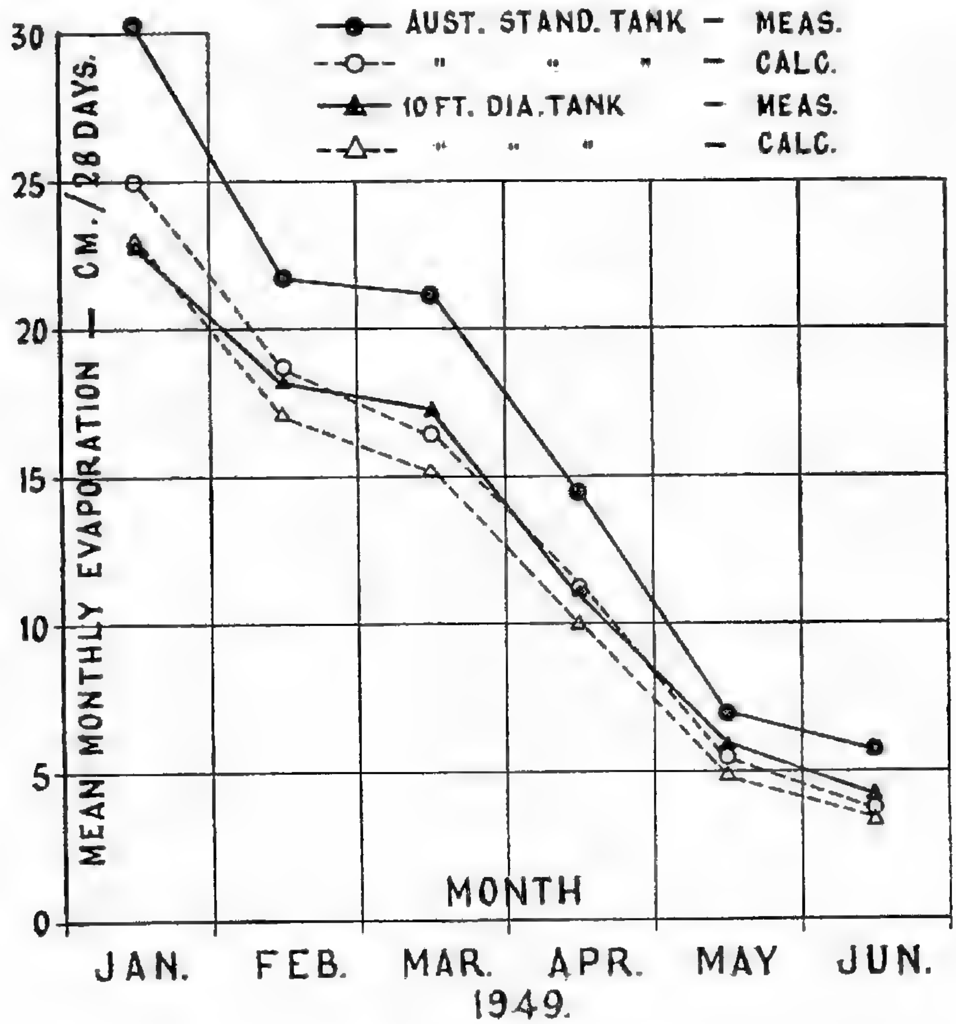

Fig. 2

Measured and calculated evaporation rates for Dry Creek.

culated E_1 for the standard tank up to the corresponding measured E_1, with good correlation over the whole range. It is hard to believe, however, that h can be this much in error).

It would seem that correction of h alone cannot bring about a simultaneous agreement between the measured and calculated values of E_1 and θ_W respectively.

Errors in Q can quite well account for the discrepancies in E_1. There is a distinct likelihood of errors here, for interchange of heat between evaporimeter and soil is possibly quite significant, and the presence of the projecting tank rim may render the calculated absorption of radiation uncertain. The Dry Creek data for January-June, 1949, have been used to back-calculate Q.

θ_a and p_a have been taken as correct, but fictitious values of h have been used so as to bring about the simultaneous mutual equality of measured and calculated E_1 and measured and calculated θ_W. This has involved first the use of equation (13) to calculate h, and then (10) to find Q from h and the other variables. Results for both evaporimeters are shown in Table V with certain former results:—

TABLE V

Period	Standard h—cal./cm²/hr./°C. Orig.	Recalc.	Q—cal./cm²/hr. Orig.	Recalc.	10-ft. diameter h—cal./cm²/hr./°C. Orig.	Recalc.	Q—cal./cm²/hr. Orig.	Recalc.
Jan., 1949	1·16	1·28	21·8	27·7	0·93	0·98	21·8	20·6
Feb., 1949	1·19	1·10	15·8	21·2	0·95	0·92	15·8	17·0
Mar., 1949	1·04	1·03	14·5	21·5	0·84	0·82	14·5	18·1
April, 1949	0·98	0·95	8·5	14·1	0·79	0·76	8·5	10·9
May, 1949	0·83	0·83	4·3	7·1	0·68	0·72	4·3	5·6
June, 1949	0·81	0·82	3·5	7·2	0·67	0·66	3·5	5·0

Re-calculated and original h are seen to be in tolerable agreement, as must be expected from the mode of derivation of original h. Hence the E_1 and θ_W discrepancies may be explained by assuming Q alone to be in error. No practical tests have been made[4] of possible sources of error in Q, but it is significant that evaporimeter-soil heat exchange is likely to be greater for the smaller evaporimeter which is the one showing the greater discrepancies between original and re-calculated Q. The effect of rim absorption must also be considered. These facts are relevant:—

TABLE VI

	Standard Evaporimeter.	10-ft. diameter Evaporimeter.
Area in contact with soil/area of water surface	3·8/1	2·1/1
Area of vertical cross-section of rim/area of water surface	0·06/1 ϕ	0·04/1

ϕ only outer rim considered.

The difference between original and re-calculated Q is more or less steady in each case throughout the six months, being very approximately 5 cal./cm²/hr. and 1.5 cal./cm²/hr. for the standard and 10 ft. diameter evaporimeters respectively. No soil temperatures were taken, so there is no evidence with which to seek correlation with evaporimeter-soil heat exchange, but rim absorption of radiation might correlate with Q discrepancy, and this possibility will now be explored. If it is assumed that the rim has the same absorption coefficient as the water, and that it is in full thermal communication with the water and is hence at the same temperature, then the problem is to find the extra absorbing surface, over and above that of the horizontal water surface, presented to sun and sky by the rim. Taking clear days with the sun between the limiting altitudes of the absolute zenith and, say, 5°-10°, the semi-circumference of the rim nearer the sun will merely shade part of the water surface, and will not pick up extra radiation but only that which the water would have received in the absence of the rim. The semi-circumference further from the sun will, however, intercept radiation that the water surface would not normally have absorbed. This part of the rim will behave

[4] Experiments with a thermally insulated evaporimeter are to be started at Dry Creek early in 1950.

approximately as a vertical plane normal to the sun's compass direction, of length equal to the tank diameter and of height equal to the rim height, i.e., the vertical cross-section of the rim. The surface presented normal to the sun's beam will be proportional to the cosine of the sun's altitude. Calculations based on cloudless days reveal the interesting fact that daily mean rim absorption is nearly constant from mid-summer to mid-winter at 30 - 27 cal./hr./cm^2 of vertical rim cross-section as against the absorption of 34 - 11 cal./hr./cm^3 of horizontal water surface. Application of these results to the Dry Creek evaporimeters is now possible. According to the above treatment the inner rim of the standard tank merely picks up radiation that would in its absence be absorbed by the water with the sun at all but low altitudes, so that the projecting rim of the jacket—which should not project, however, according to the specification (1)—presents the only effective absorbing surface. The increase in Q caused by rim absorption for the range mid-summer to mid-winter is of the order of 1 cal./hr./mean cm^2 surface area for both standard and 10 ft. diameter evaporimeters for cloudless skies. It will be less for cloudy skies.

It is apparent that rim absorption of radiation cannot, on these theoretical grounds, explain all of the Q discrepancy for the standard tank, nor is it likely to for the 10 ft. diameter tank when the prevalence of cloudy skies in winter months is taken into consideration.

Errors in the variables θ_a and p_a can conceivably be connected with the disparity in measured and calculated evaporation, but no discussion on such possibilities will be entered into.

While no solution can be offered here for the problem of possible Q discrepancy, note should be taken of the related problem of whether the apparently steep change of evaporation rate with evaporimeter dimensions is real. The observations of Sleight (20) and Rohwer (17), and also those at Dry Creek, show rough agreement with Sutton's (21) predictions in this matter. Sutton shows that there should be a decrease in evaporation with increase in extent of evaporating surface, but he bases his theory on change in what is virtually the diffusion coefficient. Now the sink strength—energy balance theory holds that any change in the diffusion coefficient brings about an adjustment in water temperature which largely, but not wholly, compensates for the coefficient change as far as overall evaporation rate is concerned, so that the decrease in the latter is much less than one of direct proportion to the decrease in the diffusion coefficient. Hence there should not be such a steep change of evaporation rate with evaporimeter dimensions as available observations tend to show. It is now suggested that though there should be such a gradient, the observed one is not real, and that some factor at present unidentified is exaggerating it.

EVAPORATION COMPARISONS OF THREE DIFFERENT SIES

There are several evaporimeter stations on the Adelaide plains, and those of the Adelaide Weather Bureau, the Waite Agricultural Research Institute and Dry Creek, having a maximum separation of about 10 miles, record widely differing evaporation rates. The 1948 totals were:—

Table VII

Adelaide	64.3 in. (163.2 cm.)
Waite Institute	54.7 in. (138.9 cm.)
Dry Creek	82.9 in. (210.7 cm.)

It was thought that the Ferguson equation might explain these differences, so comparisons were made between Adelaide and Dry Creek during November and December, 1948, and between the Waite Institute and Dry Creek during January and February, 1949. During these periods a solarimeter and an anemometer (at 3 ft. height) were set up alongside the appropriate evaporimeter, which, at Adelaide was an Australian Standard one of galvanized iron set in a small area of lawn, and at the Waite Institute was

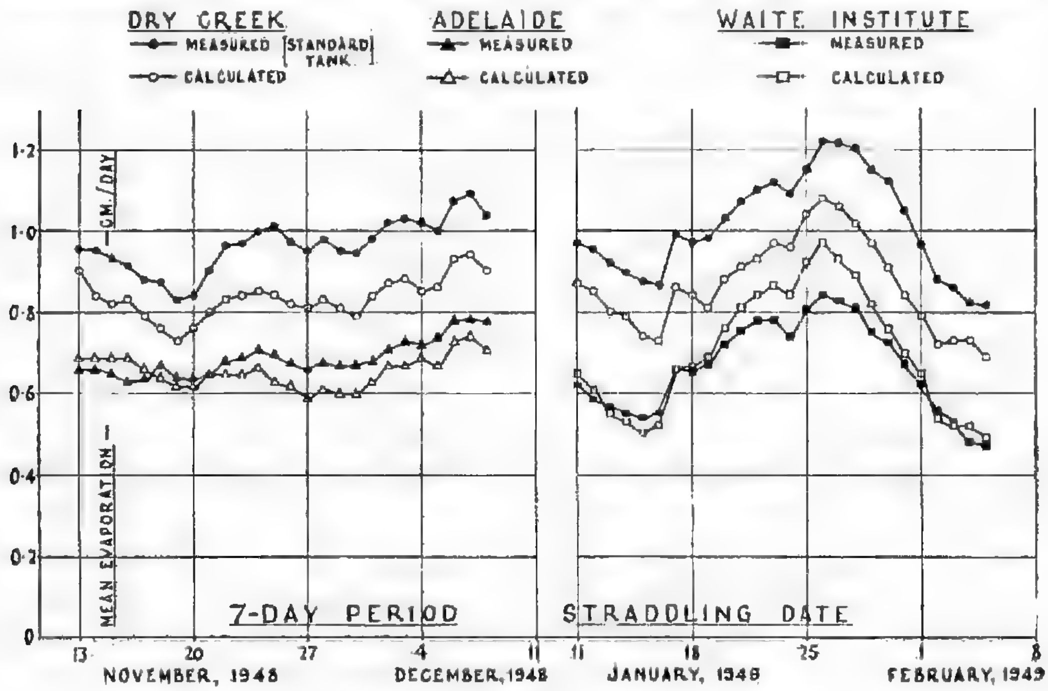

Fig. 3

Measured and calculated evaporation rates for Dry Creek, Adelaide and the Waite Institute.

an Australian Standard one of sheet copper also set in a lawn (see pl. I. fig 2 and pl. II.). Temperature and humidity measurements were available, being normally taken at these places. Simultaneous observations were made at Dry Creek using the standard evaporimeter. The observations were reduced and used to calculate evaporation by the Ferguson equation for comparison with that actually measured. h for all stations was read from fig. 1. Air temperatures were available as true daily means for Adelaide and Dry Creek, while those for the Waite Institute, available as $\frac{\text{max.} + \text{min.}}{2}$ means, were corrected empirically to the same basis by a factor given by Foley (8) as applying to Adelaide.

Table VIII shows the summarized observations and calculated results. Means for overlapping periods of 7 days' duration have been used to give both the necessary length of time and at the same time a sufficient number of results for comparing. Evaporation was calculated from

$$E_2 = 0.082\,h\,(p_W - p_a) \qquad (14)$$

where E_2 = cm./day.

Measured and calculated values of E_2 are plotted in fig. 3.

Table VIII—Measured and Calculated Evaporation for Three Localities

(a) Dry Creek and Adelaide

Date Straddled by period	DRY CREEK Q cal./cm²/hr.	θ_a °C.	p_a mm. of Hg.	V m./sec.	h cal./cm²/hr./°C.	Calc. Evap. cm./day	Meas. Evap. cm./day	ADELAIDE Q cal./cm²/hr.	θ_a °C.	p_a mm. of Hg.	V m./sec.	h cal./cm²/hr./°C.	Calc. Evap. cm./day	Meas. Evap. cm./day
13/11/48 –	19.8	19.6	8.0	3.55	1.37	0.90	0.955	17.9	19.0	7.7	1.9	0.87	0.69	0.66
14/11/48 –	18.9	18.7	8.3	3.8	1.44	0.84	0.95	17.9	19.1	7.9	2.0	0.90	0.69	0.66
15/11/48 –	19.2	18.7	8.3	3.55	1.37	0.82	0.935	18.5	18.9	7.9	1.95	0.88	0.69	0.655
16/11/48 –	19.4	19.1	8.5	3.35	1.31	0.83	0.915	18.5	18.9	8.2	1.75	0.83	0.69	0.63
17/11/48 –	20.0	18.4	8.7	3.2	1.26	0.79	0.88	19.4	18.3	8.7	1.7	0.82	0.66	0.635
18/11/48 –	19.6	18.3	8.7	3.1	1.24	0.76	0.875	19.0	18.1	8.8	1.7	0.82	0.64	0.665
19/11/48 –	19.8	17.6	8.6	2.9	1.18	0.73	0.83	19.2	17.3	8.5	1.55	0.77	0.62	0.635
20/11/48 –	20.9	18.1	8.6	2.65	1.09	0.76	0.84	19.8	17.5	8.5	1.4	0.71	0.62	0.63
21/11/48 –	21.5	19.3	8.8	2.45	1.03	0.80	0.90	20.2	18.7	8.4	1.25	0.67	0.65	0.65
22/11/48 –	21.7	19.5	8.9	2.75	1.13	0.83	0.965	19.8	18.8	8.5	1.3	0.69	0.65	0.68
23/11/48 –	22.1	19.2	8.7	2.8	1.14	0.84	0.975	20.0	18.5	8.3	1.3	0.69	0.65	0.685
24/11/48 –	22.1	19.2	8.7	2.9	1.17	0.85	1.00	20.0	18.4	7.9	1.35	0.70	0.66	0.71
25/11/48 –	22.1	18.7	8.7	3.1	1.24	0.84	1.015	19.0	17.8	7.9	1.4	0.71	0.63	0.695
26/11/48 –	22.3	18.2	8.8	3.0	1.21	0.82	0.975	19.2	17.6	7.9	1.4	0.71	0.62	0.675
27/11/48 –	22.1	18.3	9.1	3.0	1.21	0.81	0.95	17.9	17.5	8.2	1.45	0.73	0.59	0.665
28/11/48 –	21.9	18.8	9.2	3.2	1.26	0.83	0.98	17.9	18.1	8.2	1.5	0.75	0.61	0.675
29/11/48 –	21.5	18.6	9.1	3.1	1.24	0.81	0.95	17.3	18.3	8.4	1.5	0.75	0.60	0.665
30/11/47 –	21.2	18.5	9.1	3.0	1.21	0.79	0.945	17.3	18.3	8.5	1.55	0.77	0.60	0.67
1/12/48 –	21.5	19.0	8.9	3.15	1.25	0.84	0.98	17.9	18.8	8.5	1.55	0.77	0.63	0.68
2/12/48 –	22.1	19.0	8.7	3.2	1.26	0.87	1.02	19.0	19.1	8.6	1.65	0.80	0.67	0.71
3/12/48 –	21.6	19.3	8.6	3.35	1.31	0.88	1.03	18.7	19.1	8.6	1.7	0.82	0.67	0.725
4/12/48 –	21.6	18.4	8.1	3.3	1.29	0.85	1.02	20.0	18.8	8.4	1.65	0.80	0.69	0.72
5/12/48 –	22.5	17.7	7.5	3.1	1.24	0.86	1.00	20.0	17.8	8.2	1.7	0.83	0.67	0.74
6/12/48 –	22.7	19.0	7.7	3.3	1.29	0.93	1.07	20.6	18.9	8.0	1.75	0.83	0.73	0.78
7/12/48 –	22.7	19.2	7.8	3.4	1.32	0.94	1.09	20.9	19.1	8.1	1.75	0.83	0.74	0.785
8/12/48 –	22.7	18.5	7.7	3.15	1.25	0.90	1.04	20.2	18.6	8.0	1.7	0.82	0.71	0.775

(b) Dry Creek and Waite Institute

Date Straddled by period	DRY CREEK Q cal./cm²/hr.	θ_a °C.	p_a mm. of Hg.	V m./sec.	h cal./cm²/hr./°C.	Calc. Evap. cm./day	Meas. Evap. cm./day	WAITE INSTITUTE Q cal./cm²/hr.	θ_a °C.	p_a mm. of Hg.	V m./sec.	h cal./cm²/hr./°C.	Calc. Evap. cm./day	Meas. Evap. cm./day
11/1/49 –	20.5	21.1	8.8	2.6	1.08	0.87	0.975	18.1	20.4	10.0	1.6	0.79	0.65	0.625
12/1/49 –	19.4	21.0	9.1	2.95	1.19	0.85	0.955	16.9	26.0	10.3	1.5	0.76	0.61	0.585
13/1/49 –	17.9	20.7	9.1	3.0	1.20	0.80	0.92	15.6	20.2	10.7	1.5	0.76	0.55	0.565
14/1/49 –	16.1	20.0	8.9	3.05	1.22	0.79	0.895	15.6	19.0	10.4	1.55	0.77	0.53	0.555
15/1/49 –	18.1	18.8	8.9	3.05	1.22	0.74	0.875	15.4	17.7	10.0	1.55	0.77	0.50	0.54
16/1/49 –	19.2	18.4	8.9	2.85	1.16	0.73	0.865	16.3	17.8	9.9	1.55	0.77	0.52	0.535
17/1/49 –	21.0	19.6	8.6	3.15	1.25	0.86	0.995	19.9	18.9	9.1	1.7	0.82	0.66	0.66
18/1/49 –	20.2	19.1	8.1	3.05	1.22	0.84	0.975	19.0	18.9	9.1	1.7	0.82	0.66	0.66
19/1/49 –	20.9	18.9	7.7	2.6	1.08	0.81	0.985	20.0	18.8	8.3	1.5	0.76	0.69	0.67
20/1/49 –	22.1	19.7	7.8	2.6	1.08	0.88	1.03	21.7	19.8	7.9	1.5	0.76	0.76	0.72
21/1/49 –	21.9	20.7	8.1	2.7	1.11	0.91	1.07	21.5	21.0	8.0	1.65	0.80	0.81	0.755
22/1/49 –	21.7	21.4	8.2	2.75	1.13	0.93	1.105	21.5	21.5	8.1	1.85	0.85	0.84	0.785
23/1/49 –	21.7	22.3	8.8	2.85	1.16	0.97	1.12	21.7	21.6	8.2	1.9	0.87	0.86	0.785
24/4/49 –	21.2	23.1	9.2	2.7	1.11	0.96	1.09	21.3	22.7	9.1	1.75	0.83	0.84	0.735
25/1/49 –	21.9	25.3	9.9	2.7	1.11	1.04	1.155	21.9	24.9	9.4	1.75	0.83	0.92	0.81
26/1/49 –	21.9	26.8	10.8	2.75	1.13	1.08	1.22	21.9	26.3	9.9	1.85	0.85	0.97	0.845
27/1/49 –	21.0	26.7	11.3	2.95	1.19	1.06	1.215	21.5	26.3	10.9	1.85	0.85	0.93	0.835
28/1/49 –	21.0	25.8	11.2	2.9	1.17	1.02	1.205	21.3	25.6	11.1	1.7	0.82	0.89	0.81
29/1/49 –	20.0	25.4	11.3	2.85	1.16	0.97	1.145	20.5	25.0	11.2	1.5	0.76	0.82	0.755
30/1/49 –	20.2	24.0	11.0	2.75	1.13	0.91	1.115	20.2	23.8	11.1	1.45	0.74	0.76	0.73
31/1/49 –	20.0	22.2	10.6	2.7	1.11	0.84	1.05	20.0	21.9	11.0	1.45	0.74	0.70	0.69
1/2/49 –	20.2	20.7	10.3	2.6	1.08	0.79	0.965	19.6	20.2	11.1	1.5	0.76	0.65	0.63
2/2/49 –	18.5	19.8	9.9	2.6	1.08	0.72	0.88	17.3	18.7	11.1	1.5	0.76	0.54	0.56
3/2/49 –	18.5	19.9	9.7	2.45	1.04	0.73	0.865	16.5	18.2	10.4	1.5	0.76	0.52	0.525
4/2/49 –	18.3	20.5	10.0	2.4	1.02	0.73	0.825	16.1	18.6	10.6	1.4	0.72	0.52	0.48
5/2/49 –	17.7	20.2	10.3	2.4	1.02	0.69	0.815	15.8	18.2	11.1	1.45	0.74	0.49	0.475

Both the Dry Creek sets of values are higher than those for Adelaide and the Waite Institute. Measured exceeds calculated evaporation considerably at Dry Creek and only slightly in the mean at Adelaide, while calculated exceeds measured evaporation in the mean at the Waite Institute. Correlation between fluctuations in the pairs of curves is generally good.

There is little difference between the respective values of Q, θ_a and p_a for the pairs of stations, but there is disparity in V, the mean wind speed. V for Dry Creek is higher than for Adelaide and the Waite Institute, while it is roughly the same for the latter pair of stations. While it is conceivable that the Dry Creek h vs. V relationship might not be correct when extrapolated to the lower wind speeds of Adelaide and the Waite Institute—and the closer approximation to one another of the respective measured and calculated evaporation values might be so explained—this argument cannot explain why on the one hand measured exceeds calculated evaporation at Adelaide and on the other calculated exceeds measured evaporation at the Waite Institute. This effect may be related to evaporimeter construction. On the basis of material and surface finish, the Dry Creek evaporimeter could be expected to give an evaporation some 3-4% higher than that at Adelaide. The copper Waite Institute evaporimeter could be expected—on the basis of some data given by Young (24)—to give an evaporation comparable with that at Dry Creek. This argument would make the apparent discrepancy between Adelaide and the Waite Institute even greater.

The effect may be related to operating conditions: the working levels in the evaporimeters are here set out:—

TABLE IX

Evaporimeter	Distance below tank rim: Normal Range	Distance below tank rim: Mean Level
Dry Creek (Standard)	1·4 - 2·4 in.	2 in.
Adelaide	1·0 - 2·5 in.	1·75 in
Waite Institute	2·5 - 4·5 in.	3·5 in.

The data of Table III. show there to be a potential source of large error in these level differences.

Subsequently, in December, 1949, a check was made upon the actual h vs. V relationship for the Waite Institute and also for a pair of Australian Standard evaporimeters for Dry Creek using different working levels as in Table III. At the Waite Institute h for V of 1-2 m./sec. was about 25% lower than fig. 1 would show, and simultaneously at Dry Creek h for V of 2-4 m./sec. for the evaporimeter with working level 3.5 in. below the rim showed a similar depression.

No comparative evidence on possible evaporimeter-soil heat exchange is available except that the effect of insolation on the stone-covered ground at Dry Creek would have been greater than that on the lawn-covered surfaces at Adelaide and the Waite Institute.

The conclusion to be drawn from the data for these three stations is that the calculated evaporation rates are quite possibly more reliable than those measured in the evaporimeters, and that a comparison on the former basis should give the truer picture.

MEANS OF VARIABLES FOR USE IN THE EQUATION

Priestley (14) points out that the mean temperature to be used in calculating evaporation should not be the simple mean of temperature taken at regular intervals, but one which should be weighted according to the cycle of values assumed by the diffusion coefficient, k. Such an argument has more force for localities with a pronounced diurnal wind cycle, like Dry Creek.

Some data from 7 days' continuous observations made at Dry Creek in fine weather in January, 1947, will be used to illustrate this. Fig. 4 shows averages of the 7 days' readings for each hour of day for dry bulb air temperature (θ_a), wind speed at 3 ft. (V), and water temperature (θ_w) measured at 3 in. below the surface of the standard evaporimeter.

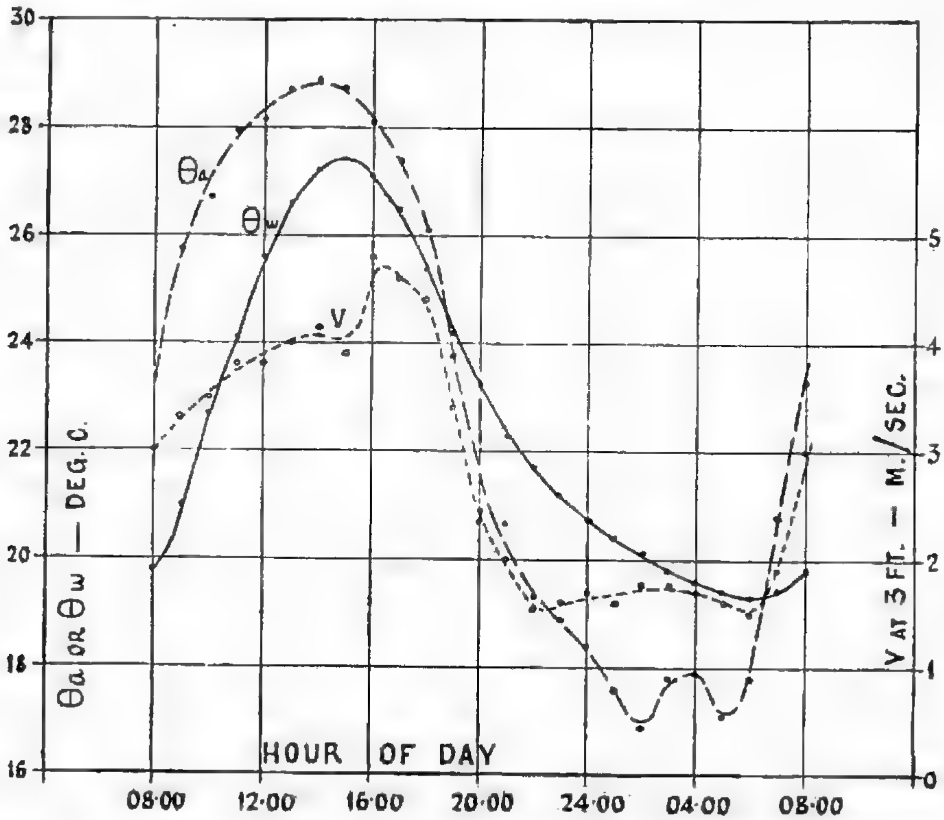

Fig. 4

Means of variables at Dry Creek for 7-day period in January, 1947

The simple means of θ_a and θ_w for the whole period were first worked out. From the simple mean of θ_a, 22.9°C., and that of θ_w, 22.7°C., it was possible to calculate the sensible heat gained by the water from the air, using h, 1.15 cal./cm²/hr./°C. It worked out at 5 cal./cm²/day. Inspection of fig. 4 will show, however, that there is apparently a relatively large $\theta_a - \theta_w$ difference at times of day when V (and hence h) is itself large. The use of weighted means of θ_a and θ_w might therefore be expected to yield a truer value for sensible heat exchange. Means were then worked out for θ_a and θ_w weighted according to the magnitude of the heat transfer coefficient (h) which had been derived from V, when they became 24.1°C. and 23.5°C. respectively. The temperature difference, $\theta_a - \theta_w$, which was 0.2°C. for the simple means, now became 0.6°C., and corresponded to a calculated sensible heat gain by the water of 17 cal./cm²/day. The difference between the two calculated heat exchange quantities of 12 cal./cm²/day amounts to only approximately 2% of the corresponding value of calculated Q. The substitution of weighted mean θ_a for the simple mean in equation (14) to calculate the respective evaporation rates for the 7 days in January, 1947, will not necessarily show the same per cent. difference in E, for calculated Q and the probable real Q (which determines the real θ_w used in the preceding discussion) are suspected to differ considerably for the standard tank. In fact, using for the variables Q = 21.9 cal./cm²/hr. (for $\theta_a = 22.9$°C.) and 21.8 cal./cm²/hr. (for $\theta_a = 24.1$°C.), $p_a = 8.4$ mm. of Hg., h = 1.15 cal./cm²/hr./°C., and $\theta_a = 24.1$°C. for the one case and 22.9°C. for the other, and calculating E_2 (cm./day) for the two cases gives respectively 1.05 cm./day and 1.01 cm./day for weighted and unweighted mean θ_a. This is a difference of 4%.

The size of the difference in E shown by the two methods of approach is enough to justify using for localities like Dry Creek a mean θ_a weighted according to h or V. An interesting point here is that the more-readily available form of mean air temperature in most localities is that of $\dfrac{\text{max.} + \text{min.}}{2}$ rather than the integrated mean. The former is biased slightly towards the maximum temperature—by 0.9°C. for Adelaide for January as shown by Foley (8)—so that, as a result of this convenient coincidence, the use of $\dfrac{\text{max.} + \text{min.}}{2}$ mean θ_a in the Ferguson equation may enable a truer evaporation rate to be calculated, while simplifying the derivation of mean θ_a.

PHASE LAG

It will be noted that from Table VIII. and fig. 3 that during the Dry Creek-Waite Institute evaporation comparison, evaporation and the related variables rose and then fell in some sort of natural cycle. There seems to be a phase lag between measured and calculated E for both stations, and this is more apparent when one of each pair of curves is moved close to the other by scaling each individual value of E using a suitable fixed factor. This has been done for the Dry Creek curves in fig. 5 where changes in measured E are seen to lag behind those in calculated E. The effect can, however, be largely explained by changes in sensible heat storage in the practical case, for these are neglected in calculating E.

All values of Q for Dry Creek have now been corrected for heat storage changes determined from changes in measured θ_w, and E values re-calculated on this basis have been scaled as before and plotted in fig. 5. This shows the effect of the lag to have been much reduced (although there is an anomaly in the parts of the curves covering the first few days).

The effect of neglecting heat storage changes over 7-day periods is noticeable, though small, but if it is desired further to minimize this effect, then periods of longer than 7 days should be taken when appreciable changes in θ_w level are taking place.

DISCUSSION ON THE RELATIONSHIP BETWEEN h AND k

Some doubt has been cast recently on the validity of the fixed relationship between mass and heat transfer in the lower atmosphere against a common resistance, which is the basis of the Ferguson and similar equations.

Priestley and Swinbank (15) have discussed this matter at length, while Pasquill (12) has demonstrated practically that the relationship between k and h in the turbulent boundary layer undergoes a change with atmospheric stability. Here h is shown to increase relatively to k as the atmosphere becomes more unstable, or, more precisely, as the Richardson number becomes negative and numerically larger.

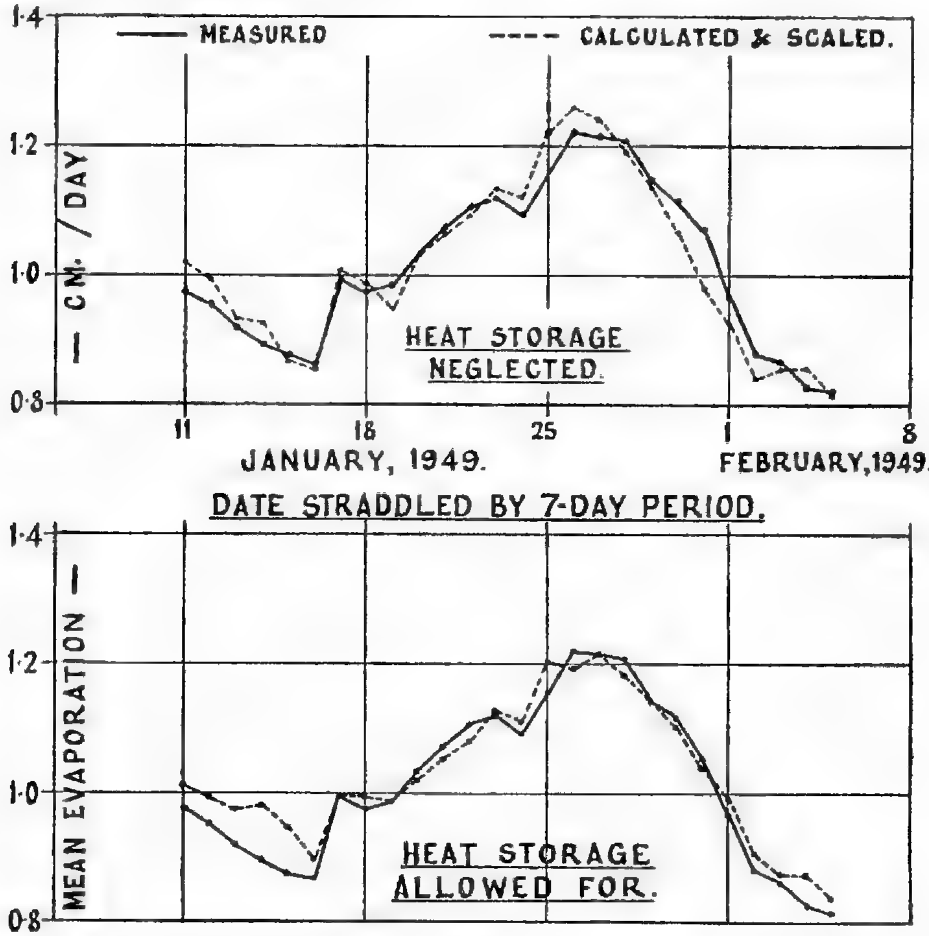

Fig. 5

Phase lag effect with Dry Creek evaporation rates in January and February, 1949

Consider the effect of this in equations (3) and (8). In (3) $\frac{h}{L\,k}$ will no longer be fixed at 0.50, but may obey the relationship

$$\frac{h}{L\,k} = 0.50x \qquad (15)$$

where x varies with Richardson number.

A modified equation (8) of this form would now hold:—

$$E = \frac{2\,h}{x\,L} \left\{ f\left(\frac{Q}{h} + \frac{2}{x}\,p_a + \theta_a\right) - p_a \right\} \qquad (16)$$

The variable relation between h and k in the turbulent boundary layer need not necessarily render E calculated from equation (8) very erroneous. The resistance against which the driving force ($p_W - p_a$) acts is not only that of the turbulent boundary layer, where matter and heat are propagated by eddy diffusion, but also that of the laminar sub layer in contact with the water surface, where molecular diffusion prevails. It is a well known principle that if in a series of resistances one is considerably greater than the other or others then this resistance "controls" the rate of the process. If it is the laminar layer that controls in the evaporation process considered, then the effect on evaporation of changes in h relative to k in the turbulent layer may be negligible.

It is a distinct possibility—for small evaporating surfaces at least—that the resistance of the laminar layer forms a substantial proportion of the total resistance. It can be observed that the value of p_a in the air an inch or so above the surface of water in an evaporimeter is little different from that measured in the free air at screen height, showing that by far the greater part of the total pressure difference, and hence resistance, is confined to this shallow layer. While this observation as it stands does not prove that most of the resistance is in the laminar layer, it at least shows that what eddy diffusion resistance there is over small evaporating surfaces is limited to a very shallow layer of the atmosphere.

Sherwood and Woertz (19) studying the diffusion of water vapour across a turbulent air stream between the two parallel walls of a duct 5.3 cm. apart found 43-72% of the overall resistance to be in the two laminar layers at the surfaces of the side walls when Reynolds' number ranged from 6,000-70,000.

Diffusion of water vapour through an air layer is controlled by the driving force or water vapour partial pressure difference across the layer and the resistance to diffusion in the layer. If different parts of the thickness of the layer are considered the fraction of the pressure difference across each part of the layer will in all cases be proportional to its resistance.

Above an evaporating surface the lower of the partial pressures, p_a, will decrease with increase in height, the p_a decrease being proportional to the resistance of that part of the air layer over which the decrease has occurred. The decrease of p_a with height is known as the "Hydrolapse."

When a certain height, z, over the evaporating surface is reached the hydrolapse will become negligible—a state to be arbitrarily assessed according to the particular conditions concerned. Only while diffusion is actively taking place across the whole of the layer thickness considered will pressure difference be proportional to the resistance of the air layer, and since at heights greater than z the air layer still has a theoretical resistance to diffusion, total pressure difference and total theoretical resistance over the total air layer reaching the heights greater than z will cease to bear the previous steady relationship. It is apparent, then, that the resistance to diffusion of the atmosphere over an evaporating surface is confined to that layer of air whose upper boundary is the level z where the hydrolapse first becomes negligible. z will be small for a small evaporating surface, and will increase as the surface is extended. z will always be above the boundary of the laminar layer and somewhere in the turbulent layer where resistance to diffusion has been shown to vary with the logarithm of the height above the effective surface. Therefore as z increases so will that part of the total resistance confined to the turbulent layer increase. The resistance of the laminar layer will, however, remain constant, so that qualitatively it may be concluded that as the evaporating surface is extended so will the total resistance increase, and so will the resistance of the turbulent layer increase relative to that of the laminar layer. It seems that the laminar layer resistance is much more likely to control the evaporation rate from small evaporating surfaces than from large ones. The practical work of Sheppard and Pasquill cited by Sutton (22) as showing the lack of correlation between evaporation from a small surface and the conditions in the turbulent boundary layer—notably the temperature gradient in the latter—lends support to the belief that the resistance of the laminar layer controls evaporation from small surfaces like those of evaporimeters.

Priestley[5] points out that h/k probably becomes more constant as the ground surface is approached—provided that this is not too rough—since eddies will become steadily smaller and will have less chance to realize the "buoyancy" effect that he has described (15). This argument does not invoke the laminar layer.

From the foregoing discussion it seems that the Ferguson equation in the form of (8) is more likely to be true for small evaporating surfaces. It is possible that ideal evaporimeters below a certain size will give results complying with the equation, while above it there will be an increasing discrepancy. The hypothetical and indeterminate limiting size will itself vary with the particular evaporation conditions, since z will vary somewhat with the latter.

It is probable in the case of both the Australian Standard evaporimeter and one 10 ft. in diameter that z will be below the level at which normal meteorological measurements of p_a are made. z must be the greater for the 10 ft. diameter evaporimeter, meaning that the total diffusion resistance for this evaporimeter must also be greater. The practically-determined diffusion coefficients for the two Dry Creek evaporimeters dealt with are different, but from the evidence at present available it cannot be determined whether the difference is due to differences in the level of z, to differences in exposure (resulting from height of rim upstand, diameter, etc.), or to a combination of the two.

CONCLUSION

If the Ferguson equation can be shown to give accurate results in predicting evaporation on the evaporimeter scale over a wide range of meteorological conditions, figures so determined would supersede those now obtained from evaporimeters. It is rather desirable to eliminate the effects of variations in exposure to which evaporimeters are now subject. Evaporation values for the whole country could be calculated on the basis of a fixed average wind speed, or at least on wind speeds extrapolated down from those measured at a level well clear of the ground, such as at the 10 m. level, so avoiding the micro-climatological differences in wind near the ground that now so affect the characteristics of individual evaporimeter sites. An evaporation map based on the Ferguson Equation and covering the whole of Australia, say, would possibly be more representative than one based on the readings of tank evaporimeters.

Thanks are due to Prof. J. A. Prescott and Mr. C. H. B. Priestley for reading the manuscript and for helpful suggestions, to the Adelaide Weather Bureau and the Waite Agricultural Research Institute for co-operation in obtaining some of the data used, to Prof. Sir Kerr Grant for help in dealing with a radiation problem, to Dr. J. Ferguson for permission to quote his equation, and finally to I.C.I. Alkali (Australia) Pty. Ltd. for permission to publish this paper.

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(5) Personal communication.

Fig. 1
The evaporimeters at Dry Creek.

Fig. 2
The evaporimeter site at Adelaide during November and December, 1948.

The evaporimeter site at the Waite Institute during January and February, 1949.

Notation

E = evaporation, cm./hr.
E_1 = ditto, cm./28 days.
E_2 = ditto, cm./day.
h = heat transfer coefficient, specifically cal./cm^2/hr./°C.
h' = modified heat transfer coefficient in equation (11), cal./cm^2/hr.°C.
k = diffusion coefficient for water vapour, specifically gm./cm^2/hr./mm. of Hg.
L = latent heat of vaporization for water, specifically cal./gm.
p_a = partial pressure of water vapour in air, specifically mm. of Hg.
p_w = vapour pressure of water, specifically mm. of Hg.
Q = nett radiant energy penetrating water surface, specifically cal./.cm^2/hr.
r = variable defined by equation (12).
T_a = mean air temperature, °K.
V = mean horizontal air speed at 3 ft. height, specifically m./sec.
w = weight of water evaporated, specifically gm./cm^2/hr.
x = variable relating h/k relationship to Richardson number.
z = height where hydrolapse first becomes negligible.
θ_a = mean air temperature, specifically °C.
θ_w = mean water temperature, specifically °C.
σ = Stefan-Boltzmann constant.

REFERENCES

(1) Australian Meteorological Observer's Handbook 1925, 96
(2) Bilham, E. G. 1931 British Rainfall, M.O. 345 (IV), 268
(3) Bonython, C. W. 1948 Aust. Jour, Instr. Tech., **4**, (5), 209
(4) Brooks, F. A. 1936 Univ. of Calif. Agric. Exp. Stn., Bull. 602
(5) Brunt, D. 1944 Physical and Dynamical Meteorology, 2nd Edn., Cambridge Univ. Press, 137
(6) Cummings, N. W. and Richardson, B. 1927 Phys. Rev., **30**, 527
(7) Field, R. and Symons, G. J. 1869 Brit. Assoc. Adv. Sci., 39th Meeting, 25
(8) Foley, J. C. 1945 C'wealth of Aust., Bur. of Met., Bull. No. 35
(9) Foley, J. C. 1947 Proc. Aust. N.Z. Adv. Sci. (Perth)
(10) Gilby, A. R., and Heymann, E. 1948 Aust. J. Sci. Res., **1**, (2), 197
(11) Heymann, E., and Yoffe, A. 1945 J. Phys. Chem., **49**, 239
(12) Pasquill, F. 1949 Proc. Roy Soc., A., **198**, (1052), 116
(13) Penman, H. L. 1948 Proc. Roy. Soc., A., **193**, 120
(14) Priestley, C. H. B. 1949 Specialist Conference in Agriculture—Australia
(15) Priestley, C. H. B. and Swinbank, W. C. 1947 Proc Roy. Soc., A., **189**, 543
(16) Raman, P. K. 1936 Proc. Ind. Acad. Sci., **3**, (2), 98
(17) Rohwer, C. 1931 U.S. Dept. of Agric., Tech. Bull. No. 271
(18) Sheppard, P. A. 1947 Q. J. Roy. Met. Soc., **73**, 277 (Discussion)
(19) Sherwood, T. K. and Woertz, B. B. 1939 Trans. Am. Inst. Chem., Eng., **35**, 517
(20) Sleight, R. B. 1917 J. Agric. Res., **10**, 209
(21) Sutton, O. G. 1934 Proc. Roy. Soc., A., **146**, 701
(22) Sutton, O. G. 1947 Q. J. Roy. Met. Soc., **73**, 257
(23) Walker, Lewis and McAdams 1927 Principles of Chemical Engineering, 2nd Edn., New York and London, McGraw-Hill Book Co., Inc., 443
(24) Young, A. A. 1947 Trans. Am. Geophys. Union, **28**, (2), 279

STONE IMPLEMENTS FROM A MANGROVE SWAMP AT SOUTH GLENELG

BY H. M. COOPER

Summary

This paper briefly describes stone implements discovered on the surface of an estuarine mangrove mud swamp at South Glenelg, laid bare after the removal of the overlying sandy beach by scour, following a heavy south-westerly gale experienced during April, 1948. It is suggested that the implements and camp debris were associated with a temporary camp site. Established by natives upon the advancing sand which encroached on and later overwhelmed the former living mangrove swamp.

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This paper briefly describes stone implements discovered on the surface of an estuarine mangrove mud swamp at South Glenelg, laid bare after the removal of the overlying sandy beach by scour, following a heavy south-westerly gale experienced during April, 1948. It is suggested that the implements and camp debris were associated with a temporary camp site established by natives upon the advancing sand which encroached on and later overwhelmed the former living mangrove swamp.

CAMP SITE AND MATERIAL

Stone implements, and certain other relics of aboriginal occupation, were found on the re-exposed mangrove mud-flat described by Cotton (1949). The implements exhibit somewhat crude workmanship, but they are nevertheless of interest because of their existence, for a considerable period of time, upon a site which is now situated below the level of high water mark on an open coast exposed to gales.

The implements are identical with types obtained on camp sites which existed on the Adelaide Plains and the coast southwards to Cape Jervis, formerly occupied by the now extinct Kaurna tribe and associated groups.

No specimens of smaller and more finely executed implements were found, but their absence may be due either to the action of the sea which swept them away after the removal of the overlying sandy beach by scour and subsequent exposure of the swamp, or because the camp was of a temporary nature and thus merely utilised by the aborigines as a convenient spot when searching for fish or shellfish and other food. An examination of similar material which occurs plentifully on temporary sites amongst the recent coastal sand dunes tends to confirm the latter view.

Since the surface of a mud swamp, even if uncovered at low tide, is totally unsuited for such a purpose, a camping place, even a temporary one, would not have been established thereon until the encroaching sand had begun to accumulate, thus providing over it a dry surface suitable for the needs of the native inhabitants. With subsequent erosion the implements would be deposited upon the surface of the mud stratum beneath, or if the accumulating layer of sand were still thin during the occupation of the site, they may have worked down and thus become embedded in the swamp.

The presence of a fragment of somewhat heavy wood—portion of a small limb or branch—partly burnt, and embedded in the mud surface, together with several small heaps of embers, apparently derived from the same type of timber, possibly *Eucalyptus* sp., suggests the existence of a former camp fire. Nearby was discovered a piece of sheoak tree (*Casuarina stricta*), in an excellent state of preservation, clearly exhibiting the distinctive grain of that timber, together with its characteristic ribbed outer bark.

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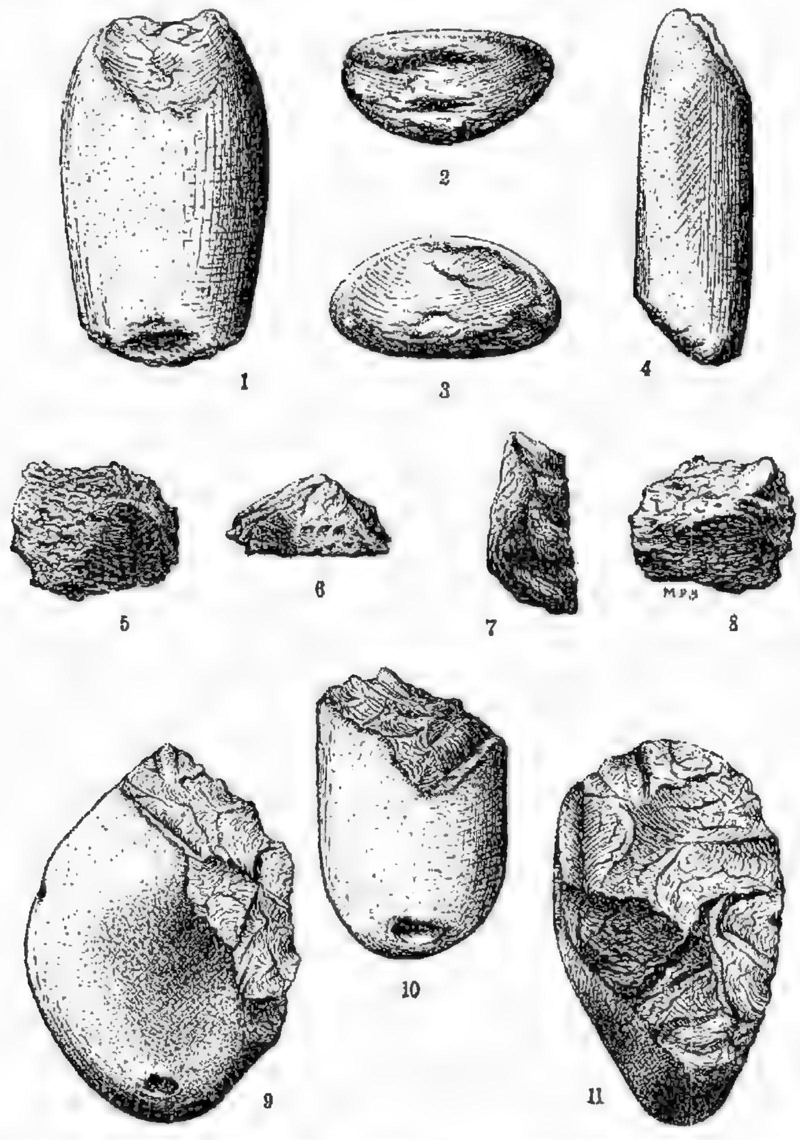
A successful attempt was made to burn the stump of a mangrove tree (*Avicennia officinalis*), extracted in situ from the swamp, after it had been thoroughly washed and then exposed to atmospheric action for several months. With the addition of a small quantity of spirits to commence combustion, the wood was completely consumed, leaving the typical white ash derived from this timber.



Description of implements shown in the accompanying drawings:—

Figs. 1-4: Fabricator or hammerstone, showing end flakes broken off during usage. Fabricators were utilised in shaping and trimming large implements similar to those shown in Figs. 9-11.

Figs. 5-8: Small trimmed adze-stone of conventional type. These implements were mounted at the extremity of a wooden handle by means of gum.

Figs. 9-11: Large chopping implement (held in the hand during use); trimmed from a water-worn pebble.

The rock in these three specimens is a fine-grained bluish quartzite.

Other material recovered:—Two pebble chopping implements, somewhat similar to Figs. 9-11; Large core derived from an angular block; Three large flakes struck from pebbles; One piece of yellow ochre; Two pebble cores.

ACKNOWLEDGEMENTS

Appreciation is extended to Mr. R. W. Searles, master boat-builder, of Birkenhead, for his assistance in determining the character of the various species of trees to which reference is made, and to Miss M. Boyce, South Australian Museum artist, for the excellent drawings accompanying this paper.

REFERENCE

COTTON, B. C. 1949 An old Mangrove Mud-flat exposed by Wave Scouring at Glenelg, South Australia. Trans. Roy. Soc. S. Aust., **73**, (1)

BALSATIC LAVAS OF THE BALLENY ISLANDS A.N.A.R.E. REPORT

BY D. MAWSON

Summary

Rocks collected on the Balleny Islands by the Australian National Antarctic Research Expedition in 1948 and by the French Antarctic Expedition in 1949, are all of a basic volcanic nature. It now seems certain that the entire group is a balsatic volcanic chain of islands, of late Cainozoic to Recent age. The rock types represented are lavas, agglomerates and tuffs. These range in composition from olivine-basalts to trachybasalts in the groundmass of some of which a minute development of nepheline is suspected.

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By D. Mawson *

[Read 11 May 1950]

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THE BALLENY ISLANDS — HISTORICAL

In 1838 the Enderbys in association with other London merchants fitted out the schooner *Eliza Scott*, 154 tons, with John Balleny in charge, and the cutter *Sabrina*, 54 tons, under H. Freeman, for the purpose of sealing and exploration in the southern seas. Early in 1839, after sealing operations on the coast of southern New Zealand and Campbell Island, they proceeded south on a voyage of discovery. When in latitude 69° further progress south was prevented by drift ice. They then proceeded westward, working along the margin of the heavier pack-ice. On February 9th (1839) a group of five islands were sighted which Balleny distinguished, each by the name of one of the partners of the firm of Enderby Brothers. Steam and smoke were reported as rising from one of the islands, and they were all regarded as of a volcanic nature. Efforts made to reach the land were impeded by drift ice.

Eventually a passage was worked in to one of the islands and both captains proceeded to attempt to land in the *Sabrina's* boat. On reaching what Balleny described as the only accessible place along the ice-ridden, cliff-bound coast, Captain Freeman jumped from the boat on to a beach of a few yards wide, uncovered only momentarily as the ocean waves withdrew; in that time, however, he secured a few beach pebbles as evidence of land. They did not linger longer, but pursued their voyage to the west in search of more hospitable shores.

Sad to relate, on March 24th when riding out a gale, some hundreds of miles further to the west, the *Sabrina* was lost with all hands. The *Eliza Scott* alone returned to tell the tale. With Captain Freeman were lost also his specimens. Only recently with the visit of the Australian National Antarctic Research Expedition, has a second landing been made and rock specimens secured for examination.

In the years that have elapsed since Balleny's visit, these islands have been sighted by very few expeditions operating in neighbouring Antarctic waters. They are comparatively inaccessible, for they are located in the pack-ice belt encircling the Antarctic Continent and their presence there obstructs the free movement of the pack-ice in its orderly drift from East to West in the off-shore waters around the Continent. As a consequence, these islands are usually embedded within an impenetrable ice-jam; thus only rarely have ships an opportunity of penetrating to their shores. Actually, the whole of the sea-ice which forms each winter in the Ross Sea to break up and drift

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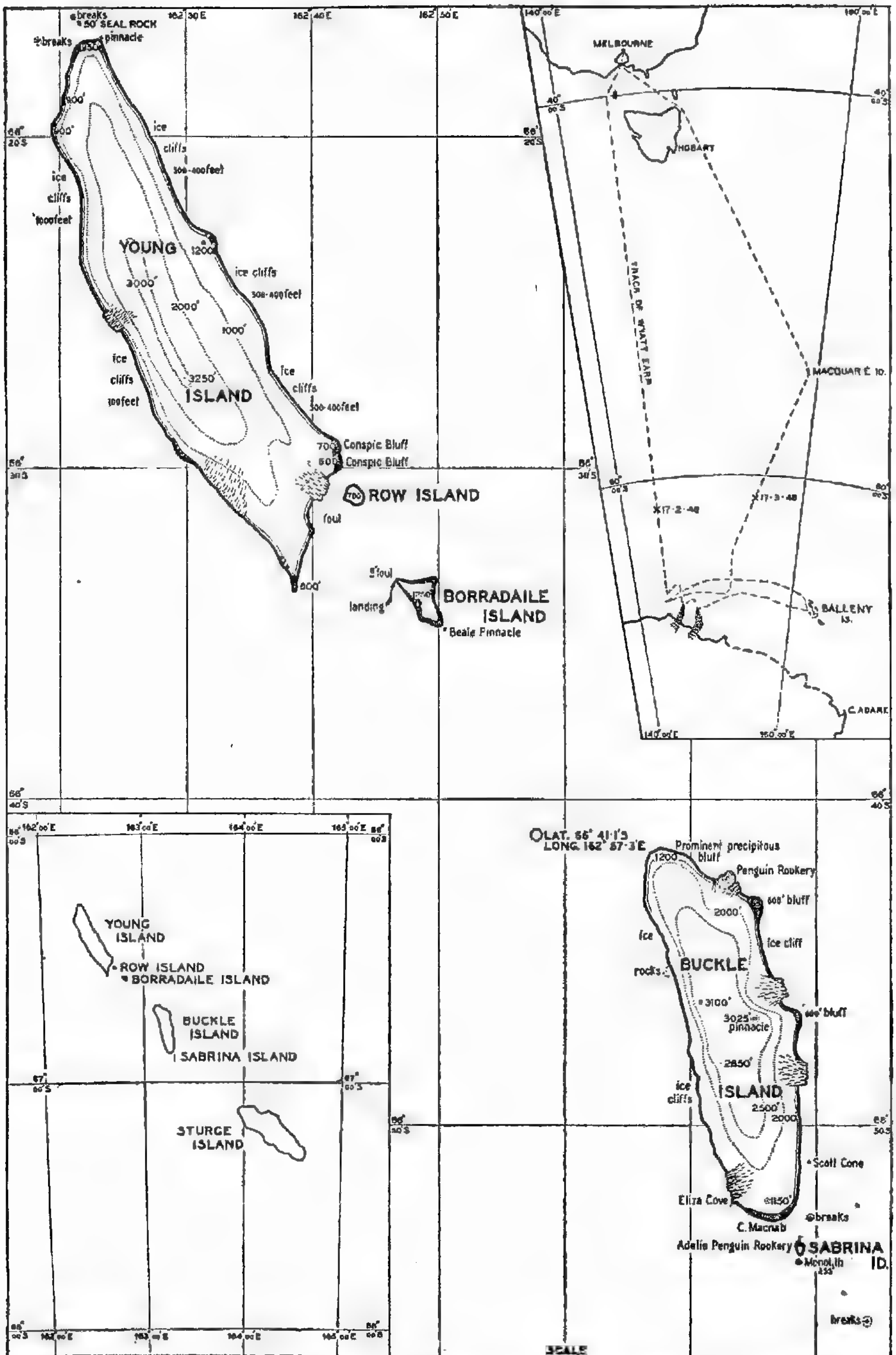

The Balleny Islands and their Geographic Location.

away to the north-westward in the ensuing summer has to negotiate this ice-jam. Only in favourable years is this ice congestion relieved and then only in the late summer.

Sir James Clarke Ross, in 1941, engaged on the memorable expedition which discovered the Ross Sea, sighted the Balleny Islands across the pack-ice but only at a great distance from them. Actually he believed this landfall to be the discovery of new islands south of Balleny's find and gave to them the name of Russell Islands.

Much later, on the return voyage of the *Discovery* during the operations of the British National Antarctic Expedition of 1901-04, Scott set a course to reach and check Balleny's discovery. That was a favourable year and they sighted and fixed more accurately the position of four of the islands. They did not, however, effect any landings.

On several occasions in subsequent years, whaling vessels operating in the neighbourhood of the Ross Sea have, late in the summer season, come within sight of one or more of the islands.

In the summer of 1934 when returning from the Ross Sea in foggy weather, the exploring vessel *Discovery II*, obtained a glimpse of one or more of the islands, but was unable to land. Later, during her 1936-38 cruise, *Discovery II*, under command of Lieut. L. C. Hill, R.N.R., returned to the region and under better weather conditions charted the four more northerly islands, fixing their position accurately.

More recently, in February 1948, the *Wyatt Earp* of the Australian National Antarctic Research Expedition found most of the islands of the Group to be sufficiently accessible to allow Commander K. Oom, R.A.N., to effect more detailed charting and to permit Wing Commander Stuart Campbell, Expedition Leader, to make a couple of landings for the purpose of securing rock specimens. The ice conditions did not permit access to Sturge Island, the most southerly of the Group.

More recently still, in the summer of 1949, the French exploring vessel *Commandant Charcot*, in command of Captain Max Douget, made a landing on Sabrina Island. This expedition succeeded in reaching Sturge Island.

GEOGRAPHICAL FEATURES.

The Balleny Islands form a chain directed from the south-east towards the north-west, extending over a length of about 140 statute miles.

These islands lie about 165 statute miles to the north of the Antarctic Continent at its nearest approach. Deep water, about 1500 fathoms, separates them from the mainland. Equally deep water exists at only a few miles to the north of the island chain.

The Group consists of three large islands (Young, Buckle and Sturge Islands), three smaller islands (Borradaile, Rowe and Sabrina) and some isolated reefs and rock pinnacles. Sturge Island, the most southerly, is some 29 statute miles long. Buckle Island has a length of about 14 miles and Young Island 21 miles. Borradaile Island is in the vicinity of two and a half miles in length, while Rowe Island and Sabrina Island are but a fraction of a mile.

With rare exceptions, the islands are cliff bound, thus limiting the possibilities of landing; hence rock collections thus far secured are but meagre. The height of Sturge Island is now taken to be about 5600 feet. Young Island, once reported to be extremely high, has lately been found to be very little over 3000 feet. The other islands are considerably lower. They are all capped with ice, and rock appears only on the cliff faces or in rare and very limited exposures as pebble banks at sea-level. The active volcanic phenomena reported by Enderby have not been observed by recent visitors. However, the rock collections hereinafter described indicate a late Cainozoic to recent volcanic origin for the entire Group.

ROCK TYPES COLLECTED

A description of the rocks collected in 1948 by the Australian Expedition is the special subject of this contribution. As an addendum thereto, reference is also made to a small collection of rocks obtained during the 1949 cruise of the *Commandant Charcot*. These latter were secured through Mr. N. Lotthowitz of Melbourne University, whom Commander Liotard kindly gave permission to accompany the French Expedition on that voyage.

The A.N.A.R.E. collection consists of some 14 specimens from two localities; the first, Borradaile Island, the second Buckle Island. These range from a boulder of about 15 lbs. weight to quite small pebbles.

Additional specimens obtained through the kindness of the *Commandant Charcot* Expedition are also 14 in number and were secured from two other islands, namely Sabrina Island and Sturge Island.

All these, with the exception of one only, are basic volcanic rocks. The one exception is specimen No. 12, composed of coarsely crystalline epidote intimately associated with grains of quartz. As this was not found *in situ*, it may be assumed that it is a transported erratic or is of the nature of a xenolith derived from an underlying formation brought up from below in the volcanic uprush.

The rock types obtained from each of the localities where collections were made are listed herewith.

Borradaile Island. A landing from the *Wyatt Earp* was made on a spit at the north-east end of the Island and two large specimens (Nos. 2 and 3) of the prevailing rocks were secured. These are both olivine trachybasalt, and represent lavas which congealed at or near the surface.

Buckle Island. The remaining 12 specimens (Nos. 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14) collected by the *Wyatt Earp* party, were obtained from the surface of old sea-ice, some 50 yards from the shore cliffs, at a point about half-way down the east coast. All these boulders are taken to have been derived from Buckle Island, avalanched down from the overtowering rock cliffs. Most of these specimens while they exhibit some faceting show very little other evidence of glaciation. Some of the pebbles suggest initial shaping by ice with subsequent water wear.

They are divisible into three groups. Firstly, fresh, grey olivine trachybasalts and basalts, most being slightly vesicular (Nos. 1, 3, 5, 6, 7, 8, 9, and 10). Secondly, scoriaceous plagioclase basalts reddened by the penecontemporaneous attack of escaping volcanic steam and other gases (Nos. 4, 11, and 13). Finally, a coarsely crystalline epidotic rock, already mentioned, not obviously of the volcanic suite and apparently of foreign origin (No. 14).

Sabrina Island. The French Expedition landed at the Adelie penguin rookery near the north-east corner of the Island and secured specimens from that location and from the Monolith. Of the material brought back by Lotthowitz and added to our set of rocks illustrative of the Balleny Islands, Nos 15 and 16 recorded as common sea-shore stones of Sabrina Island, are olivine-augite-plagioclase-basalt that has been subjected to slight reddening by solfataric attack. Nos. 22 and 23, secured *in situ*, are almost identical grey olivine-plagioclase-basalts. Nos. 18 and 26, referred to as characteristic red stones of the Island, are reddened scoriaceous basalt. No. 17, a beach stone, is a black pumiceous basalt with micro-phenocrysts of olivine and abundant labradorite needles in a dusty glass base. No. 25 is a tuffaceous basaltic agglomerate. No. 24, from the Monolith, is a grey vesicular olivine-plagioclase-basalt. No. 27 represents the finer gravel from the shores; it consists of water-worn basalt particles of a dominantly grey colour.

Sturge Island. The French Expedition collected specimens from the surface of free floating sea-ice near the north end of the west coast. Though doubtful these pebbles may represent sheddings from the lofty cliffs nearby. With them is some gritty morainic sludge.

No. 19 is a basic volcanic breccia. No. 20 is a propylitized, highly scoriaceous basalt. No. 21 is a glaciated pebble of vesicular feldspathic basalt which has undergone paulopost changes with development of chlorite, calcite, etc. No. 28 is a uniform grey morainic mud originating from the glaciation of basaltic rocks.

PETROLOGY

The following petrological descriptions of rocks of the Balleny Island collection deal only with the more important types. As there is a close similarity in composition and type among the unaltered rocks, it will suffice to describe in detail only two of them, namely No. 1 from Buckle Island and No. 2 from Borradaile Island. Brief reference will be made to others.

Olivine Trachybasalt from Buckle Island

This specimen, No. 1, is a large platy block of a dark ash-grey volcanic rock. It is perfectly fresh, with the appearance of being, in all probability, of Recent or near-Recent age. This was collected on the adjacent sea-ice within 50 yards of the shore cliffs at about the middle of the east coast of Buckle Island.

In the hand-specimen, it is somewhat rough to the feel, and with the aid of a pocket lens, some minute irregular steam-hole cavities can be detected. It is almost entirely of a very fine, even-grained nature in which the mineral constituents cannot be distinguished with the naked eye: embedded therein, however, are occasional very small olive-coloured phenocrysts of olivine, the maximum size of which is 4 mm.

In the rock slide, microphenocrysts of olivine and to a less extent augite, are observed to be embedded in a microcrystalline groundmass. The latter features a striking development of plagioclase in fresh clear laths, markedly oriented in flow lines distributed through a dark base in which minute grains of augite and magnetite are discernible.

The olivine phenocrysts which, in the slide, do not exceed 3mm. are quite fresh and unaltered: the interference figure is that characterising olivines of high magnesia content. Augite micro-phenocrysts do not exceed 1mm. in diameter and are clear and fresh: zoning is observable in some, and in these an outer zone is notably pleochroic. The non-pleochroic central area has the higher extinction angle, 44°, and an optic axial angle of about 60°, thus indicating rather normal augite: the pleochroic zone has a 2V of about 40° characteristic of a sub-calcic augite.

The most obvious mineral of the groundmass is plagioclase in tiny laths and needles up to 1 mm. in length, but averaging only about 0·6 mm. Some are without twinning, the remainder rarely exhibit more than a single albite twin. The optical characters of the laths indicate a range from andesine to medium labradorite. Other components of the groundmass are much fine granular augite of a similar composition as the outer zone of the phenocrysts, tiny grains of olivine and minute particles often perfect cubes of magnetite or ilmeno-magnetite. Minute glass-like residuals are discernible but only to a very limited extent: these are of low R.I. and exhibit faint, anomalous D.R. These may be analcite. Tiny euhedral apatites are not uncommon.

The analysis of this rock illustrates a lower magnesian and higher alkali content than is normal with basalts. Mineralogically the feldspar content is greater and the ferromagnesian minerals fewer than is the case in normal basalt. In view of the plagioclases having a higher albite content than is normal for basalts this rock may be classed as olivine-trachybasalt.

A chemical analysis and the norm derived therefrom are given on page 229. The general character of the rock is illustrated in the thin-slide microphotograph (fig. 3) appearing in the accompanying plate.

Olivine Trachybasalt (No. 2) from Borradaile Island

This is a fresh medium to darkish grey microcrystalline, volcanic rock in which are observable a few small phenocrysts, the largest being 4mm. in diameter, of olive-green olivine. It is a water-worn boulder collected on a spit at the north-east end of Borradaile Island. Occasional tiny vesicles are observable on the fracture face.

The microscope slide reveals a microcrystalline base dominated by plagioclase laths exhibiting marked flow structure: embedded in this base are small phenocrysts of olivine and augite.

The larger plagioclases have the characters of acid labradorite with 2V of about 80°. Small porphyritic olivines are abundant as well formed crystals, occasionally reaching 4mm. diameter; much of the olivine is fragmented. It is biaxial negative with 2V about 35°, thus a sub-calcic augite approaching pigeonite.

As regards the groundmass the streaming structure of the plagioclase laths and needles is the most notable feature: of these the larger of them average 0.4mm. in length. There are occasional abnormally large individuals and these exhibit well developed twinning. Albite twin extinction angles indicate labradorite ($Ab_{46}An_{54}$). Microlites and some untwinned laths with lower R.I. are apparently andesine or even more albitic. Other minerals of the groundmass are well formed olivines and augites averaging 0·3 mm. diameter as well as tiny irregular grains of augite associated with plagioclase needles and abundant tiny cubes and specks of magnetite and ilmenite; also a very little brown glass.

From the above description and the chemical composition stated in the table of analyses, this rock also may be classed as an olivine-bearing trachybasalt.

Included in the table of analyses is the chemical composition of the Balleny Island rocks numbers 1 and 2. As both of these are very similar types the mean of their chemical analyses is also given in column III. Also for comparison is included the analyses of each of two trachybasalts from Possession Island (Crozet Group) referred to by Tyrrell*. The norms are also stated below.

*B.A.N.Z. Antarctic Research Expedition Reports, Series A, vol. II, pt. 4.

	I.	II.	III.	IV.
SiO_2 - -	47.73	45.06	46.395	44.255
TiO_2 - -	2.39	2.69	2.540	2.400
Al_2O_3 - -	16.87	18.76	17.815	17.705
Fe_2O_3 - -	2.52	0.23	1.375	4.665
FeO - -	8.78	9.94	9.360	7.005
MnO - -	0.18	0.19	0.185	0.125
MgO - -	5.80	7.33	6.565	5.935
CaO - -	8.64	9.72	9.180	10.735
Na_2O - -	4.90	4.19	4.545	2.990
K_2O - -	1.99	1.57	1.780	1.295
H_2O+ - -	0.14	0.12	0.130	2.420
H_2O- - -	0.02	0.02	0.020	
P_2O_5 - -	0.65	0.65	0.650	0.395
S - - -	0.09	0.05	0.070	—
BaO - -	0.06	0.06	0.060	—
	100.76	100.58	100.660	99.825
less O for S -	0.02	0.01	0.015	—
Total - -	100.74	100.57	100.645	99.825

I. Analysis of olivine-trachybasalt from Buckle Island (Balleny Group), by A. P. Wymond (University, Adelaide).

II. Analysis of olivine-trachybasalt from Borradaile Island (Balleny Group) by R. B. Wilson (University, Adelaide).

III. Mean of analyses I. and II.

IV. Mean of analyses of (a) olivine-trachybasalt from American Bay, Crozet Island, (analyst, Herdsmen) and (b) the olivine-trachybasalt from Christmas Bay, Crozet Island (analyst, Reinish), both quoted by Tyrrell (1937).

Norms of Balleny Island Rocks

Rock	No. 1		No. 2	
Orthoclase - - -	11·68	62·02	9·45	61·11
Albite - - - -	21·48		10·48	
Anorthite - - -	18·07		27·52	
Nepheline - - -	10·79		13·63	
Diopside - - -	16·35	38·42	13·66	39·41
Olivine - - -	11·96		18·72	
Magnetite - - -	3·71		0·23	
Ilmenite - - -	4·56		5·17	
Apatite - - -	1·68		1·54	
Pyrite - - -	0·16		0·09	
Water - - -		0·16		0·14
		100·60		100·63
C.I.P.W. Classification -	III. 5. 3. 4.		III. 5. 3-4. 4.	

Specimens 3, 5, 6, 8, 9 and 14 bear a general similarity in the hand specimen, though some are vesicular and others not. The greatest difference in texture is to be noted only in the microscope section. There it becomes obvious that certain of them are more highly feldspathic than others and some have been more quickly chilled than others. Also some exhibit flow structure highly developed while in others evidence of flow is negligible.

In the case of several, at least, chemical analysis would undoubtedly reveal them to contain less alumina and alkalies with corresponding increase in magnesium and calcium: thus a more normal type of basalt. In the following notes reference is made to only the more prominent characteristics of each of these.

No. 3 is a very large boulder of medium-grey rock which, in part, is obviously vesicular, the vesicles being small, irregular and flattened. There is a paucity of olivine and augite micro-phenocrysts. Occasional white glassy inclusions as recorded in No. 8 are observable in the hand-specimen. Microscopically there is a great similarity to specimen No. 1, there being a great development of labradorite laths usually markedly oriented by flowage of the unsolidified lava.

No. 5 is another grey, water-worn boulder similar in appearance to Nos. 3 and 14. Occasional tiny olivines are observable in the hand-specimen.

No. 6 in the hand-specimen, is somewhat darker grey than No. 8, but otherwise petrologically very similar. It differs from the type represented by No. 1 in that plagioclase laths are much less abundant and there is less flow orientation. Microporphyritic olivines and augites, the latter more abundant, are a feature.

The plagioclase has the optical characters of an acid labradorite. The olivine answers to the magnesian-rich variety. The pyroxene lacks colour, is biaxial positive, and has an extinction angle $c \wedge Z$ of about 40°; it thus appears to be a pigeonitic augite.

No. 8 in the hand-specimen is a grey rock which, like certain others (No. 9 for instance) has shadowy, quick chilled areas within it. An unusual feature is that of clear colourless glassy inclusions up to 1 cm. diameter. These blebs are remnants of partly resorbed crystals whose optical characters appear to indicate a plagioclase of the oligoclase-andesine range. In addition, small phenocrysts of olivine and augite up to 0·5 cm. diameter are in evidence.

The general character of this rock is very similar to that of No. 9 in that plagioclase laths and needles are suppressed and no outstanding orientation evidenced. The base also is quite like that of No. 9.

No. 9 is externally of very similar appearance to No. 14, except that it is traversed irregularly by streaks and patches of a quicker chilled darker phase. An absence of strongly developed and oriented plagioclase laths is notable in the microscopic slide. Obvious olivines are rare in the hand-specimen and their place is taken by microporphyritic augites. The slide under low power exhibits a dark and speckled base which, when more highly magnified, is seen to be a dense assemblage of microcrystals of pyroxene and magnetite embedded in a clear glassy base.

No. 14 is another medium to dark grey, microcrystalline rock in which are occasional small porphyritic greenish-yellow olivines up to 3mm. in diameter.

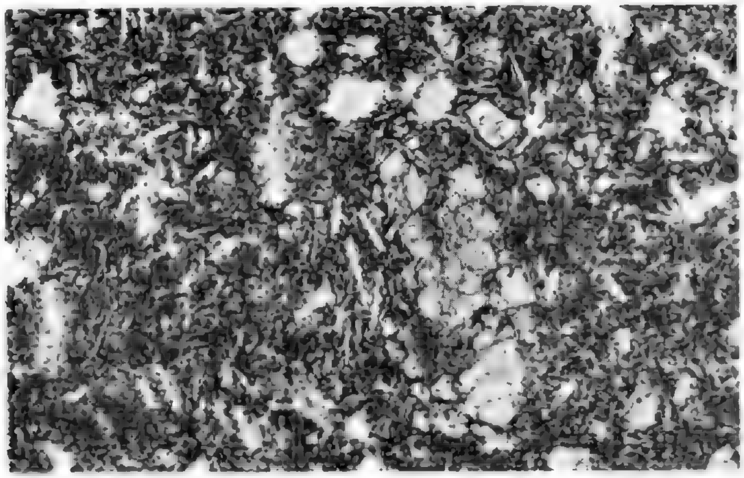

Fig. 1

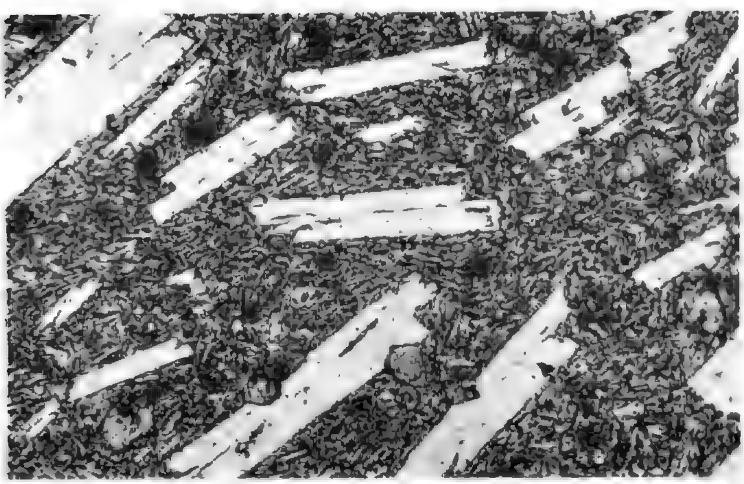

Fig. 2

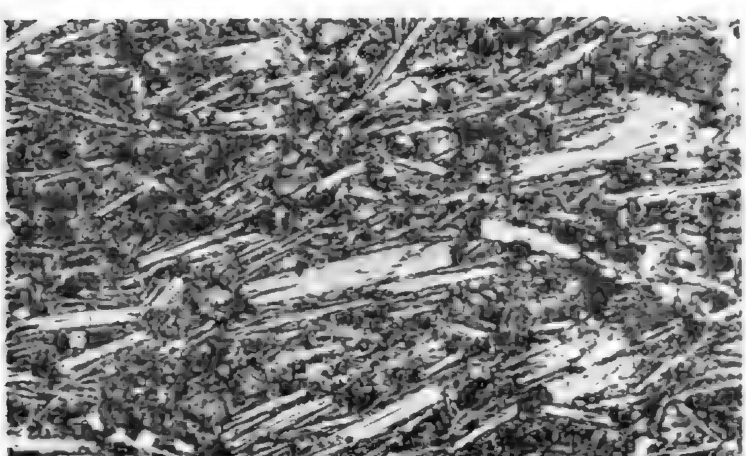

Fig. 3

Under the microscope the fine-grained base is dominated by a trachytoid arrangement of plagioclase in laths to 0.75mm long and in needles; there are occasional microporphyritic olivines. The general groundmass is constituted of small augites and to a less extent olivines with much irresolvable dark base in which euhedral magnetites and magnetite dust are obvious.

Titanaugite microphenocrysts, in part slightly pleochroic, is biaxial positive with 2V about 60°. The olivine is generally quite fresh and has a high optic-axial angle. The larger plagioclases show some zoning and have the characters of an acid to medium labradorite.

Specimens 4 and 11 are basaltic lavas that have undergone fumarolic gas attack.

No. 4 is a coarsely vesicular, reddish-brown lava. In microscope section it is seen to be basalt which has undergone chemical changes from the attack of volcanic gases. It has been subjected to considerable changes with the development of secondary minerals including some haematite, hence the colour. Originally it was a basalt with well developed laths of labradorite and microphenocrysts of olivine and augite, evidently quite similar to others of the specimens already described. Mainly as a result of late-volcanic activity subsequent to solidification, a considerable proportion of the steam holes have been filled by secondary minerals, mainly calcite and analcite.

No. 11 is another vesicular lava that has suffered penecontemporaneous gas attack resulting in partial breakdown of original minerals and reddening of the rock.

A feature as seen in microscope slide is the abundance of well developed stocky plagioclase laths in flow arrangement which, with some microporphyritic olivine and augite, are embedded in a yellowish glassy base charged with feldspar needles. The plagioclase ranges from medium andesine to labradorite (Ab_1An_1). Prisms of apatite are to be noted. The glassy base appears to be palagonitized.

DESCRIPTION OF MICROPHOTOGRAPHS

Fig. 1

Microphotograph of a thin section of rock No. 6, magnified 40 diameters. The larger individuals, especially a group on the left centre are olivines. Augite is in smaller andividuals, not conspicuous. Narrow laths and needles of plagioclase are obvious but not very noticeably developed. The bulk of the section is a base of minute granules of augite and dusty glass. Among the latter are minute patches and cavity fillings of what appears to be analcite.

Fig. 2

Microphotograph of a section of rock No. 11, magnified 40 diameters. The field is dominated by comparatively large and well formed plagioclase laths exhibiting flow orientation. A later more albitic generation of plagioclase appears as minute needles in the groundmass, which otherwise is mainly brownish dusty glass. Studded through this base are small olivines, grains of black iron-ore and occasional well-fomed apatite crystals.

Fig. 3

Microphotograph of a section of rock No. 1, magnified 40 diameters. A large part of the rock is observed to be composed of plagioclase laths in streaming arrangement. Olivine and augite in more granular form are both in evidence, the former in larger clearer crystals. The augite is in smaller granules and less conspicuous. Though in very tiny particles, there is much magnetite studded throughout the base in cuboidal and octrahedral forms. These recognisable constituents are embedded in a clear to dusty mesostasis, most of which is glass but in which there are needles of andesine and suggestions of nepheline.

THE LATE CAINOZOIC HISTORY OF THE SOUTH-EAST OF SOUTH AUSTRALIA

BY PAUL S. HOSSFELD

Summary

The late Cainozoic history of the South-East of South Australia is largely one of repeated recessions and advances of the ocean, and the preservation, wholly or in part, of the resulting stranded coastal dunes. Investigations support the view that the shorelines were unstable and the dunes were not formed in the sequence in which they exist today.

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[Read 8 June 1950]

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SUMMARY

The late Cainozoic history of the South-East of South Australia is largely one of repeated recessions and advances of the ocean, and the preservation, wholly or in part, of the resulting stranded coastal dunes. Investigations support the view that the shorelines were unstable and the dunes were not formed in the sequence in which they exist today.

A provisional chronology has been compiled in which the various shorelines are correlated tentatively with the positive and negative movements of sea-level during the Pleistocene Ice Age.

The vulcanism and other phenomena have been assigned places in the chronology.

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It is emphasised that the instability of the region during the period under review makes definite correlation with other areas in Australia or other countries impracticable at present.

The investigations carried out show that here is an area which, owing to the very low gradients of its basement, has been a sensitive indicator of changes in sea-level and on which is preserved a large part of the geological record from the Upper Pliocene to the present day. Not only will a study of this region provide a detailed picture of that time, but the results obtained by such an investigation will assist materially in the development of a clearer understanding of older epochs and periods of which a small proportion only of their original record has been preserved.

INTRODUCTION

The area to be described includes the greater part of the region usually referred to as the South-East of South Australia and more specifically as the Upper and Lower South-East. The region is the most southerly province of South Australia and comprises roughly that part of the State situated between the coast south and east of the Murray Mouth and the Victorian border. Fenner (1930) gave the names Ninety Mile Plains and South-East Plains to his regions 14 and 15, which correspond approximately to the generally accepted though ill-defined concept of the Upper and Lower South-East respectively. Recent official division of South Australia has resulted in the establishment of two regions, the Tatiara and Gambier Regions, which depart considerably, however, from the former sub-divisions. The terrain described in this paper includes the greater part of the Gambier and the western part of the Tatiara Division. The area dealt with comprises approximately 6500 square miles and includes the greater part of the Counties of Grey, Robe, Macdonnell and Cardwell and the south-western part of Buckingham. Owing to their use by previous authors, the terms Upper and Lower South-East are being retained in the present paper.

The varied and interesting problems presented in this region have not attracted in the past the attention which they merit. It is true that previous investigations include geological, geographical, soil survey, land utilization, botanical, palaeontological, economic and anthropological research of selected and limited areas; but such of the work as deals with the region as a whole is highly generalized and any detailed surveys that have been made cover small sectors only. The more important contributions include those of Tenison-Woods, Fenner, Ward, Campbell, Wade, Mawson, Tindale, Taylor, Stephens, Crocker, Cotton and various State Government Departments. Others are listed in the bibliography.

The present paper has been written as the result of fieldwork by the author, commenced in 1931 and continued at intervals as opportunity offered, until November, 1949. Recent intensive work has been made possible by facilities granted by the University of Adelaide.

The investigation embraces the study of all available bore and well records; the detailed mapping on a scale of 40 chains per mile of some areas using the published maps of the Department of Lands and Survey; the close stereoscopic examination of thousands of aerial photographs lent by the Defence Department, and of others made available by the C.S.I.R.O, and mapping on the scale of these photographs, the largest scale being 20 chains per inch.

Since the above was written, advice has been received of a paper by R. C. Sprigg on Stranded Sea Beaches of the South-East of South Australia, to be published in Trans. 18th Geol. Congr., London, 1948.

The use of thousands of levels made available by the South-Eastern Drainage Board, and the detailed contoured maps of special areas surveyed by the above as well as by the Woods and Forests Department, made it possible to construct a provisional contoured map of the basement of the greater part of the region.

The aerial photographs now available and the increasing wealth of survey data becoming available in recent years, have made it possible to examine and map the area in much greater detail than could be done previously, and has resulted in the modification or rejection of some of the hypotheses formulated by previous investigators. It will be shown that the writer accepts in principle the glacial eustatic origin of the calcareous dune ranges (Tindale, 1933, 1947) as against crustal warping (Ward, 1941). Nevertheless it is evident that crustal deformation has played an important rôle in the development of the region. The writer cannot accept the greater part of Tindale's reconstruction of the Pleistocene history of the region and considers that in the present state of our knowledge, correlation of glacial eustatic terraces of the South-East of South Australia with those of the Atlantic Coast of the U.S.A. or of the Mediterranean is impossible.

An attempt has been made by the use of such evidence as could be obtained to compile the chronological sequence for each of the calcareous dune ranges. However, this rests so largely on inference that it must be regarded as tentative only.

Reference could be made in the text to but a small proportion of the publications consulted. Those which have a direct bearing on some of the problems discussed in this paper and which are not specifically mentioned in the text are included in the Bibliography. In addition the writer was able to examine unpublished maps and reports made available through the generosity and co-operation of the Directors of Oil Search Ltd.

The assistance is gratefully acknowledged of Professor Sir Douglas Mawson of the School of Geology, and of Dr. T. D. Campbell, University of Adelaide; Mr. D. Schulz, of Rendelsham; Mr. A. J. S. Adams, Chief Forester at Mount Burr Forest; Messrs. R. N. Campbell and H. F. Kessall, of Mount Gambier; Mr. C. Willshire, of Millicent; Mr. Jackway, of Blackfellows Caves, and the officials of the Commonwealth Department of Defence at Keswick and of the State Departments of Woods and Forests, Mines, Lands and Survey, the South-Eastern Drainage Board and the South Australian Harbours Board.

TOPOGRAPHY

I General.

The region is a low level terrain which slopes very gently seaward. Owing to regional warping, the inclination of this terrain varies in different sectors both in amount and direction. In the most northerly area the slope is south-westerly, in the central portion it is westerly, changing gradually further south until southerly near the Victorian border. Although this region possesses very low and uniform gradients over a very large proportion of its surface, there are many areas of diversified relief both above and below the general level. Features above the general level are inliers of ancient rocks, aeolian deposits and volcanic accumulations, as well as escarpments produced by former marine erosion. Features below the general level include lakes, swamps and claypans, creeks, sinkholes and closed depressions (uvalas).

The inliers of ancient rocks occur north of the Kingston-Naracoorte Railway. Most of them are low and only a few of them reach heights of over 100 feet (Mawson 1943, 1944, 1945a, 1945b).

The aeolian deposits are of three types:—the calcareous dunes, the siliceous sands, and lunettes.

II The Calcareous Dunes

These are the predominant type of surface relief. Their peculiar arrangement, location and origin, as well as their economic significance attracted attention from the beginning of exploration and settlement of the region (Woods, 1862). This interest has become more pronounced in recent years, both from scientific and economic aspects. Their adverse influence, both direct and indirect, on the economic development of the region has been far-reaching.

Their general direction, though variable, has a north-westerly trend, and is approximately parallel to the present coastline and at high angles but not at right angles to the general slope of the region. Their fronts or seaward edges exhibit a small but consistent drop in height both north and south of the Mount Burr area. Failure by some previous investigators to observe these progressive variations in altitude has led to serious errors in the interpretation of the history of the region.

A traverse normal to the present coastline crosses the dune ranges at high angles and at progressively increasing heights above sea-level. Although exhibiting great variations in shape and size, they have a roughly subparallel arrangement with north-westerly trends. As they are followed in a north-westerly direction from the Mount Burr area, all but a few of the inter-dune flats decrease steadily in width until many of the ranges coalesce so that it is no longer possible to distinguish them individually. Rarely do they rise to heights as much as one hundred feet above the adjacent plains, and as a rule their summits are considerably short of that figure. However, because of the low relief of the intervening areas, these dunes are known as "ranges" and owing to their separation in the central part of the region by wide, extensive plains, bear distinctive names. Those for which no local names could be discovered have been named by the writer the Canunda (Campbell, 1946), Woolumbool, Peacock, Lucindale and Neville Ranges.

The furthest inland range is known as the Naracoorte Range. This has been divided by the writer into the East and West Naracoorte Ranges.

In the central portion of the South-East the East Naracoorte Range is the more inland and rises from a higher part of the basement than does the West Naracoorte Range. To the north and north-west of the town of Naracoorte these two ranges coalesce and at some distance beyond this convergence the range divides again. One branch turns to the north-west and forms the Black Range which apparently trends more and more westerly towards the southern margin of the Mount Boothby inliers of ancient igneous rocks. This branch is being identified by the writer with the East Naracoorte Range. The other branch, the more easterly, consists in its southern sector where it diverges from the combined range, of a series of irregular disconnected dunes, but further to the north exists as a well-developed continuous dune system. The further continuations of this system are being investigated by other workers. This branch is being identified here as the continuation of the West Naracoorte Range. Such identification implies that in the northern sector of the region the West Naracoorte Range is the furthest inland and at the highest level, whereas in the central sector this position is occupied by the East Naracoorte Range. The continuation further to the south-east extends into Victoria and does not exist in the southern sector of the South-East Region of South Australia.

Just to the south of the town of Naracoorte, the western edge of the East Naracoorte Range is 54 miles from the coast, but altitude and distance decrease continuously to the north-west, until near Chinaman Wells the corresponding part of the range is only 26 miles from the coast and at a very much lower level.

This range, known in the Hundred of Laffer as the Black Range, has been mapped over a length of 96 miles and continues to an unknown distance to the north-west and south-east. The greatest lengths recorded are those of the Reedy Creek and West Avenue Ranges which have been traced over a distance of 166 miles without their north-western or south-eastern limits having been reached. Other ranges, however, are not as persistent and their total lengths vary considerably. Some terminate abruptly; others lose height gradually towards their extremities; others consist of a series of disconnected ridges; others decrease almost to nothing then increase again in height and width; still others, particularly in the Upper South-East, are partly or completely covered by drift sand so that their location is difficult to determine. Although a rake pattern is exhibited by some, most of the ranges possess straight or smoothly curved western or seaward edges for considerable proportions of their extent, but have deeply indented or embayed eastern or inland margins. In some areas no defined ranges are discernible, and the pattern displayed by the dune limestone outcrops is extremely irregular, though exhibiting in most instances a subordinate but nevertheless definite trend. (See General Map). Because of these factors, the complete succession is not encountered in any traverse normal to the ranges. Detailed investigations by the writer have shown that the general belief expressed by previous authors, of the existence of seven to eight or even fewer ranges is erroneous. It has been possible to distinguish and map eighteen distinct ranges, each of which either already bears a local name or has been named herein.

For reasons given above and others which will be discussed later, it was found necessary to begin the critical examination of the region and determine the initial classification of the stranded dune ranges in the central sector. In this sector, commencing with the dune range at the greatest distance from the coastline and therefore rising relatively from the highest parts of the fundamental plain, the complete list in a seaward direction as now determined is:—

1. East Naracoorte
2. West Naracoorte
3. Harpers
4. Stewarts or Cave
5. Woolumbool
6. Peacock
7. Bakers
8. Lucindale
9. Ardune
10. East Avenue
11. West Avenue
12. Reedy Creek
13. Neville
14. East Dairy
15. West Dairy
16. East Woakwine
17. West Woakwine
18. Canunda

The recent naming of dune limestone ridges in the extreme Lower South-East (Crocker 1946a) appears to have been unnecessary. It is true that Crocker was correct in abolishing the term Kongorong Range used locally for the southern part of the Woakwine Range, and that giving the name MacDonnell Range to the double limestone range near Allendale can be justified. His Burleigh and Caveton Ranges however, are identical with and are continuations of the Reedy Creek and West Avenue Ranges respectively, and his Mount Gambier Range is almost certainly a continuation of the East Avenue Range.

Unless specifically mentioned, the present coastal dunes are not included in the description and general discussion of the calcareous dunes.

Despite their low altitudes, the rocky outcrops, dense scrub, and deep drift sands of many sectors have made of these ranges a series of barriers to traffic between the coast and the interior. The obstructions they placed across the natural flow of surface waters, impounded these against the eastern or inland flanks of the ranges. As a result, white sandy beaches were formed in many sectors of the inland margins of the ranges wherever permanent or semi-permanent lagoons still exist, or existed before the present artificial drainage schemes came into operation. Much of the impounded flood water moved in a north-westerly direction. As the resultant gradient in that direction is less than one foot per mile in most sectors, movement was sluggish and ill-defined except when floodwaters had raised the level of the water sufficiently to produce a temporary and adequate steepening of the local gradient. Considerable amounts of water but varying greatly in different localities, seeped through and beneath the ranges, emerging as springs, permanent or intermittent, on the next series of interdune flats. As a result, roads and tracks over most of the region were confined, unless specially constructed, for the greater part of each year almost entirely to the ranges and chiefly to their flanks or to the very narrow zone, not present everywhere, which marked the transition from range to flat. Even today when artificial drainage has improved the surface run-off in many areas, trouble is experienced in wet years, and roads and embankments are being raised in a number of localities.

Despite the poverty and general lack of depth of soil in many parts of the ranges, their relative dryness as compared with the inter-range flats, determined their use as winter quarters for stock. Observations show that many areas now exhibiting bare stony hillsides completely devoid of vegetation, that have brought to that condition by wind erosion after removal of the vegetation by overgrazing or rabbits.

Costly drainage schemes have been carried out and more are proposed to remove surface waters from such swampy inter-range areas as are considered suitable for development. As the highest surface gradient is nearly at right angles to the average trend of the ranges and natural gaps are few, excavations of considerable magnitude were necessary in some instances. The longest and deepest excavations are those of Drain L which terminates near Robe and which has a maximum depth of 54 feet through the Woakwine Range.

III The Siliceous Sands

Enormous accumulations of this material exist in the region and their fixation by vegetation ensures their stability while the plant cover remains. Although isolated deposits exist in the Belt Range near Hatherleigh and in other localities to the west of the Reedy Creek Range, in general they occur further east. These sands cover completely or in part, many sectors of the calcareous dune ranges, but do not of themselves form large dunes of great linear extent. The greatest accumulations are low, gently undulating or level expanses which in many instances were former interdune flats and swamps. They occur piled up against and on top of pre-existing hills and ridges and in general have the appearance of windsorted material distributed over an irregular landscape. In the Lower South-East they have been utilized largely for pine plantations. The resulting forest cover adds to the difficulties not only of determining their limits but also of mapping any outcrops of pre-existing formations. A study of the planning of the plantations and of the growth of the pines give in many instances clues to the subjacent rocks, but do not enable accurate geological boundaries to be drawn.

IV Lunettes

In numerous localities, but especially in the areas east of Kingston and of Robe, and in the wide interdune flats between the Cave and Harper's Ranges and the Naracoorte Range, both to the north and south of the town of Naracoorte, the flats contain very large numbers of small, shallow depressions which are filled with water during and for considerable periods after the wet season. A notable feature of very many of these is the existence on their eastern margins of crescent-shaped dunes generally varying in height and size with the adjacent lagoon. These dunes are known as lunettes and have been described elsewhere (Hills 1939, 1940), (Stephens 1946).

V Volcanic Hills

In the southern part of the region accumulations of volcanic material, chiefly of tuff with some basalt flows, form a number of elevations, the largest and most extensive area being the Mount Burr Range, culminating in Mount Burr, 802 feet above sea level and approximately 700 feet above the plains to the west. The Mount Burr Range contains within it or is adjacent to Mounts Muirhead, Graham, Muir, MacIntyre, Sinclair, William and Edward, Day's and Campbell's Hills, The Lookout, Frill, Watch and Bluff. Further to the south the isolated cones of the small extinct volcanoes of Mounts Gambier and Schank form conspicuous landmarks on the low level plateau.

VI Marine Escarpments

In several localities cliffs and escarpments produced by former wave-action occur inland at various levels. Some of the more conspicuous are the Up-And-Down Rocks near Tantanoola, a scarp between Mount Schank and Port Macdonnell, the north-eastern flank of Mount Graham, the vicinity of Blackfellow's Caves, Robe, and Nora Creina Bay.

VII Drainage

Within this region surface drainage is immature and creeks and natural drainage channels are few in number. In the eastern sector the chief streams are the Mosquito, Naracoorte and Morambro Creeks which rise in Victoria and flow westwards into South Australia but spread out on the flats west of the Naracoorte Range. In the western sector the chief creeks are the Reedy, Avenue, Salt, Cattle and Maria Creeks, and in the southern sector the Stony, Benara and Eight Mile Creeks. None of these were important drainage channels and even Reedy Creek, by far the largest, was merely a chain of swamps and small lagoons which drained slowly to the north-west during and after heavy rains. The location of the successive dune ranges, being nearly at right angles to the average slope of the region, together with the porosity of the subjacent rocks, prevented the development of a defined drainage pattern and resulted in the banking up of floodwaters on the eastern flanks of the ranges. To some extent sub-surface drainage effected the removal of surplus waters, but a very large proportion travelled slowly in a north-westerly direction to Alfred Flat and beyond, supplying some water to the Cattle, Maria and Salt Creeks; evaporation accounted for the remainder. The South Australian Government, through the South-Eastern Drainage Board, has done and is doing much to drain the more fertile areas by providing artificial channels through the blockading ranges.

Lakes, lagoons, swamps and claypans are very plentiful in some sectors, notably in the areas adjacent to the coast, as well as in the areas east of Kingston and of Robe and in the wide inter-dune flat west of the West Naracoorte Range. While some are salt the overwhelming majority of the inland basins contain fresh water. The largest basins are those adjacent to the coast and include the Coorong, approximately 90 miles long, Lakes Eliza, St. Clair and George, all of which are salt, and Lake Bonney approximately 22 miles long which contains fresh water and, as is to be expected, has an outlet to the ocean. Other lakes and swamps will be referred to in a later section, but brief mention must be made here of the Dismal Swamp, a collection of partly connected and irregular swamps which extends to the Victorian border and from the eastern portions of which surplus waters are stated to drain slowly into the Glenelg River, a stream which at present flows almost entirely within the boundaries of Victoria.

The underlying porous limestones, as well as the porous limestones of the dune ranges, in preventing the development of a definite surface drainage, produced a region of largely "cryptoreic" drainage (Fenner 1930). As a result, caves, sink-holes, and closed depressions (uvalas) indicative of the collapse of former solution chambers, are plentiful in the southern part of the region, an area of relatively high rainfall.

In order to obtain a true picture of the configuration of the basement on which the aeolian and volcanic deposits rest, a contoured map is essential. Since none was available, the writer has attempted to remedy this defect. With the aid of all available levels and contoured plans of such areas as had been surveyed by the South-Eastern Drainage Board and the Woods and Forests Department, a map of the major part of the South-East has been prepared. Insufficient levels are available for the extreme north and south of the region, but a large enough area has been contoured to supply much needed information of the morphology and history of the South-East. As the aeolian and volcanic deposits have no structural connection with the basement itself, and since the contour mapping of these highly irregular and in places convoluted areas would have served no useful purpose, they have been disregarded and the contoured map purposes to show the actual floor of the basement plain.

This floor coincides in many areas, notably in the Lower South-East, with the upper surface of the Miocene limestones and in the northern sector of the Upper South-East with the Precambrian and Miocene pavement, the surfaces in both areas being the results of marine planation. There are, however, large areas in which the marine plane is covered by later deposits of marine, lacustrine, aeolian or volcanic origin. Although this cover is thin except in the Mount Burr Range, its presence must be allowed for in the determination of the contours which are intended as nearly as possible to represent the planed-off surface of the basement rocks. It has not been possible to determine the necessary values in all localities, and to that extent the final figures used must be approximations only. In order that such cover, which is irregular in occurrence both as to area and thickness, should produce the minimum amount of distortion the scale of the final map was reduced considerably. The original one foot intervals were reduced to ten-foot contours, and the horizontal scale of 2 miles per inch was reduced to 8 miles per inch.

It will be noted that, except for a few areas in the north-eastern sector adjacent to Victoria, the basement is at higher levels beneath the Mount Burr Range and in the Dismal Swamp area than in any other part of the region.

A map has been prepared of the Mount Burr area, showing the actual surface contours. The greater part of this map is based on detailed contour plans surveyed and drawn by the Woods and Forests Department. These were extended where possible by the use of other survey data, and where these were not available, by sketch contours especially in the vicinity of The Bluff.

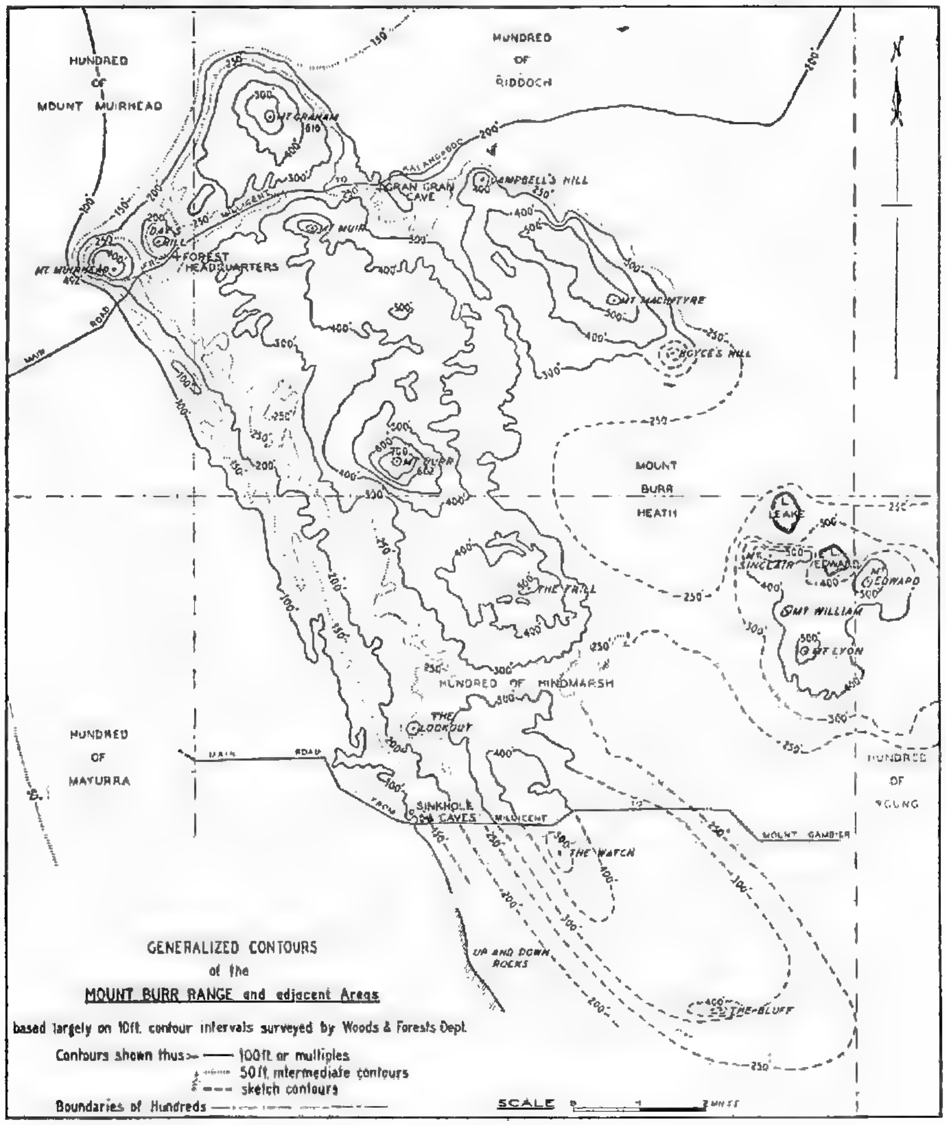


Fig. 1

VIII The Coast

North of Kingston the present shoreline is apparently prograding with the development of coastal dunes, probably an offshore bar initially, and impounding the long narrow lake known as the Coorong. To the south of Kingston the coast appears to be one of submergence with an advancing shoreline. The history and development of these features will be dealt with in a subsequent section of this paper.

GEOLOGY

I. General

The region is a sector of the former Murravian Gulf which in South Australia extended far to the north, included the greater part of the present Mount Lofty Ranges and covered extensive areas in New South Wales and Victoria. This gulf was formed by the advance of the sea during the Miocene Epoch or perhaps even earlier. The sea finally retreated from the greater part of this Gulf at or near the close of the Lower Pliocene, and formed a new shoreline which is believed to have coincided approximately with the present East Naracoorte Range. Further palaeontological work is expected to result in definite age determinations both of the submergence and emergence of the Murravian Gulf.

Before its submergence, the greater part of this area appears to have been continuous with and a part of the Great Australian Peneplain which in South Australia appears to have reached its final stages and greatest development towards the close of the Mesozoic Era.

Within the region described in this paper, the rocks immediately underlying the surface of the peneplain belonged to two groups. North of the vicinity of Kingston they appear to have consisted of Precambrian and possibly Palaeozoic sediments and igneous intrusions (Mawson 1943 and 1944). To the south of Kingston they consisted as far as is known, of Mesozoic sediments apparently lacustrine in origin.

As stated in another paper, not yet published, the writer considers that the available evidence indicates that the dismemberment of the peneplain in the region now known as the Mount Lofty Ranges commenced during the Cretaceous or very early in the Tertiary Period. In some sectors warping and faulting ended the peneplanation cycle, and as a result, terrestrial deposits such as gravels, sands and lignitic clays were formed in various parts of the region.

If the age determination of the lacustrine sediments penetrated in the lower section of the Robe bore as Jurassic (Ward 1941), is upheld by subsequent research, it is possible that the diastrophism which affected parts of Southern Australia during the later stages of the Cretaceous Period and in the Cainozoic Era was active also in the Lower South-East, an area in which diastrophism appears however, to have begun earlier. It follows that deposition, largely and probably entirely of terrestrial material, may have continued through the Cretaceous and into the Lower Tertiary Period until during the Oligocene or Miocene Epochs the sea advanced over the region and formed the Murravian Gulf. There would in that case be little or no break in deposition in the area to the south of Kingston. In the terrain north of Kingston the terrestrial deposits formed immediately above the Precambrian-Palaeozoic floor will date from the beginning of diastrophism in any given locality and will vary probably from Upper Cretaceous to Lower Tertiary in different places.

While it is true that no definite break in deposition is expected in the area to the south of Kingston, this is after all only a small fraction of the total area of the former Gulf. The great expanse of this gulf in South Australia north of Kingston, and also in New South Wales and Victoria, exhibits a sharp time and erosion break between the Cretaceous to Lower Pliocene sediments and the floor of Precambrian and Palaeozoic rocks on which they were deposited. Although the greater part of the South-East remained submerged probably to the close of the Pliocene Epoch, and hence deposits of Upper Pliocence Time were formed and probably still exist in protected areas, the emergence of the Murravian Gulf as such is considered by the writer to have been completed when the sea finally retreated to the East Naracoorte shoreline at the close of or during the Lower Pliocene Age. The writer therefore has divided the rocks and formations of the South-East into three groups which will be referred to as:—

PRE-MURRAVIAN, MURRAVIAN, and POST-MURRAVIAN

II Pre-Murravian

The Pre-Murravian rocks are those which formed the peneplain and which over the greater part of the South Australian portion of the Murravian Gulf are of Precambrian and early Palaeozoic age. As stated above, to the south of Kingston the basement rocks are believed to be of Mesozoic age, but as they do not outcrop, little is known of them.

In the region north of Kingston large numbers of inliers of the ancient rocks outcrop. Many, including the more important ones, have been mapped and described in recent years (Mawson 1943, 1944, 1945a and b). As most of them do not make conspicuous outcrops, and in fact many are close to or level with the general surface, and since much of the terrain is sparsely settled and difficult of access, it is possible that some outcrops still await

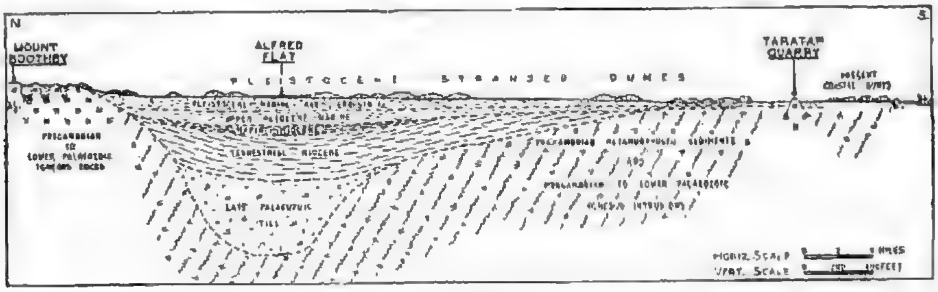


Fig. 2

Sketch Section from Mount Boothby to Taratap Quarry, north of Kingston.

discovery. An examination of the general map accompanying this paper, and on which are shown all known outcrops, suggests, however, that these inliers of ancient rocks are restricted to two separate areas. In an area bounded approximately by a line drawn from a little south of Keith and a little north of Tintinara respectively in a south-westerly direction, no outcrops of these rocks have been recorded. The evidence of the Alfred Flat and Tintinara bores (Howchin 1929) as well as of a number of bores in the vicinity of Salt Creek (Ward, 1944) supports the view that this area is underlain by a basin or valley excavated in the Precambrian rocks. The depth of this feature is shown to be about 350 and 250 feet respectively in the Alfred Flat and Tintinara bores (Fig. 2). In the other bores of the district, those near Salt Creek and adjacent areas, the Precambrian rocks were reached apparently at depths of 190, 400, 518, two of over 600 feet and one of 924 feet. (Ward op. cit). In the latter bore, the drill entered tillite at 503 feet and continued in that formation to a depth of 924 feet.

This tillite was encountered in one bore only and that one which reached the greatest depth before penetrating the Precambrian floor. Such a valley could have been an erosion feature or be of tectonic origin. In view of the stage to which peneplanation appears to have progressed in this part of Australia before the formation of the Murravian Gulf, its origin as a river valley cannot be supported, nor could it be supposed that marine erosion after submergence would have excavated it in the resistant ancient rocks. The suggestion (Ward 1944) that the tillite probably is of Permo-Carboniferous age indicates that this valley, like the Inman Valley further to the west, may be the result, in part at least, of Late Palaeozoic glacial erosion. On the other hand, this glacially filled valley could have been tectonic, originating in Early Tertiary times, but the available evidence does not support this.

On the whole, the evidence appears to favour the existence of an old glacial valley, probably Permo-Carboniferous, in which the soft glacial deposits were preserved at the level which subsequent peneplanation of the adjoining areas achieved. If that is the correct explanation, then the advance of the sea in Tertiary times to form the Murravian Gulf would have resulted in the removal, partial or complete, of the boulder clay from the greater part of the valley; then would follow the gradual deposition, on the tillite where such remained and on the Precambrian rocks where these had been exposed, of the sediments of Miocene age encountered in the various bores. The subsequent retreat of the sea during the later part of the Pliocene Epoch to the East Naracoorte shoreline would expose the Lower Pliocene deposits to erosion in the shallowed seas and effect their complete removal and partial removal of the Miocene sediments.

It is highly probable that during Upper Pliocene times when the sea still covered the region to the south-west of the East Naracoorte Range, a depression persisted in this area and was filled with, and still contains, Upper Pliocene deposits protected from erosion during the Pleistocene Epoch.

This supposed deposition of Upper Pliocene and some Pleistocene sediments would thus account for the sharp break between the Miocene and the Upper Pliocene or Pleistocene sediments as recorded in some of the bores.

III Murravian

The Murravian deposits are defined here as those which were laid down on the surface of the former peneplain from the time that diastrophism began to dismember it; deposition continued during the period of submergence by the sea and until the sea retreated finally to the East Naracoorte shoreline, a total time range, as stated earlier, of probably from the Upper Cretaceous to the close of the Lower Pliocene. As stated above, the older stages appear to have been terrestrial and were succeeded during the Miocene and Lower Pliocene by marine sedimentation. No marine deposits of Lower Pliocene age have been recorded to the south-west of the East Naracoorte Range but as will be shown later, are believed to have existed and to have been removed from this sector by subsequent marine erosion. Deposits of marine origin of Miocene age occur throughout the region, at the surface in the southern part of the area and at variable shallow depths in all except a few limited localities in the northern part of the area.

Detailed descriptions of these rocks are available in the literature, and investigations being carried out by the Geological Survey of South Australia will add considerably to our knowledge of these sediments. They consist predominantly of limestones, some of which have been dolomitized. This dolomitization appears to have affected some beds over considerable areas and it may be found that some horizons have been changed completely. One of the most spectacular can be seen at the Up-and-Down Rocks near Tantanoola. Here the resistance to weathering and erosion of the locally dolomitized limestones has produced a cliff formed by wave action during a former higher sea level, and has enabled this cliff, described by some writers as a fault scarp, to withstand erosion sufficiently to remain a prominent feature.

In many places the soft Polyzoal Miocene limestones contain vast numbers of flints. Exposures are particularly good along the coastal cliffs between Capes Banks and Northumberland, but outcrops showing these flints can be seen at a number of localities inland, especially in quarries, sinkholes and caves. Whether these flints occur on definite stratigraphical horizons was not determined, but they do occur at intervals in the sequence. They vary considerably in size, colour, shape and texture, ranging from large tabular masses to small nodules, and exhibiting a wide range of colour with dark-grey to bluish-black predominating. While it was found that under certain conditions these flints weather and disintegrate rapidly, their relatively greater resistance to erosion has resulted in the accumulation, during former stillstands of the ocean, of numerous deposits which testify to former marine action. Their occurrence in many localities and in large numbers as residual beach pebbles, as well as in immense banks on parts of the shore, made them the natural and predominant material in the manufacture of artefacts by the aborigines, who have left enormous numbers of these stone tools on their former camping grounds. In some areas weathering of these flint artefacts has affected the whole of the object and although it still bears the shape given to it by the native, it is now a white porous material and in some instances crumbles when struck. There are many artefacts, however, in which weathering is incomplete and which on being broken show a zone of weathered material surrounding a core of unweathered flint, the core inheriting approximately the shape and faces given to the original fragment by the maker (Mitchell, 1943; Campbell, 1946).

The Miocene sediments have undergone slight folding movements. Evidence of this folding can be seen in the gorge of the Glenelg River, on the surface near Mount Salt station and near Burnda Railway Station, and may, although other explanations are possible, account for the dune pattern near Cape Banks and Narrow Neck.

The Miocene limestones as seen on the coastal cliffs between Cape Northumberland and Cape Banks appear to have a very slight dip northwards. There is also, as stated earlier, the regional warping which has produced a general west-north-westerly tilt of the surface in the terrain north of Mount Burr and a south-south-westerly slope in the area to the south. Whether the folding and warping occurred at subsequent times or whether they were contemporaneous is beyond the scope of this paper to discuss. Reference must be made, however, to two major faults which have been referred to repeatedly in the literature. These are the Naracoorte and Tartwaup Faults. The Naracoorte Fault is stated (Fenner, 1930) to coincide approximately with the Naracoorte Range. This fault may exist, but the present writer has seen no evidence which would support this contention and considers that all the features observed by him can be explained more satisfactorily as having been produced by marine erosion.

The Tartwaup Fault (Ward, Crocker, Tindale, Fenner, Stephens) which is stated to pursue an arcuate course to the south and west of the Mount Burr Range, is another instance for the acceptance of which the writer requires additional evidence. It is true that the evidence cited by Ward (1946) of change in hydraulic level is strong, but it is not conclusive. The other features considered by Ward and others as evidence in support, namely the steep front of the Up-and-Down Rocks and the springs to the west of the Mount Burr Range are, it is believed, due to other factors. The Up-and-Down Rocks appear to be a wave-cut cliff in relatively resistant rocks. The existence of a sea-cave (Tindale, 1933) and the discovery by the writer on top of the cliff of calcareous dune limestone similar to that forming the other stranded dunes of the region. support this view. The springs to the west of the Mount Burr Range do not exhibit a linear arrangement except for short distances and many other springs occur elsewhere. These springs appear to be part of the natural drainage through and beneath the dune ranges as described earlier. If the Naracoorte or Tartwaup Faults do exist, and this has to be proved, then it seems probable that they are at least of Tertiary age and pre-date the oscillating retreat of the sea from the East Naracoorte shoreline.

IV Post-Murravian

These are grouped as follows:—

a. Calcareous dunes
b. Siliceous sands
c. Waterworn quartz grit and pebbles
d. Waterworn flints
e. Fossil shells
f. Lacustrine limestones
g. Swamp deposits
h. Volcanic accumulations
i. Lunettes
j. Kunkar travertine
k. Laterite

a. *The Calcareous Dunes*

These, the dominant form of surface relief of the region, have been described and their origin discussed by several observers. The impression gained from the literature is that of a region consisting of a plain sloping gently seaward in a south-westerly direction, and bearing upon it a series of dune ranges parallel or approximately so to the coastline, each dune rising from progressively lower parts of the plain as one travels towards the coast. This over-simplification of what is actually a complex pattern has led to serious misconceptions and errors in attempts to reconstruct the geological development of the region. The tendency to group together a number of individual dune ranges without determining whether they have had similar or different histories, the failure to realise the importance of those areas in which the dune ranges so far from being parallel to the coastline intersect it, the neglect of the variations in direction, horizontal and vertical spacing of the ranges, and of the great differences in amount both of erosion and chemical processes, have prevented hitherto a proper consideration and detailed study of the problems involved.

It is generally agreed that these ranges were formed as the result of still-stands of the sea and correspond approximately to the shorelines thus produced. The ranges possess in general a north-westerly trend and approximately at right angles to the prevailing wind. Although accumulation and modification by wave action was an important and probably the only factor in the early stages of development of most if not all of the dunes, wind sorting and piling became the dominant process once these accumulations projected above sea-level. As is to be expected in aeolian deposits of this type, they exhibit to leeward, that is on the inland and northeastern flanks, the usual intricate pattern. On the windward or seaward and south-western side they have, over considerable distances, straight or smoothly curved edges. In other sectors the edges vary from a regular sawtooth or rake pattern to highly irregular meanderings and convolutions. Further, the ranges from the East Naracoorte seawards as far as and including the East Avenue Range, exhibit in general an arcuate trend concave towards the south-west. From and including the West Avenue Range, the arcuate trend persists but is concave towards the north-east. This latter tendency becomes less marked as the coast is approached and in the Woakwine and Canunda Ranges it appears to be a minor feature only.

During the present investigation it was found that the region could be divided roughly into three sectors. The north-western sector in which inliers of igneous rocks are numerous but separated into two groups by a filled valley probably of glacial origin, contains a large number of relatively closely spaced dune limestone outcrops. Many of these are very irregular in form and obscured considerably by more recent drift sand, so much so that their delimitation must be regarded as approximate only in many instances and others probably exist of which no indications were observed. Erosion, considered to be partly marine and partly lacustrine, has played a large part in the removal of evidence of former continuity of individual dunes and hence makes it difficult to identify and trace some of them. The increasing effects in a north-westerly direction of downwarp and probable isostatic movements, and the almost complete absence of surveyed levels, indicate that this sector was unsuitable for the initial study of the development of the dune ranges.

In the south-eastern sector the presence of volcanic accumulations, the large amount of marine erosion in the southern and western portions, the effect of downwarping as shown by the relatively much steeper gradients of the basement as compared with the areas to the north-west, and the scarcity of available surveyed levels were factors which made this sector unsuitable for the intitial study of the dune limestones.

The central sector, where the basement gradients are very low, the dune ranges relatively widely spaced, comparatively regular and continuous, and no igneous outcrops are known, is also the sector in which surveyed levels are sufficiently numerous for the construction of a provisional contour map of the basement on which the dunes were deposited. It is in this sector therefore that the various dune ranges and their development were studied initially, and from which the mapping and investigation were extended to the north-west and south-east. The north-western and south-eastern sectors yielded much additional evidence relevant to the problems investigated, but it is the central sector, in which the general evidence is much clearer and less confused by other features, which was used primarily in the grouping and classification of the dune ranges.

The grouping of these ranges by various observers has resulted generally in the recognition of seven stages, the Naracoorte, Cave or Stewart's, Baker's, East Avenue, West Avenue, Reedy Creek and Woakwine Ranges.

Although recognising the existence of the above seven ranges as well as of the Dairy Range, Tindale has related all of them to five terraces, the Naracoorte, Cave, East Avenue, Reedy and Woakwine Terraces. This grouping of numbers of ranges may have been influenced by the remarkable tendency of most of the ranges as they continue to the north-west to approach each other and in many instances to merge so completely as to be inseparable. The present examination and mapping of the region and study of thousands of survey levels indicate that such simplified grouping is not in accordance with the individual histories of the various ranges.

The writer has been compelled, in listing the various ranges, to name some for which no names could be discovered, namely the Canunda, Neville, Lucindale, Peacock and Woolumbool, and also to separate others into their components. These are the East and West Naracoorte, the East and West Dairy and the East and West Woakwine Ranges, which are believed to have succeeded each other and formed partly on the eroded remnants of their predecessors. Thus the number of existing ranges mapped is eighteen, which with the two earlier Woakwine Ranges now eroded gives a total of twenty separate ranges to be accounted for (see fig. 3. The evidence, which is particularly noticeable on the aerial photographs, of remnants of beach and dune ridges in several areas where no dunes exist today or where they do exist but possess trends at variance with those of the remnants, as well as the occurrence of isolated dune remnants in the wide flats separating the dune ranges, can be regarded as evidence that other ranges have existed which have been eroded and removed almost completely. By following the beach ridge remnants along the strike some are found to disappear gradually, some terminate abruptly and others such as those north of Kingston can be traced to gradually rising ridges until they form the Neville Range. Other examples can be seen in the Reedy Creek and West Avenue Ranges and elsewhere. It is reasonable to suppose therefore that some at least of those low dune limestone outcrops and ridges which cannot be followed to an existing range,

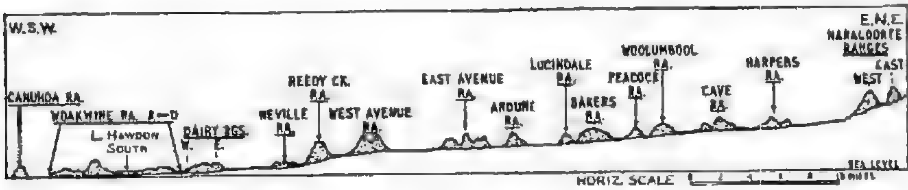


Fig. 3

Diagrammatic Section from Cape Rabelais to Naracoorte.

may be the last remnants of former dune ranges which have been denuded. This raises the question of how many ranges may have existed, of the location of which not even traces remain. If transgression of the sea took place very slowly, or sea-level remained stationary for a long period at a level at which erosion of a former dune could occur, or if such advance of the sea took place before the cementation had time to produce a resistant shell, then erosion could remove rapidly the whole or the greater portion of the dune and leave only a shoal or erase it completely. That such has occurred in the past is shown by the numerous remnants scattered throughout the region and supported by the number of eroded surfaces exposed by two drain cuttings of the Mount Hope and L drains, in which it can be seen that several successive dunes were formed and partly removed by marine erosion on the present site of the Woakwine Range, leaving fossil shells and rounded pebbles on the erosion surfaces (fig. 4).

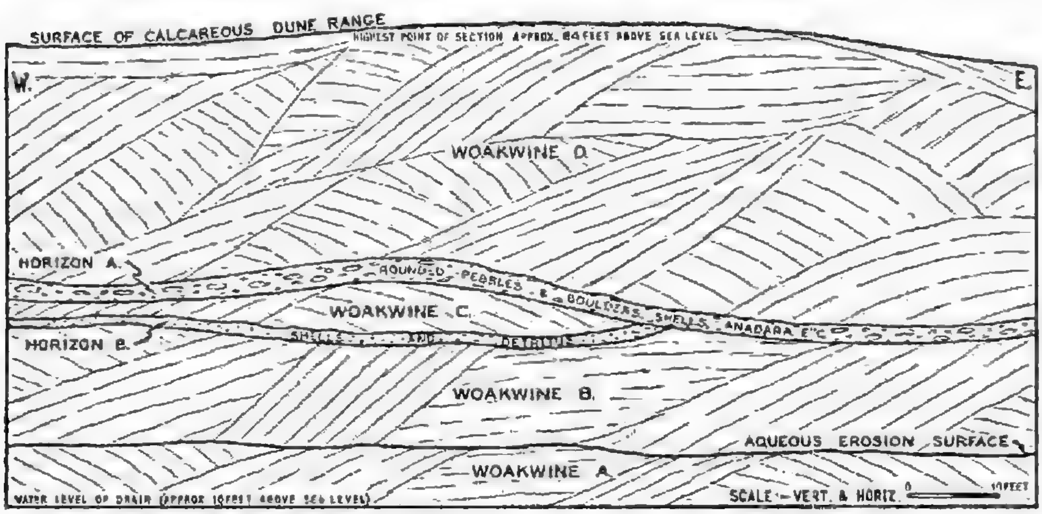


Fig. 4

Section of part of Drain L through the West Woakwine Range
(Current bedding diagrammatic.)

It must be noted also that formation of these dunes did not cease at the present shoreline which is at a much higher level than during past glaciations, during some of which world sea-level is believed to have been lowered by several hundred feet. When this occurred many dunes probably formed at the various stillstands. Close bathymetric survey of the continental shelf adjacent to the region may supply some evidence which, if it could prove the existence of submerged dunes or their remnants, would support the belief that in this region the dune ranges were formed as a result of eustatic variations of sea-level due to glaciation and deglaciation.

The succession of ranges from the East Naracoorte seawards exhibit great differences in degree and amount of erosion. Some appear to have suffered little, others show planed-off summits or wave-cut platforms, sea caves, blowholes and eroded channels, and others are merely discontinuous remnants of former long continuous ranges, such showing in many places low level platforms of dune limestone between their still existing higher segments. Height and width vary greatly in some, while others preserve relatively even summits for long distances. In the southern part of the region the ranges can be classified as little eroded, considerably eroded, very much eroded and remnants. In the northern part of the region north of Kingston, erosion appears to have been general and intensive.

Chemical processes affecting the dune ranges have been chiefly those of solution and redeposition of calcium carbonate. The solution within the surface zone and deposition of the calcium carbonate, the chief constituent of the dunes, had the twofold effect of producing an upper terra rossa and a lower cemented zone, the latter resulting in solid limestone of variable degrees of perfection and thickness. In some localities such as near Kongorong, some of the limestone has the appearance of coarsely crystalline marble, whereas in the Canunda Range, the youngest of the existing ranges, the result is a loosely compacted material, just coherent enough to withstand wave action sufficiently to produce cliffs and seastacks.

The depth and degree to which such cementation has developed will depend on a number of factors. The original material which consists of shell debris, comminuted Miocene limestone and other minor constituents, is generally similar throughout. Rainfall must have varied considerably from time to time during the existence of the ranges, so that probably all gradations from light to heavy annual precipitation have been experienced by them. The chief variable factors therefore appear to have been the length of time over which these chemical processes have operated and the freedom from or alternatively the subjection to erosion, chiefly marine, which the dune ranges have experienced. Any lengthy period of marine erosion would remove all or at least considerable portions of any cemented crust that may have been formed, and therefore any such removal would result in not only a thinner crust today in the dune remnants, but because of differential erosion would add another factor to those responsible for local variations in the penetration and consequent depth of the cemented layer. The absence of deep cementation and its irregular variations in depth can be observed or inferred in the cuttings for drains passing through the ranges. The necessity to face with stone large portions, especially the deeper sections, as well as the incoherent material visible in some sections that have not been faced, show clearly the superficial nature of the cementation in many sectors.

It follows from the above that those ranges which are the oldest and have in addition not been exposed to marine erosion, will exhibit the greatest depth and extent of cementation. It is important therefore to note that of all the ranges only the East and West Naracoorte and the Cave Ranges appear to have developed cementation to depths sufficient for the subsequent formation of extensive solution chambers and caves whenever the water table, which no doubt experienced considerable fluctuations in level, was favourable for such a development.

In addition to the dune ranges and remnants of these which have been described at length, there are other dune limestones which have not formed, nor do they form ranges, but are deposits on other hills and elevations. They occur on nearly every volcanic hill examined, and the localities include Mounts Muirhead, Graham, Muir, MacIntyre, and Burr, The Lookout, Bluff and Campbell's Hill, some unnamed hills in the Mount Burr Range, and the Up-And-Down Rocks. On the western face of Mount Burr they occur up to a height of over 650 feet above sea-level, and despite the cover of pines can be traced almost continuously down to the foot of the hill to a height of approximately 200 feet above sea-level. This occurrence of dune limestone is believed to have formed a continuous dune, piled up in sheet form against the seaward face of Mount Burr. It may and probably does represent the net accumulation during several pauses in the retreat of the sea during the development of several glaciations. Subsequent erosion, chiefly marine, appears to have removed the dune limestone along the front of the hill, leaving a "window" of volcanic material partly framed by the remaining dune limestone (fig. 5).

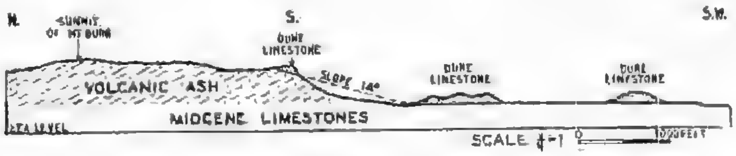


Fig. 5

The dune limestone on the various volcanic hills and on top of the Up-and-Down Rocks occurs at such widely different elevations as to preclude elevation by block faulting, but suggests rather aeolian accumulations against convenient resting points on former shorelines.

Some work had been done on the beach ridge systems fringing Guichen and Rivoli Bays, when the author was informed that these were being examined in detail by other workers. The present paper therefore records merely the existence of these relatively recent deposits.

b. *Siliceous sands*

The residual terra rossa would, no doubt, as pointed out by Crocker (1941, 1946a), give rise, especially during an arid period, to deposits of siliceous sand winnowed from the residue left after the removal by solution of the calcium carbonate. The subsequent distribution of the sands inland over the region is held to have been responsible (Crocker op. cit) for the vast accumulations of these siliceous sands throughout the region. These deposits, except for small isolated areas such as the Belt Range north of Hatherleigh, occur on and to the east of the Reedy Creek Range, as is to be expected if that is their origin, and if the prevailing winds which are from the west-south-west at the present time had a similar orientation during most, if not the whole of the Pleistocene Epoch. However, to attribute the enormous amounts of these sands existing in the region to the winnowing, during one arid period, of the siliceous fraction from the terra rossa developed on the dune ranges, appears to the writer incredible. When the total area covered by these sands is considered and compared with that of the dunes from the former surface soils of which it is said to be derived (and that implies only those dunes to windward, that is, west-south-west), it would appear that other factors must be considered as well.

It seems that several other processes acting either separately or cumulatively may have contributed materially to these deposits. Keble (1947) has postulated repeated periods of aridity or of low rainfall during corresponding phases of glaciation in the Pleistocene Epoch. During each period of aridity the terra rossa produced during the intervening period would be winnowed and supply its quota of siliceous sand, probably greatest after the initial cementation of the dune limestone, but varying as well with the duration of each period during which downward transference of calcium carbonate took place. Several such periods of aridity, if their occurrence is confirmed, could supply a more satisfactory explanation for the large accumulations of siliceous sands than does the one period generally postulated.

The discovery by the writer of specimens of *Anadara trapezia* (*Arca*) on a fossil beach (fig. 4), which is overlain by the present Woakwine Range of dune limestone, indicates a warmer climate than that of today (Crocker, 1946 a). The statement by Crocker (op. cit) that the Woakwine Range is pre-Arid, and the suggestion (Crocker, 1946 c) that these warmer seas may have been co-incident with the last great period of aridity, indicates that there could have been more than one such period.

The rises in sea-level, indicated by the fossil beaches and erosion surfaces shown in fig. 4, and produced, it is believed, by reduction of the ice-caps during warmer intervals, suggest the possibility that arid climatic conditions may have recurred during the Pleistocene Epoch.

The possibility must be admitted that winnowing of the surface soils of other dunes on terrain now submerged by a subsequent rise of sea-level could have contributed to the supply of aeolian sands, but this must be regarded at present as a possibility only. Consideration of the problems involved indicates that detailed bathymetric and palaeoclimatological research is necessary for a discussion of this aspect.

Further, the erosion by marine action of former dune ranges, and the probability that accumulations of siliceous sands could result, must be considered. Finally, the occurrence of large deposits of quartz grit and pebbles, as in the Mount Muirhead area, which appear to have been transported to this district by river action probably from Victoria, suggests another source which could, and no doubt did, supply large quantities of siliceous sands. The above detract in no way from Crocker's recognition of the responsibility of an arid period for the distribution of the sands, but it appears probable that there were several arid periods during which the winnowing action occurred and that other factors assisted greatly in supplying the material for such distribution.

In many areas the siliceous sands mask the subjacent dune limestones so completely that their existence is observable only in a few small isolated outcrops emerging from the sand cover. Mapping in those sectors must be approximate only. The sands also cover very large parts of the Mount Burr Range and adjacent areas and obscure both volcanic and calcareous dune accumulations.

c. *Waterworn quartz grit and pebbles*

Although deposits of waterworn quartz grit and pebbles have been found on the surface in a few places only, chiefly on the eastern flank of the Mount Burr Range and to the south of Mount Muirhead, the discovery of numerous perfectly rounded quartz pebbles from a bore to the west of Mount Muirhead suggests the possibility of the existence of other deposits of this type now obscured by more recent accumulations. This material could not have been derived from the local limestones, basalts or tuffs, but could in part at least have been derived from the subjacent sands and grits. Much of it appears to have been of fluviatile origin and probably from Victoria, brought to this area by streams which later were captured and formed the present Glenelg River. The presence just over the border in Victoria of rocks from which this detrital quartz could have been derived, lends support to this view, which will be discussed later.

d. *Waterworn Flints*

Waterworn flint pebbles are abundant in many localities and are so numerous that individual reference to all occurrences is impracticable here. As these flints were released in large quantities by marine erosion of the Miocene limestones, their presence as waterworn boulders, especially if in large numbers, is of great assistance in determining the location of former shorelines and also the presence, generally in close proximity, of the parent rocks. For instance, the separation of the Reedy Creek and West Avenue Ranges on the western flanks of the Mount Burr Range was difficult because the relatively high gradient of the basement in this sector when these ranges were formed, resulted in their close proximity, and the absence of the wide interdune flat which divides them further to the north where the basement had and still has a gentler slope. The two ranges, consisting as they do of a number of parallel ridges, could not be separated on morphological evidence. The existence, however, of a relatively long swale, in appearance little different from the intradune swales, which is floored with water-worn flints and contains a few boulders of polyzoal limestone (Miocene), was regarded as sufficient evidence for placing the dividing line along this valley. Crocker (1946 a) expresses the view that his Site 9, apparently the same as the one just described, "is probably closely correlated with the Joyce Flat between East Avenue and Baker's Ranges." The present writer considers that the available evidence does not support Crocker's view. Similarly, Crocker's Site 5 marks an old shoreline which continues along the corridor between two dunes referred to by him and divides the dunes into two distinct groups, the Reedy Creek and the West Avenue Ranges.

The occurrence of flints on the flats immediately to the east of Mount Graham (Stephens, 1941) led the writer to search for and locate the Miocene limestones on the hillside above. Flints occur on the planed-off summits and in the swales of the Reedy Creek Range near Burrungule, indicating its former submergence. They occur plentifully on the flats between Burrungule and The Bluff where Miocene limestones outcrop or lie just beneath the surface. Similar examples could be cited for numerous localities. Many of the older flint accumulations have been buried by drift sand, as can be seen in a number of places where they can be followed from areas clear of cover, towards areas in which they become obscured more and more, until no surface evidence of their existence can be seen. There must therefore be many more areas than are known at present where deposits of this type occur. The occurrence of flints along the present shoreline and also at slightly higher levels inland, in enormous quantities at intervals between Cape Banks and the Victorian border, has been utilized extensively for industrial purposes.

c. *Fossil Shells*

Deposits of shells marking the locations of former beaches occur both on the surface and buried by more recent deposits. A number have been described (Crocker, 1946 a). As is to be expected in a region which has experienced successive advances and recessions of the sea, deposits of fossil shells are very numerous. In view of the large number of these deposits occurring at the surface, the large areas covered by more recent material and the number discovered beneath the surface by pits and wells put down for other purposes, it is reasonable to assume that very many more exist than have been discovered. The occurrence of these shells at widely different levels has been interpreted variously in the past, both uplift of the land or rise and fall of sea-level having been held responsible.

The freshness and retention of colours of shells in some localities (Crocker, 1946 a), including some at high levels, has produced some discussion. Little appears to be known of the conditions necessary to preserve the colour and nacre of various types of shells except that some are more resistant to weathering than others. It seems to the writer that any set of conditions favourable to lengthy preservation (Crocker, op. cit. has shown that such conditions have existed and apparently still exist) could maintain such features of the fossil shells for very long periods, and at least as long as the time since the onset of quaternary glaciation. One would not expect, of course, the perfection of preservation either of colour or nacre exhibited at the Mount Graham site, but if conditions were suitable for their preservation for say 10,000 years, the processes of weathering and disintegration appear to have been acting so slowly that even after 100,000 years appreciable remains of the original colour and ornamentation should be retained. There is thus no reason why the Mount Graham site itself may not be of considerable age.

f. *Lacustrine Limestones*

In addition to the dune limestones which are predominantly of aeolian origin and were formed along the then existing coastline, there are in many places accumulations of shells and their debris of fresh-water origin. They contain common freshwater fossils of recent types and in many places they have been cemented to form tough limestones. They may form low ridges, probably wave-piled, or may occur as low flat outcrops. The ridge type is illustrated by the rises at the southern end of Wyrie Swamp south of Millicent. Typical low-lying flat outcrops occur to the north-east of Furner in the flats between the West and East Avenue Ranges. Many others were noted, as is to be expected in a region which contained and still has so many permanent and semi-permanent lagoons and swamps.

g. *Swamp Deposits*

Other deposits developed in the depressions were the typical black soils and, in many instances, peat formations. These are important agriculturally where the swamps and lakes have been drained, but are of importance also, as pointed out by Tindale (1947) in determining the history of some areas, especially where they have been truncated by an encroaching shoreline.

The presence of Coorongite, which is formed periodically in shallow lagoons from the lower forms of plant life such as algae (Mawson, 1938), has in the past led to misguided and unsuccessful attempts to obtain petroleum by drilling. Lime biscuits of algal origin (Mawson 1929) occur plentifully in some areas such as near Robe and Beachport, which are subject to temporary but at times prolonged flooding and are the reason for the name "Biscuit Flat" which is applied to several localities.

h. *Volcanic Accumulations*

These occur only in the Lower South-East and are restricted to one area, the Mount Burr Range and adjacent terrain plus two isolated volcanic foci, those of Mounts Gambier and Schank. Several authors have described the Mount Gambier area (Fenner, 1921) (Crocker 1941), etc., and numerous references to the Mount Burr Range are found in the literature of the South-East.

The petrology, chronology and correlation of this vulcanism with other areas remains to be written. The present writer had not the opportunity to study these former volcanic centres in detail and was restricted to such examination and observations as could be combined with the general plan of the research undertaken.

As is well known, the Mount Burr Range and the adjacent areas near Lakes Leake and Edward includes by far the greater part of present volcanic accumulations. This range, culminating in Mount Burr, 802 feet above sea-level, contains numerous hills consisting of volcanic material. No definite volcanic necks or foci have been discovered to date, and therefore not one of these hills can be regarded as a volcano. How many volcanic foci there were is unknown. The long duration and tremendous amount of subaerial and marine denudation have left only eroded remnants.

The Mount Burr Range owes its relative prominence to several factors. The basement of Miocene limestone, which is less than 50 feet above sea-level at Millicent, rises to 90 feet at the foot of the range, to 112 feet near the Forest headquarters and to over 200 feet at the eastern edge, from which it drops relatively sharply to the eastward. From the scattered levels available, it is inferred that the basement forms a platform sloping upwards to the east (fig. 6). From this platform rise a number of hills of volcanic material, chiefly tuff but with some basalt. The flanks of these hills are decorated here and there with variable amounts of dune limestones. In front of the range, that is on its western flanks and in some instances on or adjacent to the volcanic material, there lies a series of dune limestone ridges which it is reasonably certain are the continuations of the Reedy Creek, West Avenue and other Ranges. Within the main mass of the Range there are other dune limestone outcrops which owing to their partial burial beneath drift sands cannot be connected with any known dune ranges, although some at least are believed to be part of the East Avenue Stage.

Over the whole area but distributed somewhat irregularly, there are immense accumulations of siliceous sands which have filled many of the former hollows and swales and have covered a very large proportion of the dune limestone and volcanic material. As a result, the latter is buried so largely that the relationship of those accumulations which project above the sand cover is in most instances a matter of conjecture. All these deposits combined with the extensive pine plantations and dense natural vegetation, make detailed geological surface mapping difficult and necessarily incomplete. A number of shallow holes and bores (Stephens, 1941, Crocker, 1946 a) supply a little information, but a comprehensive plan of subsurface testing is necessary before the full story can be told. In the area adjacent to Lakes Leake and Edward the chief contributors to the present topography are the volcanic material and the siliceous drift sands. The small centres of Mounts Gambier and Schank are of interest in this connection chiefly for any light they may throw on the relative ages of the volcanic eruptions and the adjacent dune ranges (Crocker, 1941).

Reference will be made in subsquent pages to the possibility that other volcanic foci and accumulations existed to the westward of those known today. If any existed in the region between the known deposits and the present coastline they were removed completely or the low remnants buried by recent marine or terrestrial deposits. Exploration of the floor of the adjacent continental shelf may reveal evidence of such former volcanic activity.

i. *Lunettes*

These have been referred to in the section on topography and are included here merely for the sake of completeness. Their development (Hills 1940 b, Stephens 1946) is to be ascribed probably to several periods and is not considered of importance to the problems being discussed in this paper.

j. *Kunkar Travertine*

Surface accumulations of this limestone have been observed not only on the Miocene limestones, calcareous dune and freshwater limestones, but also on the basic tuffs. Some kunkar travertine and fossil soils have been noted below the present surfaces in the interior of dune limestones, where these have been dissected by marine erosion, such as the cliffs at Cape Northumberland. These occurrences are significant in the history of such dunes, indicating renewal of deposition of aeolian material after relatively long stability.

k. *Laterite*

In the vicinity of Tantanoola, and possibly elsewhere, pebbles of ferruginous laterite occur at or near the surface immediately overlying Miocene limestones. The developments noted are not extensive, but the occurrences support the opinion which is strongly held by the writer, that the existence of laterite, whether on the surface or in a subsurface section, is not proof of the former peneplanation of an area and proves merely that the area, whether large or small, is one in which surface run-off was negligible and climatic conditions were suitable.

DISCUSSION

The present paper deals mainly with the development and history of the region since the termination of the Murravian transgression. As stated earlier, this termination is defined by the writer as the time when the sea in its south-westerly retreat reached the shoreline now indicated approximately by the western edge of the East Naracoorte Range. At present the general opinion of palaeontologists is that this took place during the Lower Pliocene and probably towards its close.

To the north and east of the East Naracoorte shorelines, Lower Pliocene marine sediments occur over wide areas, overlying marine deposits of Miocene age. As will be shown later in the discussion, the East Naracoorte Range marks approximately the western limits of the Lower Pliocene marine sediments in the Lower South-East, but in the Upper South-East the Lower Pliocene southern and western limits are marked roughly by the dune range system which is described herein as the continuation of the West Naracoorte Range after its intersection with the East Naracoorte Range. Although sediments of Miocene age occur either on the surface or at shallow depths throughout the region to the south-west of the East Naracoorte Range, no marine sediments of Lower Pliocene age have been identified there. It is illogical to suppose that these sediments never existed in the region, in fact it is certain that, just as they were deposited in the areas to the east and north, they were formed also in the relatively deeper waters further west and south, during the later stages of the Murravian submergence. The reason for their absence is not far to seek. The retreat of the sea at the close of the Murravian transgression exposed an emergent marine coastal plain, and resulted also in a considerable lessening of the depth of the ocean over the continuation seawards of the emerged plain, thus forming a submarine plain covered by shallow water, for a considerable distance from the shoreline. Marine sediments deposited during Lower Pliocene times, prior to the retreat of the sea and therefore in relatively deep water, were now subjected to wave erosion and removal. This marine erosion is considered to have continued until the whole of the Lower Pliocene sediments had been removed to distances from the shoreline corresponding to effective wave action. Marine erosion continued when the Miocene sediments were laid bare, and, as will be shown later, appreciable thicknesses of these deposits were thus affected. The distance from the East Naracoorte shoreline, while this was the shoreline, to which this erosion was effective is immaterial, as the successive retreats of the sea during the succeeding glaciations to far beyond the present coastline and to a possible level of from several hundred feet lower than today would have provided conditions of maximum erosion for the whole region at various times.

The effects produced would be the lowering, by subaerial denudation only, of the areas to the east and north of the East Naracoorte coastline and extensive marine erosion and deepening of the foreshore to the west and south of that datum. The relatively long period of stability postulated, namely from the retreat of the Murravian Sea to the close of the Pliocene Epoch and the slight resistance to erosion expected of such little consolidated marine sediments, would result in a very marked difference in elevation of the surface as between the wave-cut platform and the adjacent dry land. Such differences in elevation, although not so marked because they were of shorter duration, would mark other stages of stillstand of the ocean during the subsequent glaciations. The lack of marked resistance to erosion of the marine sediments, both of the Lower Pliocene and of the Miocene, which would enable rapid lowering of the surface of the submarine plain, would tend also to prevent the formation of extensive cliffs and steep slopes along the coastline, and have the effect of softening rapidly the severity of any temporary features produced. Exceptions would occur, of course, such as the well-known Up-And-Down Rocks where hardening of the rock by local dolomitization has made cliff formation and the retention of this feature possible. The postulation of a fault (Fenner, 1930) to account for the difference in elevation on the east and west of the East Naracoorte Range appears to the writer unnecessary. Similarly, the existence of a fault, the Tartwaup Fault (Ward, 1941, 1944), along or near the front of the Up-and-Down Rocks is not necessary to explain this feature. As stated earlier, both of these postulated faults may exist, but the topographical features ascribed to them could have been, and probably were, produced by marine erosion.

Within the area which appears to have remained submerged during the latter part of the Pliocene Epoch, marine erosion should have proceeded relatively evenly except where more resistant formations such as the Precambrian rocks of the Upper South-East, and isolated dolomite beds, were present. There are two areas, however, in which although on present evidence the Miocene limestones are no more resistant than those of the adjoining terrain, they were not eroded to the same depths and today stand at much higher levels. These two areas are the Mount Burr Range and the Dismal Swamp. The former has been referred to earlier, and, although evidence is scanty, sufficient is known to indicate that the eroded surface of the Miocene limestone underlying the Mount Burr Range is a platform which slopes upwards from south-west to north-east from a height of 80-90 feet to over 200 feet above sea-level respectively (fig. 6).

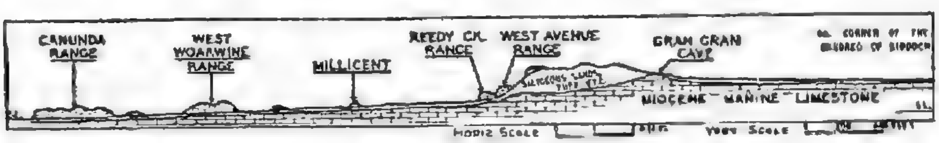


Fig. 6

Dismal Swamp is not one continuous swamp but consists of a large number of connected and partly connected swamps with numerous low ridges, many of which are dune limestones. This aggregate of swamps has therefore no well-defined boundary, but as the general swamp level appears to be approximately at 230 feet above sea-level, that height is being used here to delimit the area. The Miocene limestone floor is found at shallow depths and apparently at heights averaging a little over 200 feet above sea-level. It appears therefore that while marine erosion was effective in removing considerable thicknesses of marine Murravian deposits in the region, the two areas referred to above were protected wholly or in part from further erosion after a certain time interval during which all deposits of Lower Pliocene age and some of Miocene age had been removed (fig. 7). That protection could have been and probably was supplied by the formation of volcanic cones in the shallow seas west of the East Naracoorte Range. The formation of these volcanoes and their emergence as islands on a gently sloping submarine platform, would have supplied increasing protection from further marine erosion to the areas eastward of the most westerly islands, and account for the gradual upward slope to the east of the floor of Miocene limestone beneath the Mount Burr Range and the relatively steep drop in level on the east and north of Mount Graham, the most northerly volcanic hill existing today. The various islands probably developed a series of complex tombolos, and if not tied to the coast were responsible at least for the protection from further erosion of the area how known as the Dismal Swamp. This area probably developed initially as a series of shoals and low islands, due to the accumulation of sediment derived from the volcanoes and Miocene limestones to the west. The writer, believing that some of the streams which now form the River Glenelg flowed at that time into the sea to the east of Kalangadoo, credits that stream system with transporting large quantities of detrital material, which would assist the tendency for shoal formation west of the Mount Burr Islands, and account probably for a large proportion of the deposits of waterworn quartz found near Mount Muirhead and in other areas.

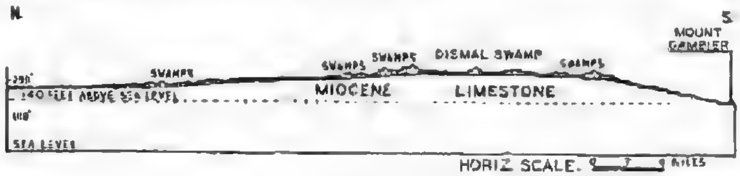


Fig. 7

Should the above reconstruction be upheld, then the commencement of volcanic activity in the South-East must have taken place during the Upper Pliocene and probably during the earlier stages of the Upper Pliocene, in order that the large amount of erosion which undoubtedly occurred in the adjacent areas, could have sufficient time for its accomplishment after the Mount Burr and Dismal Swamp areas received protection. Such age determination would correlate the older vulcanism of the Mount Burr Range with the older vulcanism of western Victoria, which is regarded as Middle to Upper Pliocene in age (Hills, 1939 a).

No definite volcanic vent has been discovered in the Mount Burr Range. In view of the time that appears to have elapsed since the eruptions took place and the vast amount of erosion both subaerial and marine but predominantly marine, the absence of obvious surface evidence of the existence of volcanic necks and vents is not surprising. Relatively small fragments of the original accumulations appear to have been left and even Mount Muirhead, believed to have been of more recent origin but owing to its location exposed to rapid erosion during at least one high sea-level period, appears to be only the eastern segment of a former much more extensive cone. It is possible therefore that other volcanoes existed in the past to the north, south or west of the present remnants, but have been removed completely by subsequent erosion or exist as residuals only in the adjacent areas now covered by the sea.

Owing to their burial by more recent deposits and also because of subsequent denudation, the known deposits of marine or probable marine origin in the Mount Burr Range are few in number. Waterworn volcanic material is recorded from a pit (Stephens 1941). Crocker (1946 a) records two sites, one at the surface and one from a pit, of deposits of shells overlying volcanic material.

There is, however, much additional evidence supporting the view that the Mount Burr Range has been subjected to marine erosion at various levels and therefore presumably at different times. The continuous series of dune limestones along the seaward slopes of the Mount Burr Range and the wide variations in elevation of the floor on which these dunes rest, the occurrence at several levels of flint boulders derived from the adjacent Miocene limestone in which they can be seen *in situ* in some outcrops, and the shelves or platforms, relics apparently of marine action, on some of the hills; all of these testify to former submergence of the lower portions of the Mount Burr Range. On the eastern flank of Mount Graham, the northern extremity of the range, a notable feature is a wide shelf at an estimated height of approximately 200 feet above present sea-level (fig. 8). This shelf could be ascribed to a basalt flow, but the continuity of this shelf with the high level fossil beach (Crocker's site 11) to the west and the occurrence on the

Fig. 8

shelf of a small remnant of dune limestone, are strong reasons for regarding this feature as a wave-cut shelf or platform. As they are the most elevated evidence of marine action on Mount Graham, this shelf and fossil beach are assigned to the West Naracoorte shoreline. A similar shelf on The Bluff and the occurrence on that hill also of dune limestone, and the existence at many localities in the Mount Burr Range of small areas of dune limestone, some fringing, some covering hills of volcanic material, all contribute materially to the formidable list of relics of former marine activity. The occurrence of dune limestone, correlated by the writer with the East Avenue Range on top of volcanic tuff as exposed in a well near the Forest Headquarters, together with the widespread occurrence at many levels of the numerous outcrops of dune limestone referred to above, prove that this volcanic activity is older than the period during which the dune limestones were deposited at the various levels.

Some observers may be inclined to postulate faulting and warping in order to explain at least some of the variations in level. In all his investigations the writer has not found any evidence to suggest that any other than oscillations of sea-level are necessary to account for the wide range in height and irregular distribution of these relics of former marine activity.

Not all of the volcanic accumulations of the Mount Burr Range are assigned to the Early Upper Pliocene.

First, the Miocene basement has an upward slope to the eastward, a slope due, it is believed, to the protection afforded by the formation of volcanic islands during the earliest eruption. The occurrence immediately on this basement of basalt and volcanic ash and tuff suggest that the initial activity was continuous for a long time or revived episodically, but before the development of the dune ranges, that is, before the Pleistocene Epoch began.

Secondly, Mount Muirhead is, strictly regarded, not a part of the Mount Burr Range, but abuts on its north-western extremity. Two parallel dune ridges to the south which have been correlated with the Reedy Creek and West Avenue Ranges, can be followed northwards beyond Mount Muirhead and are found to occur, one on the seaward and the other along the inland flank of that hill. The latter ridge which is correlated with the West Avenue Range could not have been formed in that position had Mount Muirhead been in existence and the West

Avenue Range therefore predates this volcanic activity. As the East Avenue Range nearby is found to overlie volcanic ash (near the Forest Headquarters) and this range is believed to be considerably younger than the West Avenue Range, such reversal of superposition of dune limestones and volcanic ash would not in itself be an indication of more than one period of volcanic activity. However, the Reedy Creek Range which skirts the seaward flank of Mount Muirhead appears to have been buried in part by the volcanic material and this suggests that the activity post-dates the formation of that dune range.

Further, the age assigned to the earliest phase of eruptive activity in the Mount Burr area, namely, Early Upper Pliocene and therefore before the commencement of Pleistocene Glaciation and the consequent formation of dune ranges on the eustatic shorelines, indicates that any volcanic material deposited after such dune ranges were formed must be of much later date than the earlier activity.

It is not possible, however, to say more than that the eruption of Mount Muirhead occurred during the Pleistocene Epoch and after the formation of the West Avenue and probably after that of the Reedy Creek Range.

The Mount MacIntyre - Campbell's Hill sector may represent a period of activity later than that of the Mount Burr Range, but such a suggestion must await much detailed petrological and field work before it can be considered further. The Lakes Leake and Edward sector, too, may represent a relatively later period of activity but again this is merely an opinion. The evidence of other observers (Fenner 1921, Crocker 1941) assigns the eruptions of Mounts Gambier and Schank to relatively recent times, largely based on the preservation of the cones and the relative positions of their ash to the calcareous dunes and siliceous drift sand in their vicinity. However, the collection by the writer and identification by courtesy of the National Museum, Melbourne, of particles of volcanic ash in the lower portion of a calcareous dune inland of and near Mount Schank, is proof of the existence of volcanic material prior to the time of formation of the dune and raises the possibility of the present cone of Mount Schank being a relatively recent formation above a former older period of activity, or of the existence to the westward, of a former volcanic vent, the accumulations from which have been denuded completely or are now covered by the sea.

While not admissible as scientific evidence, the remarks contained in local native legends (Smith, 1880) that Mounts Muirhead, Schank and Gambier, in that order, were "ovens," and the statement that it had "thundered and lightened" and "thundered in the ground" may be regarded at least as interesting suggestions of volcanic activity at those three foci during human occupation of the region.

The marine erosion of the marine Murravian deposits continued apparently until the close of the Pliocene Epoch and the beginning of Pleistocene glaciation. The result of the removal not only of the great mass of water formerly covering the Murravian Gulf and the great decrease in depth of water over the still submerged area west of the East Naracoorte Range, but also the removal of a considerable thickness of Murravian sediments by marine erosion may well have produced uplift of the region due to isostatic adjustment. Such uplift, if it occurred, would probably have been slow and gradual, and have brought within the reach of maximum wave action deeper and deeper zones of the Murravian sediments. Such a long-continued process could account satisfactorily for the considerable differences in elevation between the marine plane at the seaward foot of the East Naracoorte Range and the hinterland which was not subjected to this erosion.

The evidence obtained not only of former shorelines along the Mount Burr Range, as much as 200 feet or more above present sea-level, but also the widespread evidence of retreats and advances of the coastline and the evidence of fossils that these events occurred during the Pleistocene Epoch, suggest immediately the probability of eustatic control due to successive glaciations and deglaciations during that epoch.

That such increases and decreases in the severity of glaciation did produce corresponding changes of world sea-level is now generally accepted. As regards the South-East, sufficient evidence has been obtained to show that such changes of sea-level took place after the main volcanic activity of the Mount Burr Range which, as stated above, has been assigned to the Upper Pliocene and probably to an early division. The writer therefore agrees with Tindale (1933) that changes of sealevel due to glaciation were responsible for the formation of successive shorelines and the resultant calcareous dunes. The writer goes further, however, and believes that other processses were operative at the same time, complicating the over-simplified history as presented by Tindale (1947).

Further, it has not been recognised generally, nor has it been emphasised sufficiently, that many of the dune ranges show subsequent submergences and accompanying marine erosion, and that such in many instances took place after sufficient time had elapsed for an appreciable amount of cementation of the upper parts of these dunes.

Attempts to determine their relative ages by palaeontological methods do not offer much success in the present state of our knowledge. Studies of the swamp and peat deposits and their entombed flora, or of pollen grains may perhaps be of assistance in the future, but at present no such aids are practicable.

A detailed examination of the progressive heights above sea-level of the sea ward or western margins of the dune ranges shows that the differences in elevation between them decrease to the north-westward in many instances. Horizontal spacing varies considerably, as is to be expected on such a gently sloping basement. Very small differences in elevation at the time of formation, would have been recorded by relatively large irregularities of the shoreline. The close horizontal spacing, and in some places the overlap of dunes on the seaward slopes of the Mount Burr Range, is an obvious result of the relatively steep gradients of that area.

The variations in vertical spacing, however, and especially its progressive variation in one direction shown by many of the dune ranges, indicate warping of the basement between the times of formation of the shorelines concerned. It would appear therefore that all that would be necessary to determine the relative ages of the dunes marking the former shorelines would be a determination and study of the progressive differences, positive or negative, between their seaward margins in a north-westerly direction, and their approaches to or departures from a level common to both.

The solution of the problem is, however, not as simple as that. It was found that some dune ranges approach each other and then diverge, some are reasonably parallel for a distance and, further on, diverge or converge vertically. As will be shown later, the progressive downward tilting of the greater part of the region in a west-north-westerly direction to the north-west of the postulated Cape Banks axis, and a downward tilt in a south-easterly direction to the south of that axis, the probable transverse warping with north-easterly trends, the probability of positive and negative isostatic movements of the region, and the possibility of some uplift in the Mount Burr Range area and vicinity, all add to the difficulties of determining, not only the height of sea-level at which the successive shorelines existed, but also their chronological sequence. Other factors and observations indicate that a sequence compiled by the use of progressive differences in elevation, whether positive or negative, is not necessarily the order in which the dune ranges were formed. The writer was compelled therefore to examine the possibility of using other evidence in the chronological classification and to use the evidence of relative heights as an auxiliary factor in such a determination.

As stated earlier, there are indications that other dune ranges existed, which have been removed completely or almost so, and it is suggested therefore that the diagrams and tables showing the postulated succession are incomplete in so far as they do not include these former ranges. Such removal by marine erosion would apply particularly to those formed during the Günz and Mindel retreats of the ocean, because dune ranges formed then would have experienced submergence during the subsequent Interglacials.

The importance of determining their ages needs no elaboration. By using such other evidence as is available, the writer has attempted, though with some reservation, to produce a chronological sequence of the dune ranges and therefore of the successive shorelines. Naturally, in such a scheme there must be many assumptions and inferences and it is not contended that the list as compiled is final. It is submitted as a provisional classification, subject to any alterations or modifications required as the result of future research.

If it be granted that the dune ranges mark approximately the shorelines at various sea-levels and if, as seems reasonably certain, such fluctuations in sea-level were related directly to the total quantities of water removed from the ocean as ice, then if it were possible to determine, or at least to suggest, which dune ranges marked the maximum advances of the sea during the First, Second and Third Interglacials, reasonable starting points would be obtained for aligning the remaining dune ranges.

It is logical to assume that the relatively long stillstand generally accepted for the height of each interglacial advance of the sea would leave its record in the erosion of the basement and a steepening of the gradient between the landward termination of the marine plane and the hinterland.

An examination of the profile of the basement at right angles to the average trend of the ranges and along a zone which reaches the coast at Robe, shows first the very marked ascent from the former East Naracoorte foreshore, a similar but less marked rise from the Western Naracoorte Range, a smaller but none the less definite rise at the former Cave Range foreshore and a very marked rise in gradient in the vicinity of the West Avenue Range. Further, the marked change in trend, that is concave to the east as opposed to the concavity to the west, which begins at the West Avenue Range, may indicate that long continued erosion at or near a long maintained shoreline, may have modified considerably the shoreline inherited by the West Avenue foreshore as the result of previous erosion. The change in trend on the other hand may be due to diastrophism, warping or tilting, and the problem is left unsolved at present. The somewhat anomalous trends of the Neville Range between Kingston and Reedy Creek Station, and of the East Dairy Range and to a less extent of the West Dairy Range south of Kingston, could be explained by local warping or collapse, but are due most probably to the existence of more resistant rocks, probably inliers of Precambrian age, forming a protruding platform or a rounded cape.

Other things being equal, those ranges which were never submerged after their formation, and which therefore would not have experienced the removal by marine erosion of the whole or part of their cemented crust, would develop the greatest depth of cemented limestone. Subsequently if subsurface hydraulic conditions were favourable, as they must have been in all of the ranges at one or more of the many variations of sea-level, which would affect so markedly an area of flat or gently dipping porous limestones possessing generally a cryptoreic drainage, solution chambers would develop in the cemented crust of the dunes. The cave formations therefore would be more extensive and occur mainly in those ranges which have developed, or have been permitted to retain, a deep zone of calcareous cementation. The three ranges in which numerous and extensive solution chambers have developed are the East and West Naracoorte and the Cave or Stewart's Range. If, as is generally believed, the East Naracoorte Range marks the oldest, and in the Lower South-East the most inland of those ranges which are due to small variations of sea-level or of the land, then according to the writer's interpretation this range indicates the approximate position of the pre-glacial shoreline. Further, if, as is generally believed (Zeuner, 1946, *per contra vide*), sea-level during the height of the Second or Great Interglacial reached or approached closely the pre-glacial sea-level, then the West Naracoorte Range which marks a notable notch in the basement plateau, is the logical representative of that Interglacial.

The assumption, on the evidence given above, that the Cave or Stewart Range (referred to hereafter as the Cave Range) was not submerged after its formation, and the existence of a notch in its vicinity, suggests that the Cave Range is situated approximately along the coastline formed by the sea during the Third Interglacial.

One position remains to be filled, the maximum advance of the sea during the First Interglacial. For the reasons referred to earlier, the marked steepening of the gradient referable to a smoothed notch, in the vicinity of the range, with the tentative support of the marked change of direction of the coastline, suggests that the West Avenue Range is the only range with any evidence for its selection. This view is supported by the observation that the Reedy Creek Range, which in the central part of the region is located to seaward of and at a lower level than the West Avenue Range, gradually approaches the latter as it is traced to the north-west, and finally intersects it. This indicates a downward tilt to the north-west between the times of formation of the two ranges, and suggests that the Reedy Creek Range marks a shoreline during the development of a glaciation subsequent to that in which the West Avenue Range was formed. The recorded submergence in the Lower South East of the Reedy Creek Range by a rise of sea-level equivalent in that locality to a depth of at least 140 feet above present sea-level and the inference that the planed off summits owe their formation to the exisence of a cemented crust, suggests that the Reedy Creek Range was formed during the development of the Penultimate Glaciation. This places the West Avenue in the time of development of the First or Second Glaciation. As stated above, it is placed at the commencement of the latter, that is at the height of the First Interglacial for other reasons.

The four sea-levels, namely the Pre-Glacial, First, Second and Third Interglacial having been postulated, it is now possible to consider the remaining ranges one by one, examining them in order from the furthest inland range to the present coastline. Any evidence or inferences applicable will be discussed and the reasons given for the ages that are being assigned to them.

In discussing the order of formation of the various shorelines as represented by the dune ranges, the above four sea-levels will be used as definite horizons from which the relative ages of the other sea-levels will be inferred, but such use does not imply that the times assigned for the existence of the four major shorelines are regarded as proved beyond doubt. The tentative nature of their classification has been made quite clear. It is obvious that the chronology as determined on the above basis, would be modified or altered considerably should the dating of one or more of the four major shorelines be changed.

Harper's Range—This range is eroded considerably and remnants only exist. It is assumed therefore that it has been submerged since its formation, but its preservation, even though partial, must have been due to an effective amount of cementation, which would indicate the passage of a considerable period of time between its formation and subsequent submergence. The only two sea-levels high enough to have achieved this submergence were the Preglacial and Great Interglacial sea-levels. It must have been formed therefore during the retreat of the sea marking the beginning of the Günz or First Glaciation.

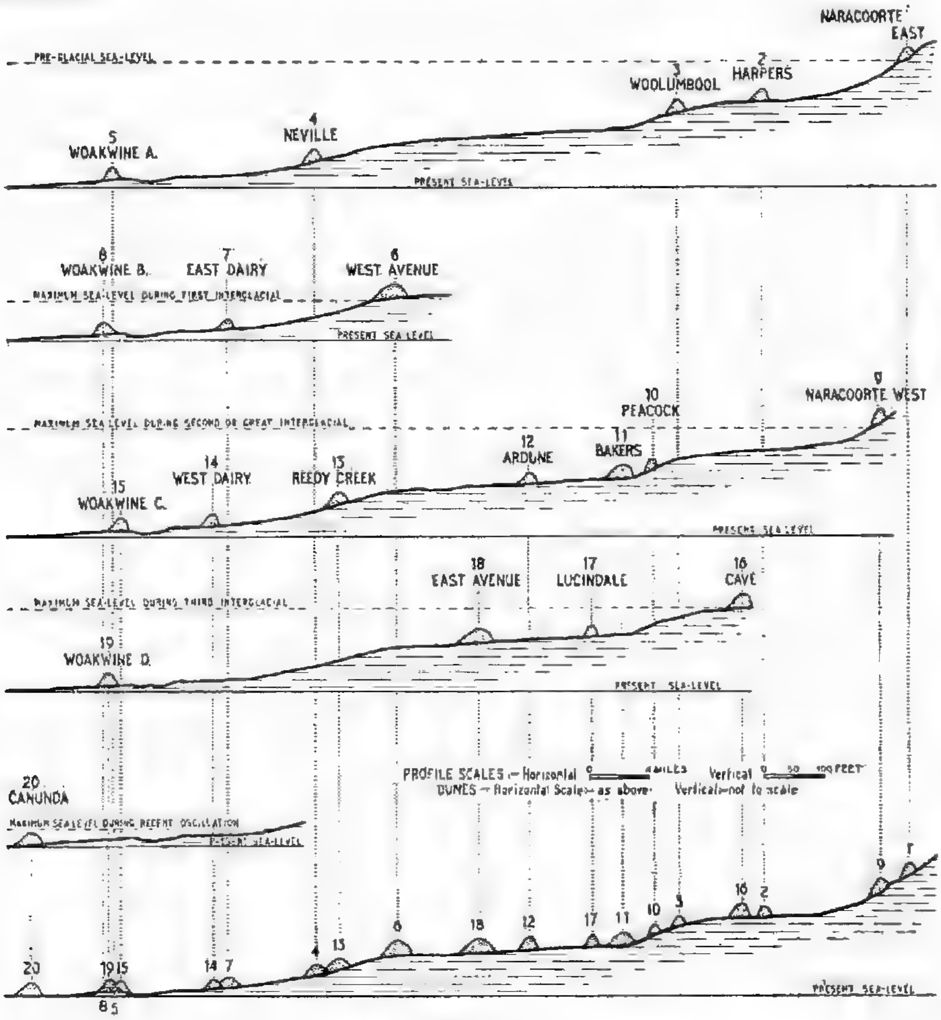


Fig. 9

Sections illustrating the postulated succession of the stranded dunes as each glaciation developed. Since the profile is that of a zone at some distance to the north-west of the inferred Cape Banks axis, the heights of the shorelines above present sea-level, indicated by the seaward margins of the dunes, are less than the true figures.

Woolumbool and Peacock Ranges—Because of their proximity the writer suggests that they represent stillstands during separate glaciations rather than two stillstands close together during the retreat of the sea during the development of a single glaciation. Further, the more inland of the two must be older since the formation of a dune immediately behind an existing one is improbable except as a purely local phenomenon. Their marked erosion indicates that both have been submerged and since, according to the writer's deductions, sea-level was not high enough (fig. 9) to cause their submergence dring the First Interglacial, the only glaciations during which they could have been formed are the First or Günz and Third or Riss respectively.

Baker's and Lucindale Ranges—Their close proximity against suggests two different ages, and being more landward, the Baker's Range would be older. Baker's Range is eroded but not excessively and the Lucindale Range appears to have suffered little or no marine erision. These two are placed therefore in the Third and Fourth Glaciations respectively.

The probability that the Lucindale Range as it is followed in a northerly direction intersects, and eventually continues to the east of Baker's Range, and the possibility that it joins part of the Peacock Range, make the determinations of the time of formation of the latter difficult. The scarcity of available surveyed levels in that sector, and the sand-obscured outcrops add to the difficulties. The position of the Peacock Range in the chronological table therefore is one of considerable uncertainty.

Ardune and East Avenue Ranges—Observations similar to Baker's and Lucindale Ranges apply. They are placed therefore in the Third and Fourth Glaciations respectively.

Reedy Creek Range—This must have been formed later than the West Avenue Range. This view is supported by the observations referred to earlier that the Reedy Creek Range intersects, in the northern part of the region, the West Avenue Range which has been selected as marking the shoreline at the beginning of the Second Glaciation. The evidence for placing it in the time of development of the Third Glaciation has been given above.

Neville Range—The much eroded remnants of this range, consisting of stumps only of dune ridges and some extensive segments, and the complete removal of the range from other areas suggest that its submergence has been effected during several periods. It appears to emerge from beneath the Reedy Creek Range in the Lower South-East and to diverge progressively in a general north-westerly direction. It probably belongs to the First Glaciation.

East and West Dairy Ranges—Their eroded condition and their existence today as remnants indicate their former submergence. As with other ranges, their close proximity is the reason for assigning them to two separate glaciations. They could therefore be placed in the First, Second or Third, but their preservation, though partial only, has led the writer to place them in the Second and Third Glaciation respectively.

Woakwine A - D—One stage has been assigned to each glaciation. It is true that the first two ranges have been eroded almost completely and that the two later ranges exist today, one as the East Woakwine, partly eroded, and the other as the West Woakwine, litttle eroded. The East and West Woakwine Ranges, that is stages C and D belong probably to two separate glaciations, the Third and Fourth respectively. Woakwine A and B may belong to two interstadial oscillations of one glaciation, that is the First or Second, but the evidence for submergence and erosion of Woakwine A before B was deposited suggests the advisability of placing them in, separate and therefore in the First and Second Glaciations respectively.

The writer was fortunately able to examine two deep sections through the West Woakwine Range, one in the cutting of Drain L near Robe and the other in the Mount Hope Drain. Although both sections were instructive the one in Drain L yielded more information and the chief purpose of the examination of the Mt. Hope Drain was the search for confirmatory evidence of observations made in the former. As will be seen from the section (Fig. 4), three erosion surfaces were observed, two of them covered with shells and detrital material. This indicates the formation of a dune at this location at least four times. It is probable that the four stages noted in the section may correspond to the four Woakwine dunes or their remnants referred to earlier, but no evidence for such correlation is possible at present.

A notable feature of Horizon A was the discovery of specimens of *Anadara trapezia* (*Arca*) on this fossil beach, at approximately 25 feet below the present surface of the overlying cemented dune. This occurrence will lead, it is hoped, to the further search for this interesting sub-fossil. (Crocker, 1946a). The suggestion that the presence of *Anadara*, now extinct in the South-East, indicates a climate warmer than today, would agree with the conclusion that a slightly warmer climate was necessary to produce eustatic rise of sea-level to at least the height at which this fossil was found in the cutting. Although exposures are poor, the Mount Hope Drain Cutting, approximately 28 miles to the south-east of Drain L, shows the existence of two fossil beaches, similar apparently in their general fossil content to those of Horizons A and B. Although *Anadara* has not been found in the Mount Hope Drain Cutting, Horizon A in both shows a mixture of reef and mudflat fauna.

The Canunda Range—The slight degree of cementation, so much less than that of any of the other dune ranges, suggests a short period of time since its formation and it is placed accordingly in an interstadial oscillation of the Present or Fourth Interglacial or as some prefer, the Fourth Glaciation. The Canunda Range marks, in the writer's opinion, a stillstand during the retreat of the sea from an advance within relatively recent times to a height which enabled it to produce erosion features now about 50 feet above sea-level in the areas where these were examined.

Subsequently to the Canunda Stillstand, the sea is believed to have retreated to some distance below present sea-level, at a later stage to have risen again to 12-15 feet above its present level, and finally retreated to its present position. To what extent any of the figures given above may include modifications by contemporaneous or subsequent isostatic adjustment of the region or further downward movement at the northern end of the tilted block, cannot be determined at present. The possibility must be considered that the heights given here do not necessarily represent the true values of corresponding changes in world sea-level.

As a result of the deductions outlined but with the stated reservations, a list has been compiled in tabular form which purposes to show the postulated succession and the glacial and interglacial phases during which the dune limestones are believed to have been formed along the successive shorelines. A diagram (Fig. 9) is intended to show graphically the postulated order and development of the various dune limestone ranges.

An attempt has been made (Tindale, 1947) to correlate a simplified grouping of the dune ranges of the South-East with the interglacial terraces of Europe, and the Pleistocene marine interglacial terraces of the Atlantic coast of North America. In order to make this possible, levels were assigned by Tindale to the terraces formed at the times of formation of the dunes. However, it is obvious even from a cursory examination of the relief map prepared many years ago by the South-Eastern Draining Board, or from a study of the numerous available levels, or from the contoured map prepared by the writer, that the range of levels at the edges of the ranges and therefore of any terraces if present, is so wide that it is easy to select whatever values are required. It is not difficult therefore to select a section across the ranges which will supply levels comparable with those of interglacial sea-levels outside Australia. The real difficulty is to determine the true heights above present sea-level at which these ranges were formed. If it were possible to do this and it could be established with certainty that in the European and North American areas the land remained immovable, and only the sea rose and fell during the epoch in question, namely that of Pleistocene glaciation, then and only then could an attempt be made to correlate these widely separated areas with the South-Eastern features. The writer has investigated the possibilities of determining the true heights of formation above present sea-level of the successive shorelines of the South-East and has reached the following conclusions:—

(a) It is reasonable to assume that the successive retreats and advances of the sea due to changes in world sea-level during the Pleistocene Epoch did not proceed smoothly and evenly from maximum to minimum and vice versa but experienced periods of stillstand at irregular intervals. The retreating ocean would leave on the emerging land a series of dunes marking the approximate positions of successive coast lines. Likewise, when the sea advanced over this region, the gentle gradients of the basement would ensure that any shorelines formed and deposits laid down, were indistinguishable from those of an emerging land surface, except where dunes were encountered by the rising sea, dunes left behind during a previous retreat. It is to be expected therefore that a series of coastal dunes would be produced at each stillstand of the rising ocean. But such dunes would disappear rapidly and leave little or no trace after their submergence by a further rise of sea level. No dune formed during such a progressive rise could remain, and only one, the one marking the furthest advance of the sea, would be left when sea-level began once more to drop. On the other hand dunes formed during a previous retreat of the sea, especially if they were predominantly calcareous as were those of the South-East, would develop a cemented crust before the next inundation and when this arrived would offer considerable but variable resistance to erosion. Some at least would probably survive a submergence, even though they were reduced to remnants only. All stages and degrees of erosion of dunes can be noted in the South-East and have been described earlier.

The development of such coastal dunes on an emerging landmass is described by Johnson (1938). Their initial development as offshore bars in a shallow sea and their enclosure, partial or complete, of the intervening waters would develop long lagoons running parallel to the shore, such as is shown today by the Coorong and its seaward dunes. The gradual movement landwards of this off-shore bar would result in narrowing the lagoon and eventually in its extinction and the deposition of the dunes on the unsubmerged land. The retreat of this offshore bar must of necessity have been irregular in some localities and hence the original offshore bar could remain as such for part of its original length but exhibit all intermediate stages of advance to its final resting place on the non-submerged land in the remaining segments. Although the gentle gradients of the basement would have been favourable to the development of off-shore bars, it is by no means certain that all of the dunes originated as such features. Some indeed may represent purely aeolian deposits above high tide level. Even if this can be demonstrated however, such deposits may be the result of the shoreward travel of an off-shore bar until it became a dune above high water level.

Further, the inland or leeward, that is the north-eastern edges of a dune would, like all aeolian deposits of this type, be exceedingly irregular and extend for variable and in places considerable distances inland. In order to obtain comparable figures the same features or as near to these as possible must be measured for each dune. It is obvious that the seaward edge is much more reliable as a guide to the height of sea-level than the irregular landward edge. Where the seaward edges of the dunes are long and straight or evenly curved, it can be assumed that they represent an even advance towards the land of the original off-shore bar, and where these edges are irregular, either differential advance or aeolian deposition on an irregular coastline is indicated. Further, it must be realized that the foot of an off-shore bar is not necessarily at sea-level and in many instances is at some distance below this line. In taking measurements designed to determine the relative heights of sea-level when these dunes were formd, the levels of the plain immediately adjacent to the seaward edges of the dunes were taken and where possible only at such places where the dunes presented a regular and even front. Even so this elevation does not represent, except in the southern sector of the region where the basement limestones outcrop at the surface, the real level of the platform on which the dunes were laid down. The variable depths of subsequent deposits which include shell deposits of marine origin, swamp deposits and drift sands, make it necessary to allow for errors which may reach 20 feet or more. However, the selection of a number of levels for each range and the knowledge that similar conditions exist at the front of each range north of the Mount Burr Range may decrease the relative errors to a degree where they cancel out partially, and while not entirely negligible, are of minor importance.

(b) A second factor of great significance is the steady decrease northwestwards of differences in elevation between the fronts of many of the dunes. Thus whereas on a line approximately normal to the ranges and passing through the town of Naracoorte, the difference in height between the fronts of the East Naracoorte and Reedy Creek Ranges is approximately 110 feet, it is less than 50 feet near Salt Creek. Corresponding decreases are noted for the intermediate ranges. It is necessary therefore, when taking levels near the fronts of the ranges, to multiply the readings by an appropriate factor for each range in order to make the figures comparable with those taken at the extreme southern limit where such readings could be taken, namely the line inland from Cape Buffon at right angles to the average trend of the Ranges. The determination of this factor presents difficulties which have been discussed in (a).

(c) Another and important fact is the downward tilting of the greater part of the region in a west-north-westerly direction. This process, which appears to have continued for a very long time, and which will be dealt with more fully under Diastrophism, probably was episodic and may even have been reversed at times. If the latter did occur, then despite the use of correcting factors, figures even approximately accurate cannot be obtained.

(d) The possibility of isostatic adjustments to the alternating decreases and increases of load on the region must be considered. It is probable that such adjustments in the form of a rise of the region and to a decreasing extent of the adjacent submarine plain, occurred after the retreat of the sea from the Murravian Gulf. Whether such adjustments continued into the Pleistocene cannot be determined at present. There is, however, the effect of the removal by marine erosion of considerable thicknesses, increasing seaward, of the Tertiary sediments west of the East Naracoorte Range, first during the postulated Upper Pliocene stillstand and later during the retreats of the sea during the successive glaciations, to depths of several hundred dred feet below present sea-level. Responses to the lessening of the load over this part of the continental shelf by the removal of enormous masses of water, and later the increase of weight due to advances of the sea during interglacial periods, must be regarded as possibilities. As a result it is clear that the levels, even if an accurate determination were possible, would represent merely the differences in height between the bases of the dunes and not necessarily the differences in height of sea-level at the times of their formation. The latter would be greater or less than the recorded differences in elevation according to whether the land had sunk or risen during the interval.

Should the isostatic rise or fall of the land have corresponded even approximately in amount at any time with the rate of rise or fall of world sea-level, an apparent stillstand would have resulted and if its duration had been of sufficient length, an off-shore bar and possibly a dune would have been produced. Many variations of these factors are possible and the probability that such complications occurred, make the value of any levels obtained somewhat doubtful. Such isostatic responses to decrease and increase of load have still to be proved in this region. A study of the spacing and trends of the fronts and seaward edges of the dunes, suggests the possibility that upward movements may have taken place.

The opinion is held by the writer, as will be shown below, that in those localities which are in the vicinity of the postulated axis of tilting, the height of the preglacial shoreline is now approximately 240 feet above present sea-level. The estimated height of potential sea-level, that is sea-level on an ice-free earth, of approximately 160 feet, would suggest that this part of the South-East has risen approximately 80 feet since the beginning of Pleistocene Glaciation. In any event, whatever be the height of potential sea-level today, the difference between that figure and 240 feet would represent the net gain in elevation of the land relative to the sea, whether by elevation of the region as a whole, or by local uplift of the Mount Burr Range and adjacent terrain.

It could be argued that this difference, whatever it be, might represent a world-wide drop in potential sea-level, a supposition which would be an approach to Zeuner's contention that world sea-level has dropped continuously throughout the Pleistocene Age. The problem must be left unsolved at present.

In view of the above variable factors the determination, first of the differences in elevation of the foreshores of the dunes, and secondly of the actual heights above sea-level at which they were formed, seems impracticable. The writer has attempted it, however, and bearing in mind the possible sources of error has tried to minimize them, or where this could not be done to average them and apply corrections. The figures finally produced (Fig. 9 and Table) are intended to show the differences between the estimated height at which these foreshores were formed and the present heights above sea-level in those areas which have not been affected, as far as can be determined, by tilting. No allowance was made nor can be made for isostatic adjustments. With all their limitations, the figures supplied do give a general picture of the relative vertical positions of the fronts of the dune ranges and therefore of the basement on which they were formed.

The contention by Zeuner (1946) that there has been a world-wide and steady drop in sea-level since the commencement of glaciation and that the

TABLE I Showing postulated succession of shorelines, their estimated heights above present sea level and relation to the Glacial and Interglacial stages of the Pleistocene Epoch.

PRE-GLACIAL					
EAST NARACOORTE (1) (238′)		**SECOND INTERGLACIAL**			
HARPER'S (2) (176′)		WEST NARACOORTE (9) (198′)			
			THIRD INTERGLACIAL		
WOOLUMBOOL (3) (159′)			CAVE or STEWART'S (16) (167′)		
		PEACOCK (10) (150′)			
?		BAKER'S (11) (140′)	LUCINDALE (17) (136′)		
	FIRST INTERGLACIAL	ARDUNE (12) (126′)			
?		?	EAST AVENUE (18) (117′)		
	WEST AVENUE (6) (106′)	REEDY CREEK (13) (85′)			
NEVILLE (4) (58′)	? EAST DAIRY (7) (54′)				
?		WEST DAIRY (14) (51′)		BRIEF (50′-60′) Rise	
		WOAKWINE, C. (15) (48′)			
			WOAKWINE, D. (19) (45′)		
WOAKWINE, A. (5) (40′)					
	WOAKWINE, B (8) (40′)				
?	?	?	?	CANUNDA (20)	BRIEF (12′-15′) RISE PRESENT
?	?	?	?		
GÜNZ	MINDEL	RISS	WÜRM		

maximum heights of sea-level reached during each interglacial were progressively lower as a result, requires further proof and explanation of the causes underlying this gradual decrease and is opposed to the views widely held, that at least during the Second or Great Interglacial world sea-level reached or approached closely that existing at the beginning of glaciation.

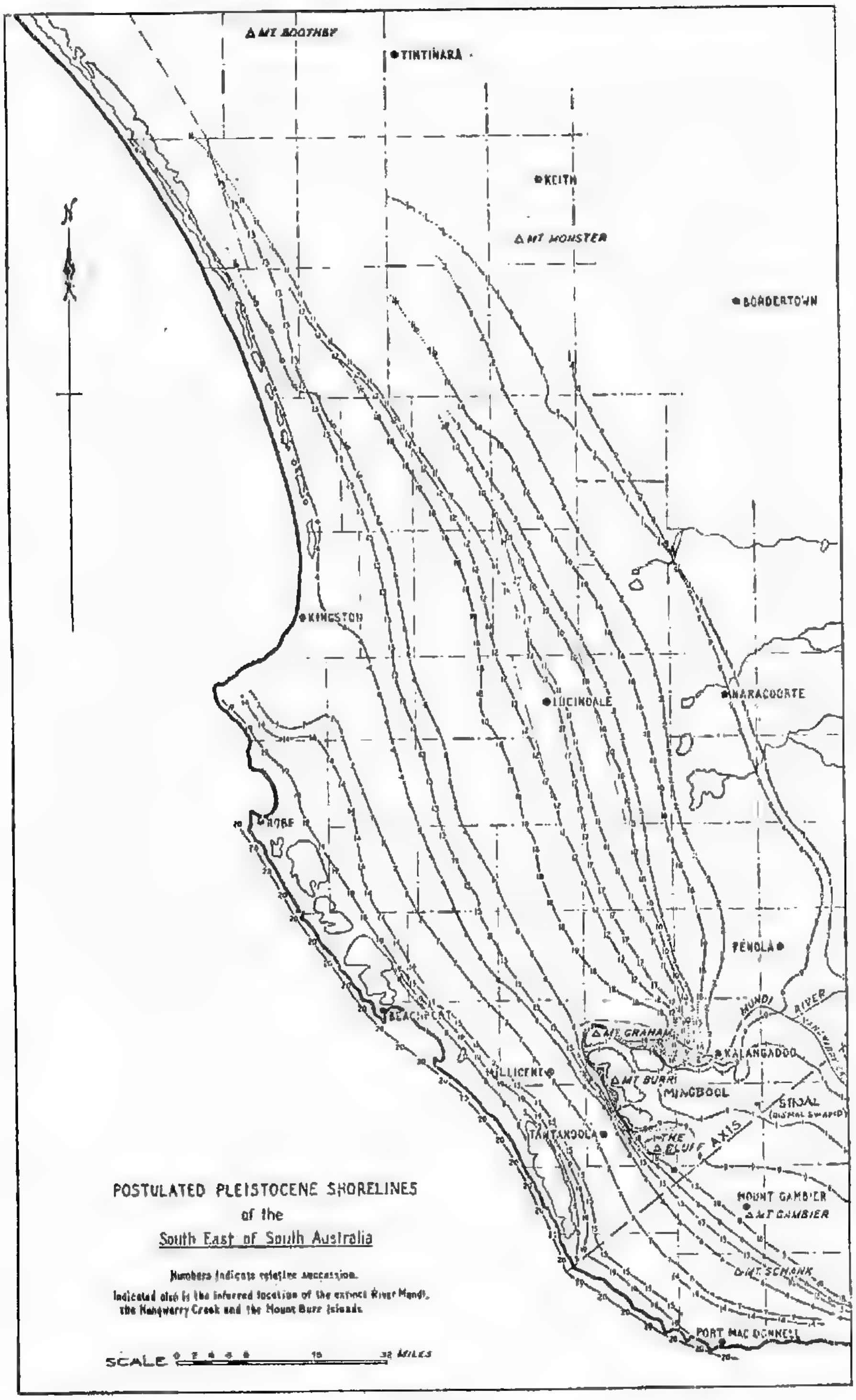


Fig. 10

This latter opinion is shared by the writer and has been used in the tentative determination of the dune ranges representing the height of the Second Interglacial. If the table and associated diagrams (Figs. 3, 9, 10) have any validity (the reasons for their construction have been given herein), then it would appear that the climate of the First Interglacial was somewhat milder than today and that it was considerably warmer during the height of the Third Interglacial. It would follow also that during the present Interglacial or as some would have it during the Fourth Glaciation, oscillations of temperature have occurred resulting in a relatively warm period in Sub-Recent times followed by more refrigeration, another period a litle warmer than today in Recent and possibly Historic time, and finally sufficient refrigeration to reduce sea-level to its present limits. On the other hand some of these later movements of sea-level may have had other causes than those of increases and decreases of glaciation. The larger and earlier of the above oscillations is believed to have been responsible for the advance of the sea to a height sufficient to form wave-cut terraces and marine shell deposits on the inland side of the Woakwine Range, sea-caves and blowholes on its western slopes and several gaps such as Narrow Neck. It is believed also to have augmented the widespread erosion, much of which probably had been produced earlier, of the dune ranges north of Kingston. The rise in sea-level is estimated by the writer to have affected those parts of the region which are at present between 50 and 60 feet above sea-level.

The retreat of the sea from that position was responsible for the formation of the Canunda Range which was partly eroded during the subsequent rise to the 12-15 feet level, and although sea-level has retreated since then to its present level, the former northern and southern extensions of this range remain submerged and the existing portions are being actively eroded by the sea.

The features of marine erosion testifying to the most recent retreat of the sea include wave-cut cliffs and platforms, sea-caves and shell deposits, and are widespread not only in South Australia but also in other parts of the continent.

One notable feature not discussed hitherto is the absence of all but minor occurrences of dune limestone in a broad area from Mount Graham, the most northerly part of the Mount Burr Range, eastwards of Kalangadoo and beyond. This absence is understandable if the prevailing wind which today is from a west-south-westerly direction was similarly oriented in the past during the Pleistocene Epoch. That this probably was the case is shown by the general trend and morphology of the ranges. Given a prevailing wind from the west-south-west, the protection afforded to the areas to the east by the Mount Burr Islands and Tombolos would prevent the formation of all except minor accumulations along the northern limits of the former shoal now known as the Dismal Swamp. This is being termed the Mingbool Shoal. This shoal is believed also to mark the southern limits of an estuary into which flowed several streams now forming part of the Glenelg River to the east in Victoria. The extensions of this estuary would have varied from time to time according to advances or retreats of the sea, and during periods of low sea-level are believed to have continued at least as far as the northern extremity of the present Mount Burr Range. The streams no doubt provided appreciable quantities of detrital material which assisted not only in the building up of the shoal and the tombolos of the Mount Burr area but supplied the material for the detrital quartz deposits on the slopes of the Mount Burr Range. The pronounced curvature of the dune ranges as they approach the position of this postulated estuary, is in accordance with the developments expected under such conditions.

An attempt has been made to reconstruct the shorelines as indicated by the various dune ranges (Fig. 10). Such a reconstruction is subject to the limitations discussed earlier and must be regarded as an approximation only. It is also recognized that there is some uncertainty in the region between Mount Gambier and the southern limits of the Dismal Swamp, and the reconstruction in that sector is based chiefly on the basement levels and such allowance as could be made for subsequent planation during periods of marine transgression.

The shorelines finally produced suggest an estuary or at least a bay with its head near the Victorian border. The very gentle slopes and numerous swamps from there to the Glenelg River support the view that the present river has captured the streams formerly discharging into the estuary in South Australia. At what period these captures occurred cannot be determined at present. The writer believes however, that the history of this river as constructed by Fenner (1918) must be modified considerably and that there is a possibility that much of the capture of the headwaters of the present river, if it took place, was accomplished by the streams which have been named the River Mundi and Nangwarry Creek, which discharged into the estuary in South Australia.

DIASTROPHISM

Despite the high probability that all or nearly all of the dune ranges represent eustatic shorelines due to successive glaciations and deglaciations during the Pleistocene Epoch, and were not in general produced by a "hesitating advance of the land" (Ward 1941), there is definite evidence that extensive movements of the land have taken place and adjustments apparently are still continuing. The earthquake off the coast of the region in 1897, and a similar disturbance in 1948, indicate that stability has not been reached. The formation is recorded, by an officer of the South-Eastern Drainage Board, of the Earthquake Springs in the Hundred of Conmurra, apparently as a result of the 1897 earthquake. The additional supply of water furnished by these newly-developed springs required the excavation of a special drain which was named the Earthquake Springs Drain. The chief evidence submitted by the writer is the steady and persistent north-westerly drop in elevation of the seaward edges of the dune ranges from the vicinity of a zone which bears inland from Cape Banks in a direction approximately normal to the present coastline. The various possibilities of error notwithstanding, it must be conceded that in following the seaward edge of a dune range marking approximately a former shoreline, though there may be upward and downward variations in level of quite appreciable magnitude, there will not be a steady and persistent decrease in the one direction as exhibited by every range, reaching in the case of the East Naracoorte a maximum of more than 150 feet within the area examined. It is obvious that depression at the northern end or elevation in the south with a resultant downward tilt to the north-west, must have been responsible.

The closer spacing of many of the ranges together with the progressive decrease in difference of elevation of their seaward edges as they are traced north-westwards, is further proof of such tilting. An examination of the contours of the zone to the north-east of Cape Banks suggests that this was relatively stable, and it is assumed therefore that depression of the north-western end is the probable explanation. Such movements would link up with the known warping and faulting of the Mount Lofty Ranges and adjacent areas during the Pleistocene Epoch. It is the writer's opinion that the region adjacent to Mount Burr, possibly because of reinforcement by basaltic intrusions, probably remained unmoved while the whole area from there to the north-west was tilted downwards. This view does not, however, deny the possibility of small vertical uplift of the Mount Burr terrain independently of the regional warping. A similar but steeper downward movement in a southerly direction of the area between Mount Burr and Port Macdonnell is suggested by the gradual drop in elevation in that direction of the fronts of the dune ranges. It has not been possible to investigate this feature in the southern part of the region in detail because survey levels are too few and because the time available for such research was insufficient.

The downward tilting to the west-north-west obviously affected not only the differences in elevation of the successive foreshores, but also their horizontal distances from each other. It must be emphasized here that the postulated isostatic movements, both positive and negative, were relatively small and the total west-north-westerly downwarp was effective in producing only a very low gradient, the resultants being less than one foot per mile to the north-north-west, and from 2-3 feet per mile to the westwward. The postulated transverse buckling with north-easterly axes is believed to have been smaller still, and even some of the eustatic variations of sea-level were small. Nevertheless, a comparatively uniformly sloping plain as measurements indicate it is even today, will provide accurate and delicate evidence of any changes in level of the land relative to the sea, or of distortions experienced between the times of formation of two successive shorelines.

In sectors where the slope is uniform, downward tilting towards the west-north-west would cause the new shoreline to approach the older shoreline progressively to the north-west and eventually to intersect it as some of the dune ranges appear to do. In the area adjacent to the axis, where little or no movement had taken place, the true spacing and differences in height would be preserved. These converging dunes are a feature of the region. Beyond their junction the two dune ranges would appear as one and on the surface could not be separated. Cuttings at selected localities could, if they were made, enable such a separation. Such cuttings may become more plentiful, it is to be hoped, in places where the information is needed.

Still further to the north-west, the new shoreline would continue to fringe the older dune until a point was reached where the sea could break through the barrier or submerge it. As a result the sea would occupy a shallow bay with a long narrow peninsula, the old dune forming a protecting ridge for the southern part of the bay. The southernmost part of the new shoreline would not be likely to develop a dune, or if dune building occurred it would be of small, irregular accumulations only for some distance to the northward, until a point was reached where wave and wind action were sufficiently unrestricted to enable regular dune-building to begin. An examination of the region shows that such irregularities and eventual regularity of dunes on the eastern side of a compound dune produced by convergence, occur in several instances. They are believed therefore to have been formed as described above.

Should tilting movements cease after the formation of a shoreline, then the following shorelines would preserve, on a uniformly sloping plain, approximately constant distances, both horizontal and vertical. An examination of the region, however, shows that nearly all of the ranges record changes in horizontal or vertical spacing or both. A few ranges diverge as they are traced, towards the north-west and this could indicate a temporary reversal of the downward tilting movement. The convergence of some and divergence of other ranges as they are traced towards the north-west, suggests the intervention of warping movements. These are believed, as stated earlier, to have consisted not only of the downward tilt of the northern and southern sectors, but also of transverse warping and variations in local isostatic adjustment. The last two could have nullified or reversed locally the effects of progressive downward tilting.

In the northern sector, reliable levels are too few in number for any determinations to be made of such movements or their effects.

While it could be argued that the downward tilting movement, which apparently commenced during Upper Pliocene times and continued throughout the Pleistocene Epoch but probably episodically, may have been reversed at times, there are, as stated above, other factors to be considered. The progressive tilting of the region towards the west-north-west would result in increasingly large areas being inundated by rises of sea-level even if of minor amounts. Such increased tendency to drowning of the north-western sector would increase the load borne by the block during inundations by the sea, and might result in isostatic adjustment by depressing the area, and corresponding elevation after the sea retreated. Such isostatic adjustments could in that event be more intense than in the areas further south in which rises or falls of sea-level would not affect such wide areas nor inundate them to the same relative depths. Further, it is by no means certain that the axis of tilting was located always in the zone to the north-east of Cape Banks. Though no doubt predominantly in this zone, there are indications that an axis or transverse warp may have been located in a zone from Rendelsham to the north-east and similar features may have existed even further to the north.

As referred to earlier and summarized here, it is possible that isostatic response to release of the load when the Murravian Gulf was drained, occurred during the Upper Pliocene and possibly later. The Naracoorte Fault, if its existence is confirmed, may have been formed during and as the result of such uplift. Further, the reduction by marine planation of the level of the area still submerged, such planation extending at the height of the glaciations far beyond the present coastline, could have resulted in elevation of the region. It would appear that the East Naracoorte foreshore, which is estimated to have been formed at approximately 240 feet above present sea-level, has been elevated since its formation by the amount represented by the difference between 240 feet and potential sea-level at the time. However, such elevation, if proved, may have been produced by other causes.

As stated in an earlier section, there is evidence that the Miocene sediments of the southern part of the region have been folded to a small extent. Whether such folding movements did produce, over a long distance, elevations of the order referred to earlier is beyond the scope of the present investigation. The age of the folding was not studied by the writer but it is hoped that the work being done in the region by the State Geological Survey will furnish the desired information.

HUMAN OCCUPATION

The legends quoted earlier which refer to Mounts Muirhead, Gambier, and Schank may or may not indicate that these eruptions were witnessed by human beings. Another legend stating that the land formerly extended to the south far beyond the present southern coastline at Port MacDonnell and referring to an advance of the sea over this area, an event which is believed to have occurred during the partial deglaciation since the height of Würm Glaciation, may be merely a legend and have no foundation in actual knowledge of this event by the earlier natives. There is, however, another feature which may point to the existence of the natives for a considerable period. At numerous localities, chiefly in the Woakwine Ranges, but also in the Reedy Creek Range, weathering of the cemented dune limestones has etched in sharp relief the existence of numerous stones and boulders of cemented dune limestone embedded in the aeolian material of the dune, which is also a cemented dune limestone. Only the sensitive effects of slow subaerial weathering could have emphasised the slight difference in cementation of the boulders and the latter cemented matrix sufficiently to permit of their visual recognition. The occurrence of boulders on a dune is itself an anomaly and suggests transportation by living beings. Their concentration in limited areas is further evidence of such planned accumulation. Of special interest, however, is the occurrence at intervals amongst these former boulders of stones which are blackened by smoke or fire (Campbell 1946). The presence of free carbon was established in those examined. Similar material is recorded from The Bluff south-east of Geelong (Coulson, 1935). These blackened stones occur in diverse methods of aggregation. In some places they lie close together forming roughly circular areas, in others they occur as if scattered from a common centre, the latter occurrence showing a decrease in size and increase in number of stones away from the apparent centre. These accumulations of blackened stones are in appearance and in plan indistinguishable from similar aggregates which are known to have been used as hearths by the natives on recent camp sites. These, too, occur both as close aggregates and widely scattered fragments, the amount of scattering being apparently a function both of time and insolation. While not regarded as absolute proof, these blackened stones, as well as those which have not been charred, are at least an indication that natives lived on these dune ranges while they were in process of formation, especially as all the known occurrences are not at the surface, but some occur beneath the present surface within the dune itself. If the natives were responsible for the collection and use of these stones, and if the date of formation of the Reedy Creek Range is upheld by further investigation, then the natives lived in this region at least as early as the initial stages of the Riss Glaciation.

THE PRESENT COASTLINE

As indicated earlier, the coastline presents varied features, being apparently one of submergence between Capes Jaffa and Northumberland, and one of emergence north of Cape Jaffa and east of Cape Northumberland. Further, the sea has broken through into the Canunda - West Woakwine interdune flat at Guichen and Rivoli Bays and to the south of Cape Banks. This interdune flat which probably represents an ancient Coorong, now contains Lakes Eliza and St. Clair which are salt and below sea-level, Lakes George, Canunda and Frome all salt originally but the two latter drained almost completely by artificial means, Lake Bonney which is fresh and the above two bays which represent no doubt the sites of former lakes.

Beyond Cape Jaffa and Cape Northumberland the sea has entered the wide flats separating the Dairy and Woakwine from the Neville and Reedy Creek Ranges.

It is in the last two sections from Cape Jaffa northwards and from Cape Northumberland eastwards that the coastline appears to be one of emergence. The writer's views are that the present coastline in addition to the recent rises and falls of the sea-level, owes its configuration to the continued tilting both to the north-west and south-east along an axis which extended inland from Cape Banks in a direction approximately normal to the present coastline. It is obvious that this would submerge in a north-westerly direction a succession of interdune flats and in a south-easterly direction the easterly sector of the south coast. The advance of the sea over the wide interdune flat north of Cape Jaffa and its very gentle slopes would produce the same effect as would an emerging coastline with its gently sloping marine plain and would in fact be indistinguishable. The Sub-Recent submergence due to world rise in sea-level is therefore the dominant feature of the section from Cape Buffon to Cape Banks, but loses this dominance and becomes more and more subordinate to the tilting effects as the coastline is followed north and southwards away from this section.

It is this tilting which is believed to have been responsible for the depressed area in which Lakes Alexandrina, Albert and associated lakes and swamps occur, and the prime factor which produced the sudden turn to the west of the River Murray towards Mannum and the Mount Lofty Horst, and its subsequent course southwards in close proximity to that elevated region.

CHRONOLOGICAL TABLE

LOWER PLIOCENE

Draining of Murravian Gulf as far as the East Naracoorte shoreline.

LOWER PLIOCENE TO EARLY UPPER PLIOCENE

Erosion of Lower Pliocene and upper members of Miocene sediments by marine planation. Possible rise of land and adjacent sea floor due to isostatic adjustment.

EARLY UPPER PLIOCENE

Volcanic eruptions in Mount Burr area. Formation of tied islands and tombolos.

UPPER PLIOCENE

Protection from further marked marine erosion of Dismal Swamp area. Formation of Mingbool Shoal. Discharge of streams from Victoria and formation of estuary north of Mingbool Shoal. Partial protection from marine erosion of Miocene sediments in the Mount Burr area. Further erosion of Miocene sediments in remainder of region assisted probably by further elevation of sea floor. Downward tilting probably commenced.

PLEISTOCENE

Beginning of Glaciation. Gradual lowering of sea-level and formation of stranded dunes—Harper's, Woolumbool, Neville and probably Woawine A. Probably other dunes, since removed completely by erosion.

GÜNZ GLACIATION

Tilting downwards to the west-north-west and to the south-east continued. Probable uplift of land due to lowering by erosion of basement by retreating shallowing sea and removal of sea itself. Extension of river estuary to the west of Mount Graham over the emerging coastal plain.

FIRST INTERGLACIAL

Rise of sea-level to West Avenue shoreline, cutting of notch in the basement at approximately 130 feet below pre-glacial level. Climate milder than today. Isostatic adjustments probably small.

MINDEL GLACIATION

Gradual lowering of sea-level and formation of stranded dunes, West Avenue, East Dairy and Woakwine B. Probably slight rises of land.

SECOND OR GREAT INTERGLACIAL

Rise of sea-level to West Naracoorte shoreline. Cutting of notch in the basement at approximately 40 feet below pre-glacial level. Climate much warmer than today. Intersection to the north of Naracoorte of the East and West Naracoorte shorelines and establishment further north of the West

Naracoorte as a new shoreline to the east of the older, preglacial, East Naracoorte shoreline. Isostatic depression of land probably appreciable. Forty feet may represent net gain in elevation of land due to removal of Murravian sediments and resulting isostatic adjustment.

RISS GLACIATION

Gradual lowering of sea-level and formation of stranded dunes, West Naracoorte, Peacock, Baker's, Ardune, Reedy Creek, West Dairy and Woakwine C. Probably appreciable rise of land. Further tilting down to west-north-west and south-east. Mount Muirhead may have erupted during the later stages. Human occupation of the region may have begun.

THIRD INTERGLACIAL

Rise of sea-level to Cave shoreline. Cutting of notch in the basement at approximately 70 feet below pre-glacial level. Climate warmer than today. Probable depression of land appreciable. Owing to continued tilt down to the west-north-west, greater inundation of that area, and possibly greater local depression of land in that sector.

WÜRM GLACIATION

Gradual lowering of sea-level and formation of stranded dunes, Cave, Lucindale, East Avenue and Woakwine D. Mounts Gambier and Schank probably erupted after the climate became warmer.

FOURTH INTERGLACIAL OR OSCILLATIONS IN WÜRM GLACIATION

Rise of sea-level to reach features about 50 feet above present sea-level. Climate milder than today. Sea retreated and left Canunda Range as a stranded dune. Sea retreated further for an unknown distance. Sea-level rose again to 12-15 feet above present sea-level. Climate a little milder than today. Sea-level fell to present position. Tilting down to west-north-west and south-east continued and resulted in encroachment by the sea on the flats between the Dairy and Neville and Reedy Creek Ranges north of Cape Jaffa and east of Cape Northumberland. Formation of Rivoli and Guichen Bays. Building of offshore bar and formation of present Coorong. Erosion of non-submerged parts of Canunda Range along present coastline between Capes Jaffa and Northumberland. Erosion of Miocene limestones between Cape Banks and the Victorian border, setting free numbers of flints and forming the extensive beach deposits of this mineral today.

REFERENCES AND BIBLIOGRAPHY

ANDREWS, E. C. 1916. Shoreline Studies at Botany Bay. Journ. Proc. Roy. Soc. N.S.W., **50**, 165-176

ANDREWS, E. C. 1916. Further Notes on the Shoreline Topography of Botany Bay. *Ibid.*, XXXVII-XL

ANTEVS, E. 1928 The Last Glaciation. Amer. Geogr. Soc. Res. Ser., New York, 17, 292 pp.

ANTEVS, E. 1930 Stand of Sea Level at the Climax of the Last Glaciation. Geogr. Rev., **20**, 339

AUROUSSEAU, M. and BUDGE, E. A. 1920. The Terraces of the Swan and Helena Rivers and their bearing on Recent Displacement of the Strand Line. Journ. Roy. Soc. W. Aust., 7, 24-39

BARTRUM, J. A. 1926. Abnormal Shore Platforms. Journ. Geol. **34**, No. 8

BARTRUM, J. A. 1938. Shore Platforms. Journ. Geomorphology, 1

BEASLEY, A. W. 1948. Heavy Mineral Beach Sands of Southern Queensland, Part II. Proc. Roy. Soc. Qld., **59**, Pt. II

BLANC, A. C. 1937 Low Levels of the Mediterranean Sea during the Pleistocene Glaciation. Q.J.G.S., London, **93**

BROUGHTON, A. C. 1921. Notes on the Geology of the Moorlands (South Australia) Brown Coal Deposits. Trans. Roy. Soc. S. Aust., **45**

BROWNE, W. R. 1945. Proc. Linn. Soc. N.S.W., **70**, Pres. Address

BUDDINGTON, A. F. 1927. Abandoned Marine Beaches in South Eastern Alaska. Amer. Journ. Sci., **13**

CAMPBELL, T. D., CLELAND, J. B. and HOSSFELD, P. S. 1946. Aborigines of the Lower South-East of South Australia. Rec. S. Aust. Mus. **8**, No. 3

CHAPMAN, F. 1928. Rec. Geol. Surv. Vict., **5**

CLARKE, E. V. 1928. A recent Raised Beach near Port Turton, Yorke Peninsula. Trans. Roy. Soc. S. Aust., **52**

COLEMAN, A. P. 1926. Ice Ages, recent and ancient. London, 296 pp.

COLEMAN, A. P. 1941. The Last Million Years, a history of the Pleistocene in North America. Toronto, 216 pp.

COOKE, C. W. 1930. Correlation of Coastal Terraces. Journ. Geol. Chicago, **38**, No. 7

COTTON, C. A. 1942. Geomorphology, 3rd Ed., Whitcombe and Tombs, London.

COTTON, L. A. 1926. Pleistocene and Post-Pleistocene Movements of the Strand in Australia. Proc. 3rd Pan-Pacific Congr., Tokyo, 1777, 1778

COTTON, L. A. 1946. Pulse of the Pacific. Journ. and Proc. Roy Soc. N.S.W., **80**

COULSON, A. 1935. Geol. Notes on Lake Connewarre, near Geelong. Proc. Roy. Soc. Vict., **48** (N.S.) Pt. I

COULSON, A. 1940. The Sand Dunes of the Portland District and their relation to Post-Pliocene Uplift. Proc. Roy. Soc. Vict., **52**, (N.S.), Pt. II

COULSON, A. 1941 The Volcanoes of the Portland District, Proc. Roy. Soc. Vict., **53**, (N.S.) Pt. II

CRESPIN, I. 1943. The Stratigraphy of the Tertiary Marine Rocks in Gippsland, Victoria. Comm. Aust., Min. Res. Surv. Pal. Bul. No. 4

CROCKER, R. L. 1941. Notes on the Geology and Physiography of South East South Australia with Reference to late Climatic History. Trans. Roy. Soc. S. Aust., **65**, 1

CROCKER, R. L. and COTTON, B. C. 1946a. Some Raised Beaches of the Lower South-East of South Australia and their significance. Trans. Roy. Soc. S. Aust., **70**, 1

CROCKER, R. L. 1946b. Notes on a Recent Raised Beach at Point Brown, Yorke Peninsula, South Australia. Trans. Roy. Soc. S. Aust., **70**, 1

CROCKER, R. L. 1946c. Post Miocene Climatic and Geologic History and its Significance in Relation to the Genesis of the Major Soil Types of South Australia. Coun. Sci. Ind. Res. (Aust.) Bull. 193

DALY, R. A. 1925. Pleistocene Changes in Sea Level. Amer. Journ. Sci., **10**

DALY, R. A. 1929. Swinging Sea Level of the Ice Age. Geol. Soc. Amer. Bull. 40

DALY, R. A. 1934. The Changing World of the Ice Age. Yale University Press

DAVID, T. W. E. 1932. Explanatory notes to accompany a New Geological Map of the Commonwealth of Australia. Sydney: Commonwealth Coun. Sci. Ind. Res. (Aust.)

FAIRBRIDGE, R. W., and GILL, E. D. 1947. The Study of Eustatic Changes of Sea Level. Aust. Journ. Sci., **10**, 3

FENNER, C. 1918. The Physiography of the Glenelg River. Proc. Roy. Soc. Vict., **30** (N.S.) Pt.2

FENNER, C. 1921. The Craters and Lakes of Mt. Gambier, South Australia. Trans. Roy. Soc. S. Aust., **45**

FENNER, C. 1930. The Major Structural and Physiographic Features of South Australia. Trans. Roy. Soc. S. Aust., **54**, 1

GILL, E. D. 1947a. Ecklin Hill — a Volcano in the Western District of Victoria. Vict. Naturalist, **64**

GILL, E. D. 1947b. Some Features of the Coastline between Port Fairy and Peterborough, Victoria. Proc. Roy. Soc. Vict., **58** (N.S.) Pts. 1 and 2

GILL, E. D. 1948. Geology of the Point Lonsdale-Queenscliff area, Victoria. Vict. Naturalist, **65**

HILLS, E. S. 1934. Some Fundamental Concepts in Victorian Physiography. Proc. Roy. Soc. Vict., **47** (N.S.) Pt. 1

HILLS, E. S. 1939a. The Age and Physiographic Relationships of the Cainozoic Volcanic Rocks of Victoria. *Ibid.*, **51** (N.S.) Pt. 1

HILLS, E. S. 1939b. The Physiography of North-Western Victoria. *Ibid*, **51**, (N.S.), Pt. 2

HILLS, E. S. 1940a. The Question of Recent Emergence of the Shores of Port Philip Bay. *Ibid.*, **52** (N.S.) Pt. 1

HILLS, E. S. 1940b. The Lunette, a new land Form of Aeolian Origin. The Aust. Geographer, **3**, 7

HILLS, E. S. 1940c. The Physiography of Victoria. pp. 292. Whitcombe & Tombs (Melbourne and Sydney)

HILLS, E. S. 1949. Shore Platforms. Geol. Mag., **86**, 3

HOWCHIN, W. 1912. Notes on Recurrent Transgressions of the Sea at Dry Creek. Trans. Roy. Soc. S. Aust., **36**

HOWCHIN, W. 1929. Notes on the Geology of the Great Pyap Bend (Loxton), River Murray Basin and Remarks on the Geological History of the River Murray. *Ibid.*, **53**

HOWCHIN, W. 1930. The Building of Australia and the Succession of Life, with Special Reference to South Australia. Govt. Printer, Adelaide, Brit. Sci. Guild, S. Aust. Handbook

JACK, R. L. 1921. The Salt and Gypsum Resources of South Australia. Mines Dept. S. Aust. Bull. 3

JACK, R. L. 1923. The Building Stones of South Australia, Mines Dept. S. Aust. Bull. 8

JOHNSON, S. W. 1928. The Physiography of the North Atlantic Coast of North America. Internat. Geogr. Congress, Cambridge

JOHNSON, S. W. 1938. Shore Processes and Shoreline Development. New York

JUTSON, J. T. 1914. An Outline of the Physiographical Geology of Western Australia. Geol. Surv. W. Aust. Bull 61

JUTSON, J. T. 1934. The Physiography of Western Australia. Geol. Surv. W. Aust. Bull. 95

JUTSON, J. T. 1939. Shore Platforms near Sydney, N.S.W. Journ. Geomorph., **2**

JUTSON, J. T. 1940. The Shore Platforms of Mt. Martha, Port Philip Bay, Victoria, Australia. Proc. Roy. Soc. Vict., **52** (N.S.) I

KEBLE, R. A. 1947. Notes on Australian Quaternary Climates and Migration. Mem. Nat. Mus. Melbourne, **15**

LEWIS, A. N. 1934. A Correlation of the Tasmanian Pleistocene Glacial Epochs and Deposits. Pap. and Proc. Roy. Soc. Tas.

LEWIS, A. N. 1935. Correlation of the Tasmanian Pleistocene Raised Beaches and River Terraces in Unglaciated Areas. *Ibid.*

LEWIS, A. N. 1945. Pleistocene Glaciation in Tasmania. *Ibid.*

MAWSON, D. and CHAPMAN, F. 1922. The Tertiary Brown-Coal Bearing Beds of Moorlands. Trans. Roy. Soc. S. Aust., **46**

MAWSON, D. 1929. South Australian Algal Limestones in Process of Formation. Q.J.G.S., **85**

MAWSON, D. 1938. Further Discoveries of Sapropelic Deposits in the Coorong Region of South Australia. Oil Shale and Cannel Coal.

MAWSON, D. and PARKIN, L. W. (1943). Some Granitic Rocks of South-Eastern South Australia. Trans. Roy. Soc. S. Aust., **67**, 2

MAWSON, D. and DALLWITZ, W. B. 1944. Palaeozoic Igneous Rocks of Lower South-Eastern South Australia, *Ibid.*, **68**, 2

MAWSON, D. and SEGNIT, E. R. 1945a. Granites of the Tintinara District. *Ibid.*, **69**, 2

MAWSON, D. and SEGNIT, E. R. 1945b. Porphyritic Potash-Soda Microgranites of Mt. Monster. *Ibid.*

MAZE, W. H. 1945. Evidence of an Eustatic Strandline movement of 100 to 150 feet on the Coast of New South Wales, Proc. Linn. Soc. N.S.W., **70**, 1-2

MINES DEPARTMENT OF S. AUST. Min. Reviews, 24, 25, 43, 45, 53, 54 and 73.

MITCHELL, S. R. 1943. Geology and Ethnology of the Kongorong Hills, South Australia. Vict. Naturalist, **60**, 4

PENK, A. 1933. Eustatische Bewegungen des Meeresspiegels während der Eiszeit. Geogr. Zeitschrift

PRICE, A. 1939. Offshore Bars and Eustatic Changes of Sea Level. A Reply. Journ. Geomorphology, **2**, 4

RICHARDS, H. C. 1940. Recent Sea-Level Changes in Eastern Australia. Proc. Sixth Pac. Sci. Cong., California

SINGLETON, F. A. 1941. The Tertiary Geology of Australia. Proc. Roy. Soc. Vict., **63** (N.S.) Pt. 1

SMITH, MRS. JAMES, 1880. The Booandik Tribe of South Australian Aborigines: Adelaide

STEPHENS, C. G. et. al. 1941. A Soil and Land Use Survey of the Hundreds of Riddoch, Hindmarsh, Grey, Young and Nangwarry, County Grey, South Australia. Coun. Sci. Ind. Res. (Aust.) Bull. 142

STEPHENS, C. G. and CROCKER, R. L. 1946. Composition and Genesis of Lunettes. Trans. Roy Soc. S. Aust., **70**, 2

TAYLOR, J. K. 1933. A Soil Survey of the Hundreds of Laffer and Willalooka, South Australia. Coun. Sci. Ind. Res. (Aust.) Bull. 76

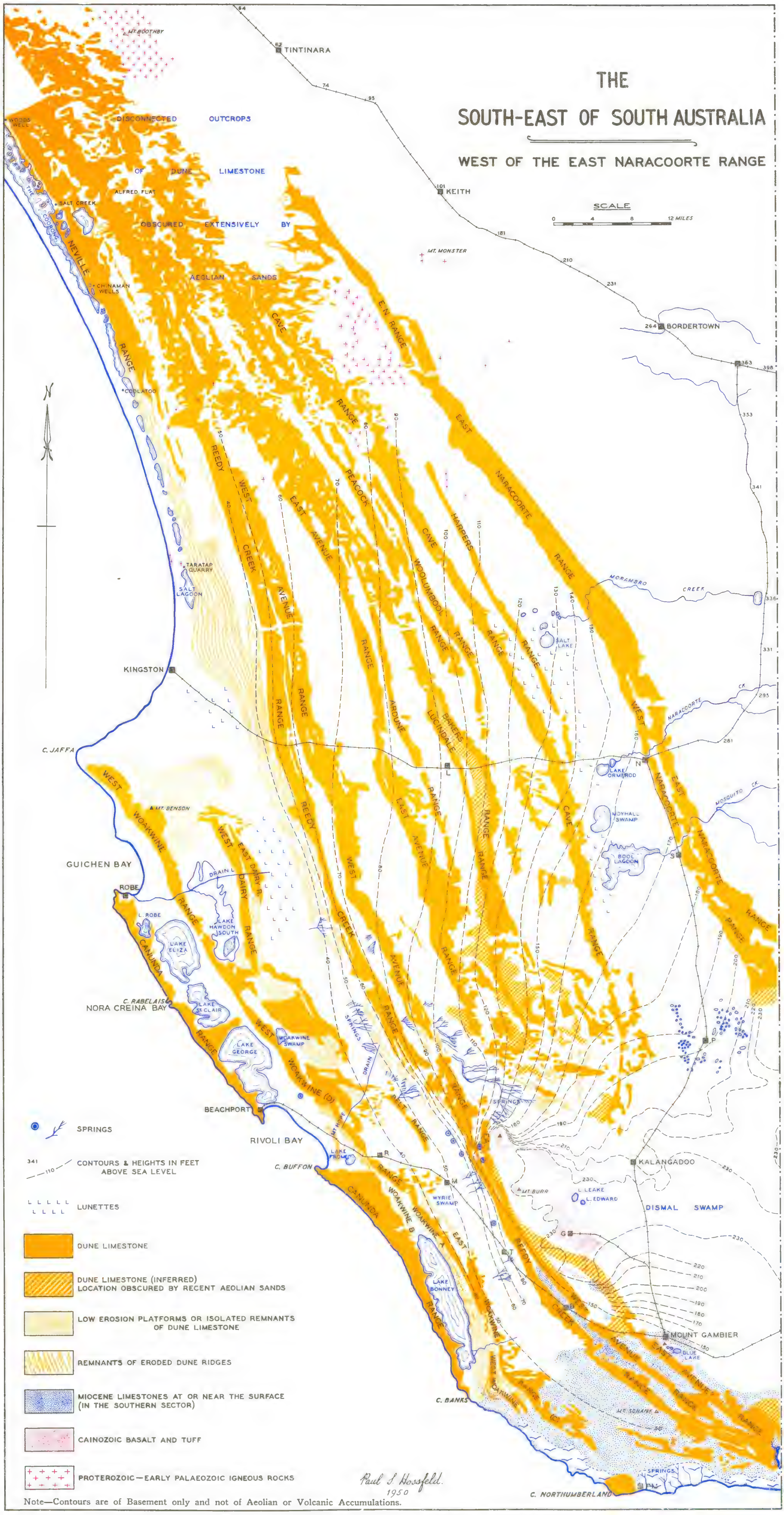
TINDALE, N. B. 1933. Tantanoola Caves, South-East of South Australia: Geological and Physiographic notes. Trans. Roy. Soc. S. Aust., **57**

TINDALE, N. B. 1947. Subdivision of Pleistocene Time in South Australia. Rec. S. Aust. Mus.

UMBGROVE, J. H. F. 1947. The Pulse of the Earth. Martinus Nijhoff, The Hague

WADE, A. 1915. The Supposed Oil-Bearing Areas of South Australia. Mines Dept S. Aust., Bull. 4

WARD, L. K. 1941. The Underground Water of the South-Eastern Part of South Australia. Mines Dept. S. Aust., Bull. 19



THE
SOUTH-EAST OF SOUTH AUSTRALIA
WEST OF THE EAST NARACOORTE RANGE
SCALE
0 4 8 12 MILES
DISCONNECTED OUTCROPS OF DUNE LIMESTONE OBSCURED EXTENSIVELY BY AEOLIAN SANDS
SPRINGS
CONTOURS & HEIGHTS IN FEET ABOVE SEA LEVEL
LUNETTES
DUNE LIMESTONE
DUNE LIMESTONE (INFERRED) LOCATION OBSCURED BY RECENT AEOLIAN SANDS
LOW EROSION PLATFORMS OR ISOLATED REMNANTS OF DUNE LIMESTONE
REMNANTS OF ERODED DUNE RIDGES
MIOCENE LIMESTONES AT OR NEAR THE SURFACE (IN THE SOUTHERN SECTOR)
CAINOZOIC BASALT AND TUFF
PROTEROZOIC—EARLY PALAEOZOIC IGNEOUS ROCKS
Paul S. Hossfeld
1950
Note—Contours are of Basement only and not of Aeolian or Volcanic Accumulations.
TINTINARA
KEITH
BORDERTOWN
KINGSTON
GUICHEN BAY
ROBE
NORA CREINA BAY
BEACHPORT
RIVOLI BAY
KALANGADOO
DISMAL SWAMP
MOUNT GAMBIER
C. JAFFA
C. BUFFON
C. BANKS
C. NORTHUMBERLAND

Ward, L. K. 1944. The Search for Oil in South Australia. Mines Dept. S. Aust., Bull. 22

Ward, L. K. 1946. The Occurrence, Composition, Testing and Utilisation of Underground Water in South Australia, and the Search for further supplies. Mines Dept. S. Aust., Bull. 23

Woods, Rev, J. F. 1862. Geological observations in South Australia: principally in the district South-East of Adelaide. Longman & Co., London

Zeuner, F. E. 1945. The Pleistocene Period. Its climate, chronology and faunal succession. Ray. Society, London

Zeuner, F. E. 1946. Dating the Past. An Introduction to Geochronology. Methuen & Co., London

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WORORA KINSHIPS

BY J. R. B. LOVE

Summary

I have taken Professor Elkin's table of the Ungarinyin kinship, and have transferred it to the Worora, which tribe has the same social organisation as Ungarinyin (or Ngarinjin). I have extended the table to bring in all the terms, and also to show how the terms reappear in alternate generations.

WORORA KINSHIPS

By J. R. B. Love

[Communicated by H. K. Fry]

Read 13th July, 1950.

I have taken Professor Elkin's table of the Ungarinyin kinship, and have transferred it to the Worora, which tribe has the same social organisation as Ungarinyin (or Ngarinjin). I have extended the table to bring in all the terms, and also to show how the terms reappear in alternate generations.

There are two peculiarities of Worora and Ngarinjin, namely,

(1) All the men of a wife's horde are known by the same term, Waia in Worora.

(2) A man may, and among the older men often has done so, marry another man's sister and his daughter.

You say "children of irregular marriages take the class determined by that of the mother, not of the father." Not in Worora, in which the mother is always of the opposite moiety from the child. No doubt all your references to the patrilineal area of North-Western Australia refer to the tribes further South from here, as these Kimberley tribes have no sections but named moieties, e.g., marriage with sister's son's daughter is prohibited in Worora, she being kulanja, which is primarily sister's husband's sister, a forbidden wife; so all Kulanja are forbidden.

I do not know any meaning for the moiety names; they are just the names of moieties.

The horde names are territorial. At least one horde name is animal; and that again is territorial, being the name of a district around a hill which is a mythical rat's nest, so that the district is called "rat" and the men of the horde "rat-men."

[A kinship terminology, published later in the paper "Worora Kinship Gestures" cited below, was included here.]

The forbidden relationship is called rambadba.

The forbidden pairs are (reciprocally),

(1) wolbaia and kurumanja, also wolbaiinja and kurumanja, also wolbaia and kurum; but not wolbaiinja and kurum.

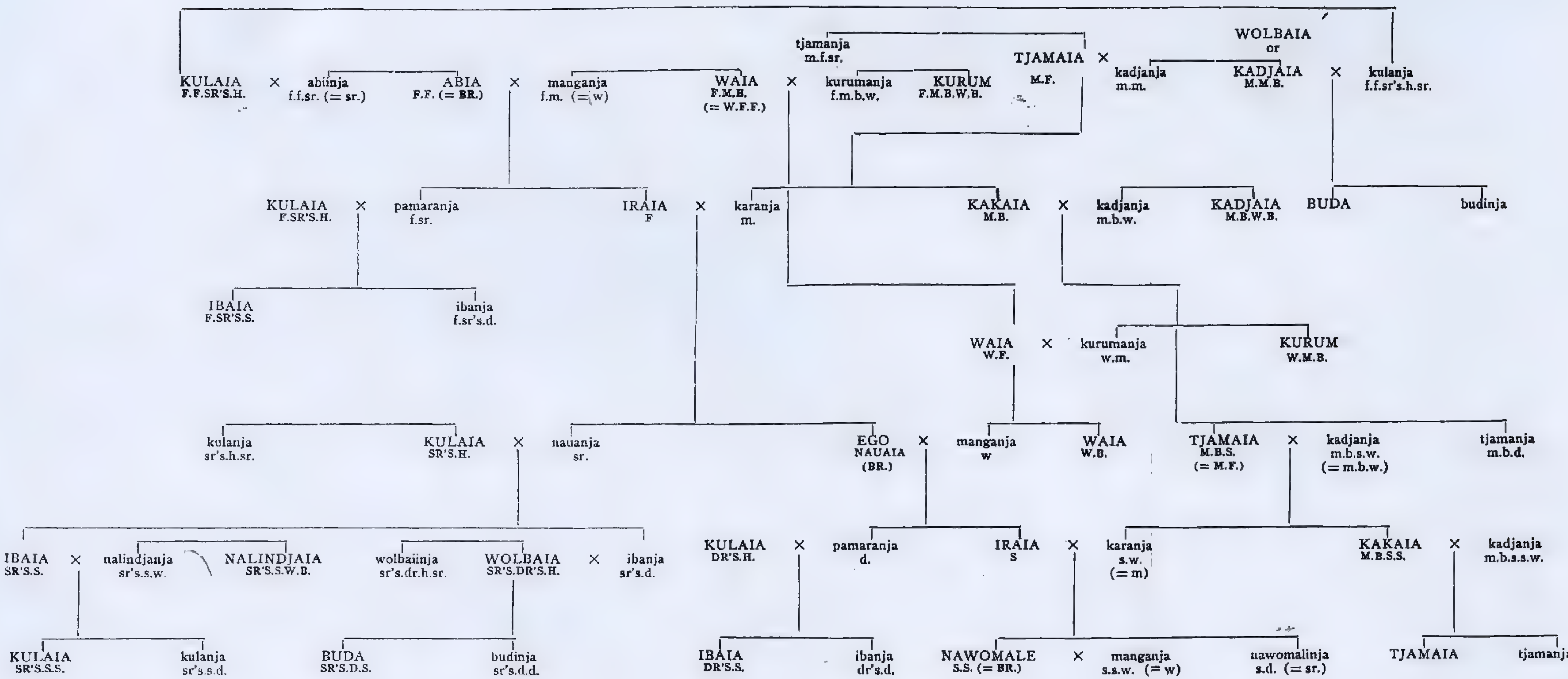
i.e, man and his mother-in-law, woman and her brother's mother-in-law, man and his mother-in-law's brother: but not woman and the brother of her brother's mother-in-law.

(2) buda and kadjanja, but not buda and kadjaia, nor budinja and either kadjanja or kadjaia.

These are, man and his mother's brother's wife, and, not so strictly, all women who are kadjanja to him; but not including his own mother's mother, who is also kadjanja.

Of these forbidden pairs the son-in-law and mother-in-law groups are strictly observed, even between those of the same sex; the other groups are not so strict.

WORORA KINSHIP TABLE



CAPITALS = ♂

small script = ♀

× joins husband and wife

| joins parents and children

|——| joins brother and sister

Corrigenda:

For - -	manganja,	nauaia,	nauanja,	nalindjaia,	nalindjanja,	nawomale,	nawomalinja
read - -	maŋganja,	ŋauaia,	ŋauanja,	ŋalindjaia,	ŋalindjanja,	ŋawomale,	ŋawomalinja.

Kunmunya Mission.
June 21st, 1939.

Table appended.

The above communication consists of extracts from a letter written to me by the late Rev. J. R. B. Love. The subject matter presented has not been published elsewhere by Mr. Love in his writings on the social organisations of the Worora, namely,

1917. Notes on the Worora Tribe of North-Western Australia. Trans. Roy. Soc. S. Aust. 41 .21.

1935. Mythology, Totemism and Religion of the Worora Tribe of North-West Australia. Report of the 22nd Meeting A.N.Z.A.A.S. 22.222.

1936. Stone Age Bushmen of Today. London.

1941. Worora Kinship Gestures. Trans. Roy. Soc. S. Aust. 65. (1). 108.

This communication has been presented with the consent and co-operation of Mrs. J. R. B. Love.

ABORIGINAL SOCIAL SYSTEMS

BY H. K. FRY

Summary

Marriage and kinships which form the basis of Australian aboriginal societies have been explained in recent years in such complicated terms that an understanding of them is difficult. This paper is an attempt to simplify the problem.

ABORIGINAL SOCIAL SYSTEMS

By H. K. Fry

Read 13th July, 1950.

Marriages and kinships which form the basis of Australian aboriginal societies have been explained in recent years in such complicated terms that an understanding of them is difficult. This paper is an attempt to simplify the problem.

The unit of all aboriginal societies is the exogamous local family group or horde, which owns a definite area of country and the sacred places, ceremonies and legends belonging to that country. Varying numbers of adjacent hordes constitute a tribe.

With the exception of a few atypical societies, the hordes and therefore every man and woman of a tribe belong to one of two named exogamous moieties. Frequently these moieties are subdivided into named classes (or sections) and each individual of such a tribe is identified by one such class name This class name is used commonly as a term of address or reference. In all tribes without exception every man and woman is recognised as a relative by every other person and is addressed or referred to by a kinship term which naturally is variable and dependent upon the recognised kinship of the speaker.

The aboriginal knows the moiety, class name if any, and kinship of every known person as a matter of common knowledge from his or her early childhood. He therefore has a practical basis for knowing the effect of these distinctions in everyday life which is denied to the student unless the latter has had a long and intimate association with the society in question. As there are only two moieties, at most eight named classes, and a limited number of kinship terms for each tribe, it follows that a great number of individuals possess equivalent status in regard to each of these social distinctions. By adopting an appropriate system of symbols, each of which will represent all those many individuals of a certain moiety, class and kinship status, the student can study these social distinctions in a considerably simplified form.

I adopted a set of such symbols in 1931 (8), and have found them useful. The form of the symbols was modified later (9, 10). My interpretation of data concerning aboriginal societies has been modified progressively. As I wish to present new material in coherent relation to my present conclusions, I trust I shall be pardoned for including some recapitulations in this paper.

The symbols which I have adopted are as follows:—

1. *Moieties.* The letters A and B, as is usually done, are used to represent the two named moieties. Individual members of these moieties are symbolised by the same letters A and B as capitals if males, and as small case letters a and b if females.

Marriages between members of moieties are indicated by a line, thus,

A———b
a———B

2. *Classes (Sections).* These named subdivisions of moieties are of two types, which I propose to term the α and β subdivisions.

(1) The α subdivision classifies children in a class different from that of either of the parents. The symbols adopted to represent such classes are

obtained by prefixing the numbers 1 and 2 to the moiety symbols A and B, the numbers distinguishing the named classes in alternate generations. Male and female members of the four named classes are represented by the symbols 1A 1a, 1B 1b in one generation and 2A 2a, 2B 2b in the alternate generation. Marriages between members of classes normally take place according to the following diagram:—

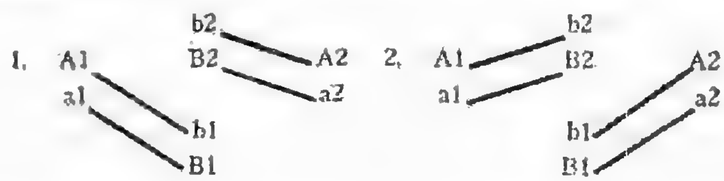
1A————1b   2A————2b
1a————1B   2a————2B

As diagrams become complicated as will be seen later, I have adopted a convenient convention by which a number prefixed to a line or group of symbols is considered to be a prefix to every symbol in that line or group. The above diagram represented in this simpler form is

1. A————b   2. A————b
a————B   a————B

A few tribes have differently named classes for four successive generations in each moiety. These are symbolised by prefixing the numbers 1, 2, 3 and 4 to the moiety symbols A and B to distinguish the named classes in successive generations.

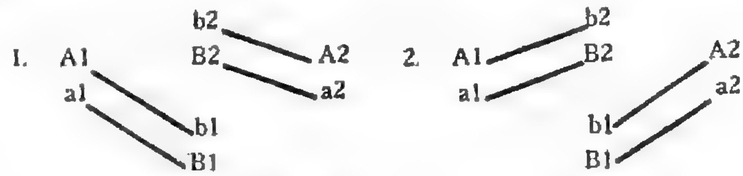
(2) The β type of moiety subdivision classifies members of each moiety of the same generation into two subclasses. The symbols adopted to represent such named subclasses are obtained by adding the numbers 1 and 2 as suffixes to the symbols for the named classes used above. Male and female members of the eight named subclasses are therefore 1A1 1a1, 1A2 1a2, 1B1 1b1, 1B2 1b2 in one generation and 2A1 2a1, 2A2 2a2, 2B1 2b1, 2B2 2b2 in the alternate generation. The normal marriages between members of the eight subclass divisions are as follows:—



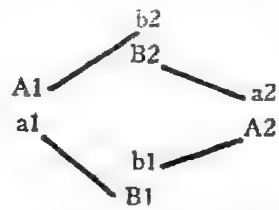
It is to be remembered that in this and subsequent diagrams the initial numbers 1 and 2 are to be read as prefixing each symbol in the group so designated.

3. *Kinship terms.* When local family groups in a closed society, in which all members are recognised as relatives, intermarry according to rigid customary rules, obviously a clearly defined pattern of kinships must be present. As the number of terms used to define these kinships is limited, numerous persons in the tribe will be distinguished as of equivalent kinship status and addressed by the same kinship term by all persons who are themselves of equivalent kinship status in the society. Family groups in a tribe with eight named subclasses intermarry under such conditions in accordance with the diagram given above, and the persons grouped as of equivalent kinship status are found to be of the same subclass. The symbols used to represent the subclasses in such a tribe therefore also serve to represent the kinship terms and the persons of equivalent kinship status designated by such terms.

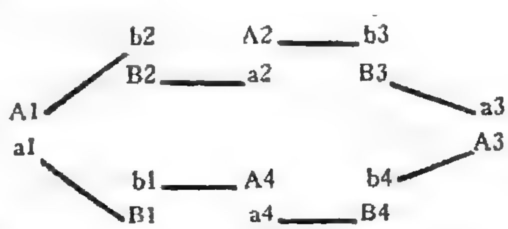
The thesis maintained in this paper is that the customary rule of intermarriages between family groups of a tribe with eight subclass divisions is also the customary rule of intermarriages between the family groups of the great majority of Australian tribes, whether named class divisions or even moieties are existent or non-existent. This may be stated alternatively that the social organisation of the great majority of Australian tribes is based on a custom of marriages between family groups which can be represented by the diagram—



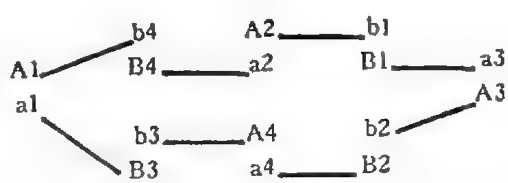
This normal custom of marriages involves the exchange of women between two intermarrying family groups. There are a few tribes in which this exchange of women is not customary. The simplest diagram of such marriages which is possible in a society with moiety divisions is as follows:—



I have been unable to find any described kinship system which conforms accurately to the pattern determined by this system of marriages. I propose to show in this paper that described kinship systems conform to more complex marriage systems of this type involving twice the number of distinguished kinship groups which will be denoted by the symbols A1 a1, A2 a2, A3 a3, A4 a4, B1 b1, B2 b2, B3 b3, and B4 b4. The marriage diagrams of these systems are respectively



and one in which the above system alternates with the following system in alternate generations:—



These diagrams appear at first sight to be very complex. If, however, they are visualised as the customary marriages between members of eight local family groups, the complexity is simplified.

Consideration of some of the features of aboriginal societies can now be undertaken making use of the symbols described above.

1. *Moieties.* Totemism undoubtedly provided the original conditions under which the moiety system took shape. All members of any one totemic group are considered to be of one blood and must not marry within that group. The practice of treating certain totems as associated no doubt led eventually to the classification of all the family totemic groups of the tribe into two named exogamous moieties.

Children in a patrilineal society are of the moiety of the father, in a matrilineal society of the moiety of the mother. A woman on marriage usually joins the horde of her husband. Each local group or horde in a patrilineal society consists of males and one moiety in all generations, their unmarried sisters of the same moiety, and wives of the opposite moiety. The horde in a matrilineal society consists of males of opposite moieties in alternate generations, unmarried sisters of the same moiety as their brothers corresponding to the moiety of their mothers and of the moiety opposite to that of their fathers. This can be illustrated by the following diagrams using the adopted symbols to cover five successive generations.

A		b	B		a
A		b	B		a
A	a	b	B	b	a
A	a	b	B	b	a
A	a		B	b	

Diagram 1 (a). Moiety constitution of hordes in a patrilineal society. Two distinct types of hordes.

A		b	B		a
B		a	A		b
A	a	b	B	b	a
B	b	a	A	a	b
A	a		B	b	

Diagram 1 (b). Moiety constitution of hordes in a matrilineal society. Identical except for difference in generation level.

The actual co-existence of five generations in a horde is naturally unusual, and in such circumstances it would be most unlikely for unmarried sisters of the first two generations to remain with the horde or for males of the fifth generation to have wives.

The genealogical relationships of any individual in a tribe can be expressed clearly by charting symbols for "sons" immediately below symbols for their respective "fathers," and symbols for "daughters" below those for their respective "mothers" in successive generations. The diagram of marriages between moieties is as stated previously

A————b
a————B

Using this as a key, genealogical moiety relationships can be charted to form the following patterns:—

A	a	B	b
A	b	B	a
A	a	B	b
A	b	B	a
A	a	B	b

Diagram 2 (a)
Genealogical moiety relationships in a patrilineal society.

A	a	B	b
B	a	A	b
A	a	B	b
B	a	A	b
A	a	B	b

Diagram 2 (b)
Genealogical moiety relationships in a matrilineal society.

The great convenience of this diagrammatic form is that direct lines of male or female descent can be read vertically for as many generations as one wishes to include in the diagram, while symbols for "brother" and "sister" in any one horizontal line lie immediately below those for "father" and "mother" respectively in the line above, so identifying husband and wife in that generation.

The moiety divisions have two important consequences, extending totemic conceptions to cover the tribe as a whole. Firstly, children of all tribal brothers are of the same moiety, and children of all tribal "sisters" are of the same moiety. "Parallel cousins" being of the same moiety therefore cannot marry. The nearest kinship outside this prohibition is that of a "cross cousin," that is the marriage of children of a "brother" with those of a "sister" Secondly, the children of a "brother" being of the moiety opposite to that of the children of a "sister" underlies the normal custom in aboriginal society whereby a woman addresses the children and grandchildren of her "brothers" by the same kinship terms which they use, and a man addresses the children and grandchildren of his "sisters" by the same kinship terms which they use. Consequently, with the exception of special terms for "in-laws," or for relative seniority in age, it is normal for a man, his "brothers," and his "sisters" to use the same kinship term for each individual in the tribe.

2. The a Moiety Subdivision into named Classes (Sections). The diagram of marriages between members of the named subdivisions being

1. A———b	2. A———b
a———B	a———B

the diagrams of the genealogical relationships of the classes will be as follows:—

1. A a B b	1. A a B b
2. A b B a	2. B a A b
1. A a B b	1. A a B b
2. A b B a	2. B a A b
1. A a B b	1. A a B b
Diagram 3 (a) Genealogical Relationships of Classes in a Patrilineal Society.	Diagram 3 (b) Genealogical Relationships of Classes in a Matrilineal Society.

From this diagram it will be seen that family groups will consist of male members of the Classes 1A 2A or 1B 2B in a patrilineal society, and of the classes 1A 2B or 1B 2A in a matrilineal society.

The significance of this grouping of parents and children into distinctively named classes is an emphasis on the prohibition, which is normal in aboriginal societies, whereby a man must not marry a woman of his father's or his son's generation. If he marries a woman outside his own generation she must be of his grandchildren's generation. The same emphasis in some tribes is also expressed by the use of a different name to distinguish all members of each alternate generation. The northern Aluridja tribes use such names even though they have no named moieties or classes (7b, 16). The origin of this prohibition is not obvious. The suggestion is made that it represents the recognition of totemic restrictions inherited from both father and mother. Let us postulate that the moiety symbols Aa and Bb now represent dominant associated totems inherited from the fathers in a patrilineal society or from mothers in a matrilineal society, and that x and y represent subsidiary associated totems inherited from the other parent. The following genealogical patterns could then emerge.

A a B b	A a B b
x x y y	x x y y
A b B a	B a A b
y x x y	x y y x
A a B b	A a B b
x x y y	x x y y
Patrilineal Pattern	Matrilineal Pattern

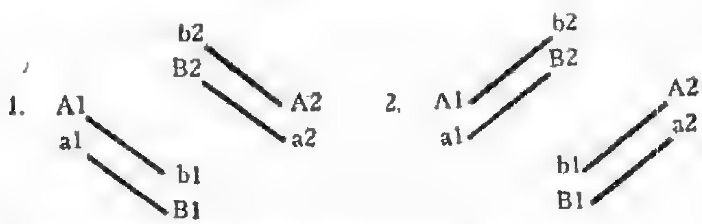
Such patterns of inheritance would permit Ax ax and By by people to intermarry, and in intermediate generations permit Ay ay and Bx bx people to intermarry, but prohibit intermarriage of Ax ax and Bx bx peoples and of Ay ay with By by peoples of alternate generations.

The inheritance in matrilineal tribes of a subsidiary totem from the father is well-known (3), the converse not so. Howitt (11a) mentions a possible instance of the latter. I discussed the question with T. G. H. Strehlow, who referred me to two passages in his father's book (14) which record that an Aranda man inherits from his mother a totem which is his *Altjira,* the man knows the place where his mother was conceived as his *Altjira-tmara,* and when a man is buried his face is turned towards this spot. The Aranda are a typically patrilineal tribe, so this evidence gives support to the above proposal.

3. *The β Moiety Subdivisions into Subclasses (Subsectons).*

These named subdivisions are found only in patrilineal societies which inhabit the northern central regions of Australia.

The diagram of marriages between subclasses being



the diagram of genealogical relationships will be

1. A1 a1 B1 b1 A2 a2 B2 b2
2. A1 b1 B1 a1 A2 b2 B2 a2
1. A1 a2 B1 b2 A2 a1 B2 b1
2. A1 b2 B1 a2 A2 b1 B2 a1
1. A1 a1 B1 b1 A2 a2 B2 b2

Diagram 4. Genealogical Relationships of Subclasses. Patrilineal societies only.

It will be seen that subclasses distinguish four varieties of family groups of which the male members are of the subclasses 1A1 2A1, 1B1 2B1, 1A2 2A2, and 1B2 2B2 respectively.

The sub-class division provides that a son marries a woman of a family group whose members are of subclasses distinct from the named subclasses of the family group of his mother.

The subclasses of the Aranda tribe may be taken as an example to illustrate the application of Diagram 4 as follows:—

1.	A1	a1	B1	b1	A2	a2	B2	b2
	PANANKA	pananka	**PURULA**	purula	**KNURAIA**	knuraia	**NGALA**	ngala
2.	A1	b1	B1	a1	A2	b2	B2	a2
	BANGATA	kamara	**KAMARA**	bangata	**PALTARA**	mbitjana	**MBITJANA**	paltara
1.	A1	a2	B1	b2	A2	a1	B2	b1
	PANANKA	knuraia	**PURULA**	ngala	**KNURAIA**	pananka	**NGALA**	purula
2.	A1	b2	B1	a2	A2	b1	B2	a1
	BANGATA	mbitjana	**KAMARA**	paltara	**PALTARA**	kamara	**MBITJANA**	bangata
1.	A1	a1	B1	b1	A2	a2	B2	b2
	PANANKA	pananka	**PURULA**	purula	**KNURAIA**	knuraia	**NGALA**	ngala

Diagram 5. Genealogical Relationships of Aranda Subclasses.

It will be seen that the subclass names "fit" the pattern of Diagram 4 with complete accuracy. The male symbol 1A1 is always associated with PANANKA, the female symbol 1b1 with purula, 2A1 with BANGATA, 2b1 with kamara and so on.

The functions of the subclasses are not only to distinguish alternate generations among members of each local group, but also to classify local groups into two categories in each moiety according to marriageable status. The moiety divisions, as has been mentioned previously, require that the marrying pair have the kinship status of "cross-cousin." The subclass divisions require that this kinship status of cross-cousin should not be one which is "too close up." For example, referring to Diagram 5, the children of a Pananka man (1A1) and his "sister" (1a1) are Bangata (2a1 2a1) and Kamara (2B1 2b1) respectively. These children are of the kinship status of first cousins. Marriages between them are permitted under special circumstances, but the kinship is "too close" to be considered "proper." The children of a Bangata man and of a Kamara man are Pananka and Purula respectively, and, being "second cousins," marriages between them are "proper." The children of a Bangata woman are Ngala (1B2 1b2) and are first cousins of Pananka people. The subclasses Purula (1B1 1b1) and Ngala (1B2 1b2) in regard to Pananka people distinguish family groups whose members of equivalent generation level are second cousins (1B1 1b1) and are marriageable, from family groups with members who are first cousins (1B2 1b2) and whose kinship is too close for a proper marriage. A similar distinction applies to all B1 b1 B2 b2, and all A1 a1 A2 a2 groups.

4. *Kinship Terms*

The pattern of the genealogical relationships of subclasses portrayed in Diagrams 4 and 5 is also the pattern of kinships developed in any patrilineal society in which (a) intermarriages are between members of hordes, or local family groups, which belong to opposite moieties (b) the hordes exchange women in marriage (c) all known persons are kindred (d) the marrying pair must have the kinship status of "cross-cousins, not too close up," and this kinship status is distinguished from that of "first-cousin."

If any two of the symbols representing "brother" and "sister" in one horizontal line of Diagram 4 be taken as EGO for male-speaking and female-speaking kinship terms respectively, and the Aranda kinship terms plotted on this pattern in accordance with their genealogical significance, it will be found that the terms will "fit" the pattern accurately. One kinship term will be found to be associated with one symbol only This is illustrated in Diagram 6. In this and all subsequent kinship diagrams EGO male-speaking and *ego* female-speaking are 1A1 and 1a1 respectively in the middle line of the diagram. A genealogical interpretation of each kinship term is indicated by letters of which

f = father	d = daughter	Genealogical data for terms used by a
m = mother	w = wife	woman are enclosed in brackets when
b = brother	h = husband	they involve a genealogical relationship
sr = sister	e = elder	different from that of the term used
s = son	y = younger	by her brother for the same person.

The close identification of kinship terms and subclass names exhibited by Diagrams 5 and 6 is of interest. A kinship term varies in its application in accordance with the kinship status of the speaker. Named divisions of moiety, class, and subclass can now be seen to be ingenious devices for grouping persons with increasing accuracy under permanent names indicating marriageable status.

When it is stated that kinship terms "fit" a genealogical pattern, the terms must not only satisfy the genealogical interpretation given for example in Diagram 6 but also every other possible genealogical interpretation of the term. For example, Strehlow (15) gives 174 genealogical identifications of 22 kinship terms and Diagram 6 satisfies them all. Again, for example, 1b1 *palla* of the last generation of Diagram 6 is not only sister's son's daughter (a sequence through 1a1, 2B1 to 1b1), but also sister's daughter's husband's sister's daughter (1a1, 2b1, 2A2, 2a2 to 1b1), and father's mother's brother's son's son's son's daughter (2A1 1b1, 1B1, 2B1, 1B1, 2B1 to 1b1) mother's mother's brother's son's son's daughter's daughter (2b2, 1a2, 1A2, 2A2, 1A2, 2a2 to 1b1), and so on for innumerable genealogical sequences ending in 1b1. Needless to say the aboriginal does not think normally in genealogical sequences of such magnitude. EGO 1A1 of Diagrams 5 and 6 would know the woman in question 1b1 as *Purula-palla*, daughter of *Kamara-amba* and *Paltara-marra*, whose parents again are known to him by subclass name and kinship term, and so on. Also the woman is marriageable, and if he marries her she becomes *Purula-noa* and her father becomes *Kamara-antara*. Complex genealogical sequences relevant to a special problem are worked out by the aboriginal with laborious argument taking account of the relative kinship status of each of the factual kinsfolk involved in the problem.

If the kinship terms of other patrilineal Australian tribes be charted on the pattern of Diagram 4 as has been done for the Aranda in Diagram 6, it will be found that almost all will "fit" the pattern with some degree of accuracy. All these tribes countenance marriage with "first-cousins" under certain conditions. When such conditions are relaxed, the terminology becomes less precise, separate terms normally associated with A1 and A2 distinctions or with B1 and B2 becoming used less discriminatingly although differentiated at times in accordance with the normal pattern. The most precise differentiation is found in the sparsely populated areas of northern central Australia, where each individual is relatively most important, and where the named subclass divisions tend to keep marriages "straight."

If the kinship terms of a matrilineal Australian society be charted on the genealogical pattern of Diagram 4, the terms do not fit the pattern. Diagram 4 is patrilineal in type and is not symmetrical in regard to male and female genealogical sequences. If the pattern be varied by transposing the male and female symbols, the kinship terms of a matrilineal society will then be found to conform to this matrilineal pattern. The diagram of marriages is the same for both matrilineal and patrilineal forms of the pattern. Diagram 7 illustrates the charting of the kinship terms of the Dieri tribe on this matrilineal form.

Professor Elkin (4, 7a) has described a number of ways in which the Dieri kinships differ from those of the Aranda. All these apparent anomalies are clearly explained by the differences in genealogical sequences in a matrilineal and in a patrilineal form of an asymmetrical genealogical pattern. Professor Elkin has also attempted to prove by an elaborate argument that the possibility of a man marrying his mother's mother's brother's son's son's daughter's daughter is a point in common between the Dieri and Aranda systems. The Dieri like other tribes countenance occasionally a marriage with a first-cousin, a so-called *kami* marriage. Reference to Diagram 7 shows that the woman having the relationship status cited by Elkin is normally 1b2 *kami*, sister's son's daughter. The normal wife 1b1 *nadadu* in that generation has the relationship status of daughter's daughter as recorded by Howitt. Mother's mother's brother's son's son's daughter's daughter can only be 1b1 *nadada* as a consequence of the interpolation of a *kami* marriage in this genealogical sequence. An old Dieri man in 1934 gave me numerous kinship terms. A later check of these showed that though most of them were correct, there were several instances of *kami* marriage influence, and on two occasions terms were used for persons of the wrong moiety. This is mentioned to indicate the difficulty of obtaining information from last survivors of lost societies.

The constitution of the four varieties of family groups of the matrilineal pattern of Diagram 7 as regards males is as follows:—

1A1	1B1	1A2	1B2
2B1	2A1	2B2	2A2
1A2	1B2	1A1	1B1
2B2	2A2	2B1	2A1
1A1	1B1	1A2	1B2

It will be seen that the first and third also the second and fourth include the same terms but there is a difference of two generations in the sequence of the terms.

There are comparatively few full descriptions of kinship terms of matrilineal societies. Such as are available fit the pattern of Diagram 7 with some degree of inaccuracy, dependent upon the degree to which the *kami* marriages are permissible.

The great majority of Australian tribes therefore have kinship systems which conform to the pattern of Diagram 4 in its patrilineal or matrilineal variation.

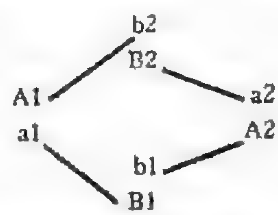
The tribal subdivisions of moiety, class and sub-class have every indication of representing stages in an evolutionary sequence of classifications of individuals according to similarity of marriageable status with increasing accuracy. Howitt (11) contrasted the kinships systems of the Urabunna (Arabana) and Dieri tribes. He interpreted the former as expressing a rule of marriages between first cousins, the latter a rule of marriages between second cousins. He stated "The Dieri rule is evidently a development of that of the Urabanna, and is therefore the later one." Elkin (6, 7) has found the Dieri and Arabana systems to be similar, the Arabana being intermediate between the Wailpi and the Dieri. The Wailpi also has features in common with the Dieri (personal observation). The Arabana is therefore not an example of a simpler marriage rule. Radcliffe Brown (1, 2) adopted the same idea as Howitt but selected the Kariera system as the type of the less evolved and the Aranda as the type of the more developed system. He described the Kariera system by charting the male-speaking and female-speaking terms separately, thus overlooking the fact that an aboriginal man and his sister normally use the same kinship term for each person in the tribe, excepting special terms for "in-laws." If the Kariera kinship terms are charted on the normal pattern as in Diagram 8, they will be seen to conform to that pattern in great part though with divergences. The Kariera is definitely not a type or norm of a simple system in the evolutionary sense. The hypothesis that there is existing evidence of an evolutionary development of kinship marriage rule from that of marriage of first-cousins to that of marriage of second-cousins is not proven.

There is every indication that there is one fundamental marriage rule throughout Australian societies, namely, that marriages take place between family groups of opposite moieties and between individuals of those groups who are "cross-cousins, not too close up," this requirement being normally the recognition of the kinship status of "second-cousin" as the proper one for marriage This rule is usually associated with the exchange of women between family groups when marriages occur. By virtue of the genealogical pattern of relationships determined by such marriages certain women of a man's grandchildren's generation incur the kinship status of second-cousin and are marriageable to him. The genealogical relationship of these women to the man in question is "sister's son's daughter" in a patrilineal society, and "daughter's daughter" in a matrilineal society.

The major variations from the patrilineal and matrilineal forms of the dominant kinship pattern in Australian societies are found in those few tribes where the customary exchange of women in marriage is lacking. The husband then squares his obligations to his wife's family by gifts and services. A relatively numerous population would seem to be necessary under these circumstances.

When women are not exchanged in marriage, marriages then take on a unilateral trend as "father's sister's daughter" is considered to be a kinship "more close up" than is "mother's brother's daughter." This idea has been explained as close identification of father with father's sister. This explanation is, however, inadequate, as it is obvious that when a man marries a "mother's brother's daughter" his kinship from his wife's point of view is that of "father's sister's son." A more adequate explanation is that the aboriginal recognises a closer kinship between a father and a son and between a mother and a daughter than between a father and daughter and a mother and son. This conception is manifested clearly by the existence of sex totems in some tribes, males having one totem in common and women another.

The simplest diagram of possible marriages in a tribe possessing the moiety division and where women are not exchanged in marriage is



in all generations.

The genealogical relationships of members of family groups intermarrying under the above customary rule in a patrilineal society would be

A1	a1	B1	b1	A2	a2	B2	b2
A1	b1	B1	a2	A2	b2	B2	a1
A1	a2	B1	b2	A2	a1	B2	b1
A1	b2	B1	a1	A2	b1	B2	a2
A1	a1	B1	b1	A2	a2	B2	b2

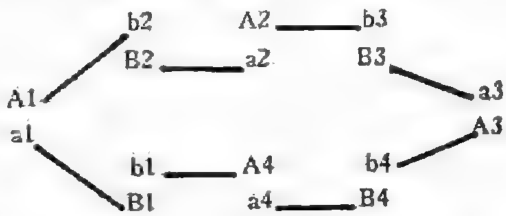
Diagram 9

Genealogical relations of members of family groups in the simplest possible system of marriages with "mother's brother's daughter" not "father's sister's daughter" in a tribe with moiety divisions.

It will be seen that all the males in the above diagram marry a woman who is "mother's brother's daughter" and not "father's sister's daughter." Apart from the absence of prefix numbers, the appearance of the pattern of the diagram is extraordinarily close to that of Diagram 4, being identical save for the transposition of a1 and a2 terms in generations two and four. These apparently small differences, however, change the genealogical sequences profoundly. I have been unable to find any description of an Australian kinship system which fits the pattern of Diagram 9 simply and accurately. The Karadjeri kinships have been cited as typical of systems based on marriages with mother's brother's daughter, not father's sister's daughter. The Karadjeri recorded kinship terms (5, 12) are plotted in Diagram 10 on the pattern of Diagram 9 and they will be seen to conform only sketchily with the pattern.(1)

Lloyd Warner has described very fully the kinship system of the Murngin tribe (17) which has the kinship marriage rule under discussion. Warner's identifications of kinship terms are formidable, ranging over as many as eight genealogical sequences. Diagrams therefore have to be extended to cover eight generations to plot the terms. If this be done with the pattern of Diagram 9, it will be found that the kinship terms fit the pattern accurately, but that almost every symbol in the pattern becomes loaded with two dissimilar kinship terms. In two generations the two terms are the same for B1 b1 and B2 b2 placements. It therefore appears that the pattern of Diagram 9 must be doubled and retain its inherent form to cope with the Murngin kinships.

A series of marriages between members of eight family groups in accordance with the following diagram will provide the pattern required:—



The genealogical pattern of such a system is given in Diagram 11. Also the Murngin kinships described by Lloyd Warner are charted upon the pattern and will be seen to conform accurately. The normal patterns of aboriginal kinships complete their cycle in four generations. The Murngin pattern takes eight generations to complete its cycle. Tribes of this group have eight named classes, one for each moiety in each generation, but with differentiated class names for four generations. The generation lines of Diagram (11) are therefore numbered 1, 2, 3 and 4. The pattern of the class names recorded by Webb (18) is appended to Diagram 11.(2)

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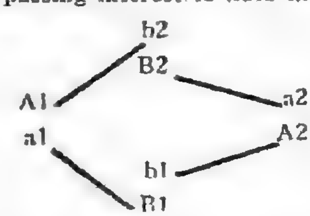
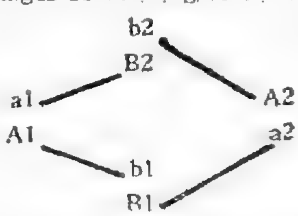
(1) It is of passing interest to note that marriages conforming to the system

1. 

2. 

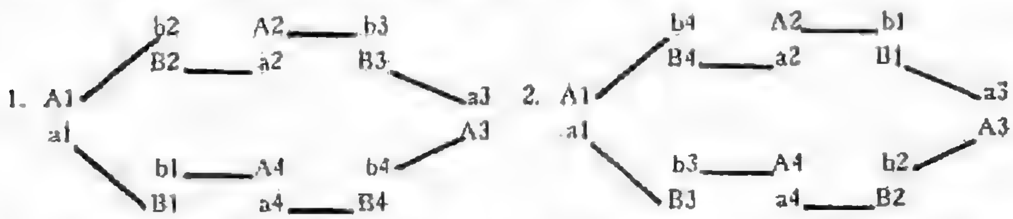
and similar systems comprising a larger number of family groups would result in a genealogical pattern representing marriages of men with their "father's sister's daughters," not "mother's brother's daughters." No such systems exist in Australian aboriginal societies.

(2) There are no Murngin terms to fill A3 a3 placements in Diagram 11. Similarly Yir-Yiront kinship terms published by Sharp (1934, Oceania, 4, (4), 413) fit a pattern of the Murngin type, based on marriages between six instead of eight hordes, and there are no terms for B3 b3 placements.

Hordes at the opposite pole to that of EGO in the cycle of marriages are unrepresented in the terminology of both tribes.

The kinship rule of Murngin marriages is apparently simple but definitely is not associated with a simple type of kinship terminology.

Many years ago I attempted to find a genealogical pattern which would conform with some kinship terms of the Ungarinyin tribe published by Elkin (5). In 1939 the late J. R. B. Love sent me a detailed description of the kinships of the Worora tribe, neighbours of the Ungarinyin and with the same type of kinship. The Worora kinships did not fit the pattern which had been found to satisfy the relatively few Ungarinyin terms available, so this pattern was incorrect. Attempts to build up the Worora terms into a genealogical pattern were not successful. Finally it was discovered that if Worora terms were charted on the pattern of Diagram 9, the terms fitted the pattern but many symbols of the pattern were associated with two kinship terms. These two terms were representative of kinships which a father and son would apply respectively to one individual. The kinship terms did not conform to the pattern which satisfies the Murngin kinships. The Worora and the Ungarinyin share a very anomalous marriage custom whereby a man is permitted to marry both sister and daughter of another man. Such a custom makes its desirable that the family group from which a son takes a wife should be differentiated from the family group from which his father had taken a wife. This consideration suggests that not only should the number of distinguished family groups of Diagram 9 be doubled but also that alternate generations should marry alternate family groups as occurs in the marriage customs of the great majority of Australian tribes and as is illustrated in the marriage diagram upon which Diagrams 4, 6 and 7 are based. A system of marriages between eight family groups complying with such conditions is supplied by the following diagram:—



The genealogical relationships of this system of marriages are given in Diagram 12. The recorded kinship terms of the Worora are also plotted on this diagram and will be seen to fit accurately. The diagram also conforms to the requirement mentioned elsewhere by Love (13) namely, "The actual relationship for legal marriage is that of second-cousin." The vacant spaces in Diagram 12, excepting those for the terms 1A3 1a3, can be filled in by direct inference from the general pattern. The final proof of the accuracy of the pattern presented will lie in a confirmation of kinships and marriages so predicted.

The value of the methods adopted in this paper for charting marriages and kinships is illustrated particularly well in the instances of the last two unusual kinship systems. The complexity of the kinships in an amorphous form is appalling. Reduced to a coherent pattern based on a set of systematised marriages between local family groups it is possible to visualise the structure of the society as it were as a miniature model. It can also be understood how problems concerning these kinships come within the scope of the intelligence of ordinary human beings such as the aborigines, who have a practical matter-of-fact knowledge of the kinships of all the family groups within the range of their acquaintance. With the same key the study of the minor complexities of the normal aboriginal kinship systems can become simple. Moreover the use of the basic patterns is useful in field work as it is extraordinarily easy to miss some important items of information concerning kinships, and such omissions are minimised if one insures that all the placements of a standard genealogical pattern have been filled. Further, as the normal pattern is being filled anomalies become apparent immediately and can be checked and followed up with greater detail.

REFERENCES

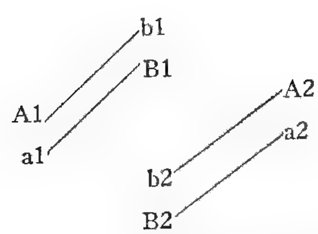
1 Brown, Radcliffe A. R. 1913 Three Tribes of Western Australia. Journ. Roy. Anth. Inst., **43**, 143
2 Brown, Radcliffe A. R. 1930 The Social Organisation of Australian Tribes. Oceania, **1**, (1), 46
3 Brown, Radcliffe A. R. *Ibid*, **1**, (2), 221
4 Elkin, A. P. 1931 The Dieri Kinship System. Journ. Roy. Anth. Inst., **61**, 495
5 Elkin, A. P. 1932 Social Organisation in the Kimberley Division, Oceania, **2**, (3), 300
6 Elkin, A. P. 1931 The Social Organisation of South Australian Tribes. Oceania, **2**, (1), 56
7 Elkin, A. P. 1938 Kinship in South Australia. Oceania, **8**, (4), 438
7a Elkin, A. P. 1938 Kinship in South Australia. Oceania, **9**, (1), 47
7b Elkin, A. P. 1939 *Ibid*, **10**, (2), 212
8 Fry, H. K. 1931 A Table showing the Class Relations of the Aranda. Trans. Roy. Soc. S. Aust., **55**, 12
9 Fry, H. K. 1932 Genealogical Studies of Australian Tribal Systems. Trans. Roy. Soc. S. Aust., **56**, 27
10 Fry, H. K. 1934 Kinship and Descent among the Australian Aborigines. Trans. Roy. Soc. S. Aust., **58**, 14
11 Howitt, A. W. 1904 The Native Tribes of South-East Australia. London, 189
11a Howitt, A. W. *Ibid*, 229
12 Piddington, R. 1932 Karadjeri Initiation. Oceania, **3**, (1), 63
13 Love, J. R. B. 1936 Stone Age Bushmen of Today. London, 93
14 Strehlow, C. 1908, 1915 Die Aranda- und Loritja-Stamme in Zentral-Australien. Frankfurt am Main, Theil II, 57, Theil IV, ii, 16
15 Strehlow, C. *Ibid*, Theil IV, i, 66
16 Tindale, N. B. 1935 Initiation among the Pitjandjara Natives of the Mann and Tomkinson Ranges in S. Aust. Oceania, **6**, (2), 200
17 Warner, W. Lloyd 1930 Morphology and Function of the Australian Murngin Type of Kinship. Am. Anthropologist, N.S., **32**, 207
18 Webb, T. T. 1933 Tribal Organisation in Eastern Arnhem Land. Oceania, **3**, (4), 406

ARANDA KINSHIPS ILLUSTRATING THE DOMINANT AUSTRALIAN KINSHIP PATTERN — PATRILINEAL

1	A1 ARANGA F.F.	a1 aranga f.f.sr.	B1 PALLA F.M.B. W.F.F.	b1 palla f.m.	A2 EBMANNA M.M.B.	a2 ebmanna m.m.	B2 TJIMIA M.F.	b2 tjimia m.f.sr. w.m.m.
2	A1 KATA F.	b1 intoa w.f.sr.	B1 ANTARA W.F. AMBA [H.F.]	a1 wonna f.sr.	A2 MARRA W.M.B.	b2 maia m.	B2 KAMUNA M.B.	a2 marra w.m. nerra [h.m.]
1	A1 KALJA ITIA B EGO man speaking	a2 ebmannna f.sr.s.w.	B1 MBANA W.B. NOA [H.]	b2 ankalla f.sr.d. m.b.d.	A2 ILIARRA F.SR.D.H. M.B.D.H.	a1 kwaia itia sr. [ego] [woman speaking]	B2 ANKALLA F.SR.S. M.B.S.	b1 noa w. intanga [h.s.]
2	A1 ALIRRA S. [B.S.]	b2 namara s.w. [b.s.w.]	B1 AMBA SR.S. [S.]	a2 marra sr.s.w. nerra [s.w.]	A2 MARRA SR.D.H. [D.H.]	b1 amba sr.d. [d]	B2 KAMUNA D.H. [B.D.H.]	a1 alirra d. [b.d]
1	A1 ARANGA S.S. [B.S.S.]	a1 aranga s.d. [b.s.d.]	B1 PALLA SR.S.S. [S.S.]	b1 palla sr.s.d. [s.d.]	A2 EBMANNA SR.D.S. [D.S.]	a2 ebmanna sr.d.d. [d.d.]	B2 TJIMIA D.S. [B.D.S.]	b2 tjimia d.d. [b.d.d.]

DIAGRAM OF MARRIAGES BETWEEN FOUR HORDES

GENERATION 1



GENERATION 2

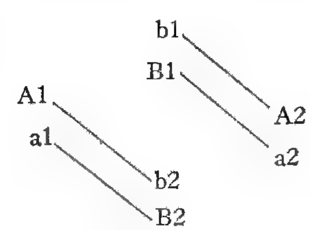


DIAGRAM 6

DIERI KINSHIPS
ILLUSTRATING THE DOMINANT AUSTRALIAN KINSHIP PATTERN — MATRILINEAL

1	a1 kanini m.m.	A1 KANINI M.M.B.	b1 nadada m.f.sr.	B1 NADADA M.F.	a2 yenku f.f.sr.	A2 YENKU F.F.	b2 kami f.m.	B2 KAMI F.M.B.
2	a1 ngandri m.	B1 NGATAMURA M.M.B.S. PAIERA W.M.B.	b1 ngatamura m.m.b.d. paiera w.m.	A1 KAKA M.B.	a2 tidnara f.m.b.d. taru w.f.sr.	B2 NGAPARI F.	b2 papa f.sr.	A2 TIDNARA F.M.B.S. TARU W.F.
1	a1 kaku ngatata sr. [ego] [woman speaking]	A2 YENKU M.M.B.S.S.	b1 noa w. kamari [h.s.]	B2 KAMI M.B.S. F.SR.S.	a2 yenku m.m.b.s.d.	A1 NIYI NGATATA B. EGO man speaking	b2 kami mbd. f.sr.d.	B1 KADI W.B. NOA [H]
2	a1 tidnara sr.d. ngatani [d.]	B2 PAIERA SR.D.H. [D.H.]	b1 ngatamura d. [b.d.]	A2 TARU D.H.	a2 taru s.w.	B1 NGATAMURA S. [B.S.]	b2 kalari sr.s.w. [s.w.]	A1 TIDNARA SR.S. NGATANI [S.]
1	a1 kanini sr.d.d. [d.d.]	A1 KANINI SR.D.S. [D.S.]	b1 nadada d.d.	B1 NADADA D.S.	a2 yenku s.d.	A2 YENKU S.S.	b2 kami sr.s.d.	B2 KAMI SR.S.S.

Divergences from true pattern are 2 B1,b1 and 2 B2,b2 PAIERA, and 2 A2,a2 and 2 a1,A1 TIDNARA.

DIAGRAM OF MARRIAGES

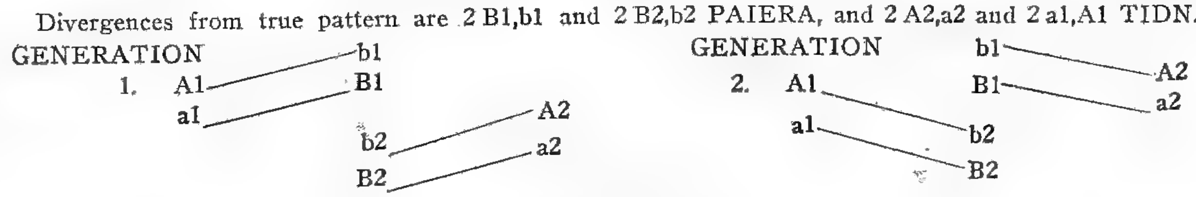


DIAGRAM 7

KARIERA KINSHIPS

CHARTED UPON THE DOMINANT AUSTRALIAN KINSHIP PATTERN — PATRILINEAL

1	A1 MAELI F.F.	a1 kandari f.f.sr. w.f.m. [h.f.m.]	B1 TAMI F.M.B. W.F.F. [H.F.F.]	b1 kabali f.m.	A2 MAELI M.M.B. W. M. F. [H.M.F.]	a2 kandari m.m.	B2 TAMI M.F.	b2 kabali m.f.sr. w.m.m. [h.m.m.]
2	A1 MAMA F.	b1 nganga w.f. sr. [h.f.sr.]	B1 KAGA W.F. [H.F.]	a1 toa or yumani f.sr. m.b.w. yuro [f.sr.] [m.b.w.]	A2 MAMA W.M.B. [H.M.B.]	b2 nganga m.	B2 KAGA M.B. F.SR.H.	a2 toa or yumani w.m. yuro [h.m.]
1	A1 KAJA MARGARA B. EGO male speaking	a2	B1 KUMBALI S.H. W.B. NUBA [H.] [S.H.] [H.B.]	b2 nuba f.sr.d. m.b.d. bungali [f.sr.d.] [m.bd.]	A2	a1 turdu mari sr. [ego] [female speaking]	B2 KUMBALI M.B.S. F.SR.S. NUBA [M.B.S.] [F.SR.S.]	b1 nuba w. b.w./w.s. yarungu b.w. bungali [b.w.] [h.s.]
2	A1 MAINGA S. TOA or YUMANI [B.S.] [H.SR.S.]	b2 ngaraia or bali s.w.	B1 KULING or YARAIJA SR.S MAINGA [S.]	a2 ngaraia [s.w.]	A2 TOA OR YUMANI [D.H.]	b1 ngaraia or bali sr.d. kundal [d]	B2 KULING or YARAIJA D.H.	a1 kundal d. ngaraia [b.d.]
1	A1 MAELI S.S.	a1 maeli s.d. kandari [s.s.w.]	B1 KABALI [S.S.]	b1 kabali [s.d.] tami s.s.w.	A2 KANDARI [D.S.]	a2 kandari [d.d.] maeli d.s.w.	B2 TAMI D.S.	b2 tami d.d. kabali [d.s.w.]

Divergences from the normal pattern are: (1) in the grandparent generation the terms MAELI and TAMI are used for males only, kandari and kabali for females only. The terms are used normally in the grandchild generation; (2) similarly, in EGO's generation the term KUMBALI is used only for males, bungali only for females; (3) most anomalous of all, in the children's generation the terms MAINGA, ngaraia, and kundal are applied to individuals of both moieties; (4) many terms are applied to both A1 and A2, or to both B1 and B2, kinships, thereby simulating a simpler kinship pattern, but the pattern is of normal type in the grandchild generation, and kumbali, bungali are suggestive of former normality in EGO's generation; (5) a man and his sister in the Kariera use the same term MAINGA for the son, and kundal for daughter; (6) the conflicting marriages in grandparent and grandchild generations are quite anomalous.

DIAGRAM 8

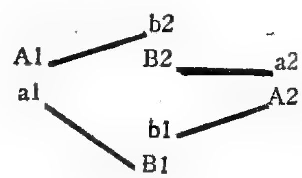
KARADJERI KINSHIPS

Charted on Pattern of Unilateral Marriages — with mother's brother's daughter, not father's sister's daughter.

A1 KALUDJ F. F.	a1	B1	b1 yagu w.m.m.	A2 KAMI M.M.B. W.M.F.	a2 kami m.m. w.f.m.	B2 DJAMBAD M.F. F.M.B. W.F.F.	b2 djambad m.f.sr. f.m., also kabali f.m.
A1 TABALU F	b1 djalbi w.m.b.w.	B1 KAGA F.SR.H.	a2 tabalu m.b.w. dalu w.m.	A2 DALU or MUGALI W.M.B.	b2 kurdang m.	B2 KAGA M.B. W.F.	a1 tabalu f.sr.
A1 MAMA BABALA B. EGO	a2 kabadju w.b.w.	B1 DJAMBAD F.SR.S. YAGU SR.H	b2 djambad m.b.d. kabali w.	A2	a1 kabadju sr.	B2 DJAMBAD M.B.S. YAGU W.B.	b1 djambad f.sr.d. sr.h.sr.
A1 NGENI S	b2 djalbi s.w.	B1 DJELANGA SR.S. D.H.	a1 tabalu d. sr.s.w.	A2 DALU SR.D.H.	b1 djalbi sr.d.	B2	a2
A1	a1	B1	b1	A2	a2	B2	b2

Divergences from the pattern are b1, b2 djalbi; a1, a2 tabalu; B1, B2 KAGA; a1, a2 kabadju; and most crucial B1, b1, B2, b2 DJAMBAD, so not differentiating mother's brother's son and daughter from father's sister's son and daughter.

DIAGRAM OF MARRIAGES
BETWEEN FOUR HORDES FOR THE ABOVE GENEALOGICAL PATTERN TO DEVELOP.



in all generations.

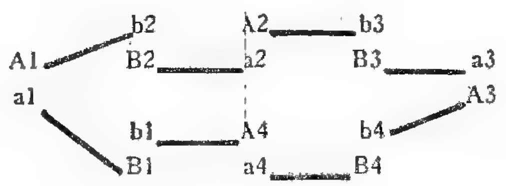
DIAGRAM 10

MURNGIN KINSHIPS

1	A1	a3	B1	b3	A2	a4	B2	b4	A3	a1	B3	b1	A4	a2	B4	b2
2	A1 F.F.F.F.F.	b3	B1	a2	A2	b4 m.m.m.m.m.	B2	a3	A3	b1	B3	a4	A4	b2	B4 M.M.M.M.M.B.	a1 f.f.f.f.f.sr.
3	A1 F.F.F.F.	a2	B1	b2	A2	a3 m.m.m.m.	B2	b3	A3 M.M.M.M.B.	a4	B3	b4	A4	a1 f.f.f.f.sr.	B4	b1
4	A1 F.F.F.	b2	B1	a1 f.f.f.sr.	A2	b3 m.m.m.	B2	a2	A3	b4	B3 M.M.M.B.	a3	A4	b1	B4	a4
1	A1 MARIKMO F.F.	a1 marikmo f.f.sr.	B1 DUE F.F.F.SR.S.	b1 due f.f.f.,sr.d.	A2 MARI M.M.B.	a2 mari m.m.	B2 NATI M.F.	b2 momo f.m.	A3	a3	B3 NATCHIWALKER M.M.M.B.S.	b3 momelker m.m.m.b.d.	A4 KUTARA F.F.F.F.SR.D.S.	a4 kutara f.f.f.f.sr.d.d.	B4 DUMUNGUR F.F.F.F.F.SR.D.D.S.	b4 dumungur f.f.f.f.f.sr.ddd.
2	A1 BAPA F	b1 waku f.f.sr.d.	B1 WAKU F.F.SR.S.	a4 gurrong f.f.f.sr.d.d.	A2 MARELKER M.M.B.S.	b2 arndi m.	B2 GAWEL M.B.	a1 mokul bapa f.sr.	A3	b3 arndi m.m.m.b.s.d.	B3 GAWEL M.M.M.B.S.S.	a2 mokul rumeru m.m.b.d.	A4 GURRONG F.F.F.SR.D.S.	b4 waku f.f.f.f.sr.d.d.d.	B4 WAKU F.F.F.F.SR.D.D.S.	a3
3	A1 WAWA YUKIYUKO B EGO	a4 kutara f.f.sr.d.d.	B1 DUE F.SR.S. SR.H.	b4 dumungur f.f.f.sr.d.d.d.	A2 MARI M.M.B.S.S.	a1 yeppa sr.	B2 GALLE M.B.S.	b1 due f.sr.d.	A3	a2 mari m.m.b.s.d.	B3 NATCHIWALKER M.M.M.B.S.S.S.	b2 galle m.b.d. w.	A4 KUTARA F.F.SR.D.S.	a3	B4 DUMUNGUR F.F.F.SR.D.D.S.	b3 momelker m.m.m.b.s.s.d.
4	A1 GATU S	b4 waku f.f.sr.d.d.d.	B1 WAKU SR.S.	a3	A2 MARELKER M.M.B.S.S.S.	b1 waku sr.d.	B2 GAWEL M.B.S.S.	a4 gurrong f.sr.d.d.	A3	b2 arndi m.b.s.d.	B3 GAWEL M.M.M.B.S.S.S.S.	a1 gatu d.	A4 GURRONG F.SR.D.S.	b3 arndi m.m.m.b.s.s.s.d.	B4 WAKU F.F.SR.D.D.S.	a2 mokul rumeru m.m.b.s.s.d.
1	A1 MARAITCHA S.S.	a3	B1 KAMINYER D.S.	b3 momelker m.m.m.b.s.s.s.s.d.	A2 MARI M.M.B.S.S.S.S.	a4 kutara sr.d.d.	B2 GALLE M.B.S.S.S.	b4 dumungur f.sr.d.d.d.	A3	a1 maraitcha s.d.	B3 NATCHIWALKER M.M.M.B.S.S.S.S.S.	b1 kaminyer d.d.	A4 KUTARA SR.D.S.	a2 mari m.m.b.s.s.s.d.	B4 DUMUNGUR F.SR.D.D.S.	b2 galle m.b.s.s.d.

MARRIAGE DIAGRAM

ALL GENERATIONS



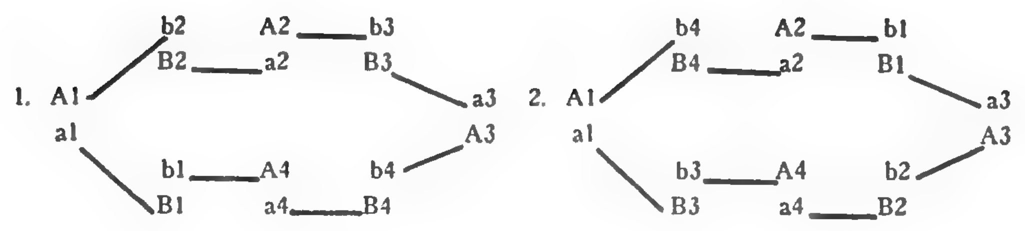
CLASS (SUBSECTION) RELATIONSHIPS

1	A1, 2, 3, 4 NGARIT	a1, 2, 3, 4 ngaritjan	B1, 2, 3, 4 BALANG	b1, 2, 3, 4 bilindjan
2	A1, 2, 3, 4 BANGARDI	b1, 2, 3, 4 kumandjan	B1, 2, 3, 4 KARMARUNG	a1, 2, 3, 4 bangaritjan
3	A1, 2, 3, 4 BULAIN	a1, 2, 3, 4 bulaindjan	B1, 2, 3, 4 BURALANG	b1, 2, 3, 4 kalian
4	A1, 2, 3, 4 KAIJARK	b1, 2, 3, 4 warmutjan	B1, 2, 3, 4 WARMUT	a1, 2, 3, 4 kaitjan
1	A1, 2, 3, 4 NGARIT	a1, 2, 3, 4 ngaritjan	B1, 2, 3, 4 BALANG	b1, 2, 3, 4 bilindjan

DIAGRAM 11

1	A1 ABIA F.F.	a1 abiinja f.f.sr.	B1 KULAIA F.F.SR.H.	b1 kulanja f.f.sr.h.sr.	A2 KURUM F.M.B.W.B.	a2 kurumanja f.m.b.w.	B2 WAIA F.M.B. W.F.F.	b2 manganja f.m.	A3	a3	B3	b3	A4 WOLBAIA or KADJAIA M.M.B.	a4 kadjanja m.m.	B4 TJAMAIA M.F.	b4 tjamanja m.f.sr.
2	A1 IRAIA F	b1 ibanja f.f.sr.d.	B1 IBAIA F.F.SR.S.	a4 budinja m.m.b.d. kurumanja w.m. [b.w.m.]	A2 KADJAIA M.B.W.B.	b2	B2 WAIA W.F.	a1 pamaranja f.sr.	A3 NALINDJAIA [h.m.b.]	b3	B3 KULAIA F.SR.H.	a2 kadjanja m.b.w.	A4 BUDA M.M.B.S. KURUM W.M.B.	b4 karanja m.	B4 KAKAIA M.B.	a3 nalinjanja [h.m.]
1	A1 NAUAIA B EGO man-speaking	a2	B1 KULAIA SR.H. [H.]	b2 manganja w.	A2	a3	B2 WAIA W.B.	b3 ibanja f.sr.d.	A3	a4 kadjanja m.b.s.w.	B3 IBAIA F.SR.S.	b4 tjamanja m.b.d.	A4	a1 nauanja sr. [ego] [woman speaking]	B4 TJAMAIA M.B.S.	b1 kulanja sr.h.sr.
2	A1 IRAIA S	b2	B1 IBAIA SR.S. [S.]	a1 pamaranja d.	A2 WOLBAIA SR.D.H. [D.H.]	b3	B2 WAIA W.B.S.	a2 wolbaiinja sr.d.h.sr. kadjanja m.b.s.s.w.	A3 NALINDJAIA SR.S.W.B. [S.W.B.]	b4 karanja s.w.	B3 KULAIA D.H.	a3 nalindjanja sr.s.w. [s.w.]	A4 BUDA SR.H.SR.S. [H.SR.S.]	b1 ibanja sr.d. [d.]	B4 KAKAIA M.B.S.S.	a4 budinja sr.h.sr.d.
1	A1 NAWOMALE S.S.	a3	B1 KULAIA SR.S.S.	b3 ibanja d.d.	A2 BUDA SR.D.S. [D.S.]	a4	B2 WAIA W.B.S.S.	b4 tjamanja m.b.s.s.d.	A3	a1 nawomalinja s.d.	B3 IBAIA D.S.	b1 kulanja sr.s.d.	A4	a2 budinja sr.d.d. [d.d.]	B4 TJAMAIA M.B.S.S.S.	b2 manganja s.s.w.

DIAGRAM
OF MARRIAGES
BETWEEN
EIGHT TOTEMIC
HORDES



Corrigenda—*Vide* Table in J. R. B. Love's paper, this volume, facing page 280.

DIAGRAM 12

ROYAL SOCIETY OF SOUTH AUSTRALIA (INCORPORATED)

Receipts and Payments for the Year ended 30 September 1949

RECEIPTS	£	s.	d.	£	s.	d.
To Balance, 1st October, 1948				21	11	8
,, Subscriptions				158	11	0
,, Life Membership				30	0	0
,, Exchanges				0	6	2
,, Government Grant for Printing, etc.				400	0	0
,, Sale of Publications and Reprints:						
University of Adelaide	45	6	0			
Sundries	61	16	11	107	2	11
,, Use of Room				9	15	0
,, Interest — Transferred from Endowment Fund				213	18	3
				£941	5	0

PAYMENTS				£	s.	d.	£	s.	d.
By Transactions—Vol. 72, Pt. 1, and portion of Pt. 2							472	12	0
,, Reprints							37	15	0
,, Librarian							37	4	0
,, Sundries—									
Lighting				3	10	7			
Printing, Postages & Stationery				54	16	5			
Petty Expenses				3	19	6			
Insurances				6	12	6			
Cleaning Rooms				12	17	6	81	16	6
,, Life Membership Subscription transferred to Endowment Fund							30	0	0
,, Balances, 30th Sep. 1949— Savings Bank of S.A.:									
General Account				248	18	11			
Endowment Fund				5	0	3			
Bank of Aust	£28	18	4						
Less Outstanding Cheque	1	0	0	27	18	4	281	17	6
							£941	5	0

ENDOWMENT FUND as at 30 September 1949

1948—1 October	£	s.	d.	£	s.	d.
To Balance—						
Aust. Inscribed Stock	6,008	10	0			
Savings Bank of S.A.	32	18	7	6,041	8	7
,, Interest—						
Inscribed Stock	207	17	1			
Savings Bank of S.A.	6	1	2	213	18	3
,, Life Membership Subscription				30	0	0
,, Profit on Stock converted				1	10	0
				£6,286	16	10

1949—30 September	£	s.	d.	£	s.	d.
By Revenue Account				213	18	3
,, Balance—						
Aust. Inscribed Stock	6,010	0	0			
Savings Bank of S.A.	62	18	7	6,072	18	7
				£6,286	16	10

Audited and found correct. The Stock and Bank Balances have been verified by certificates from the respective institutions.

Hon. Auditors—

F. M. ANGEL

N. S. ANGEL, A.U.A. (Com.)

Adelaide, October 1948

HERBERT M. HALE,
Hon. Treasurer

AWARDS OF THE SIR JOSEPH VERCO MEDAL

1929 Prof. Walter Howchin, F.G.S.
1930 John McC. Black, A.L.S.
1931 Prof. Sir Douglas Mawson, O.B.E., D.Sc., B.E., F.R.S.
1933 Prof. J. Burton Cleland, M.D.
1935 Prof. T. Harvey Johnston, M.A., D.Sc.
1938 Prof. J. A. Prescott, D.Sc., F.A.I.C.
1943 Herbert Womersley, A.L.S., F.R.E.S.
1944 Prof. J. G. Wood, D.Sc., Ph.D.
1945 Cecil T. Madigan, M.A., B.E., D.Sc., F.G.S.
1946 Herbert M. Hale

LIST OF FELLOWS, MEMBERS, ETC.

AS AT 30 MARCH 1950

Those marked with an asterisk (*) have contributed papers published in the Society's Transactions. Those marked with a dagger (†) are Life Members.

Any change in address or any other changes should be notified to the Security.

Note—The publications of the Society are not sent to those members whose subscriptions are in arrear.

Date of Election.

Honorary Fellows

1945. *Black, J. M., A.L.S., (*Hon. causa*), 82 Brougham Place, North Adelaide—*Verco Medal*, 1930; Fellow, 1907-45; *Council*, 1927-31; *President*, 1933-34; *Vice-President*, 1931-33.

1945. *Fenner, C. A. E., D.Sc., 42 Alexandra Avenue, Rose Park, Adelaide—Fellow, 1917-45; *Council*, 1925-28; *President*, 1930-31; *Vice-President*, 1928-30; *Secretary*, 1924-25; *Treasurer*, 1932-33; *Editor*, 1934-37.

1949. *Cleland, Prof. J. B., M.D., Dashwood Road, Beaumont, S.A.—*Fellow*, 1895-1949; *Verco Medal*, 1933; *Council*, 1921-26, 1932-37; *President*, 1927-28; 1940-41; *Vice-President*, 1926-27, 1941-42.

Fellows.

1946. Abbie, Prof. A. A., M.D., D.Sc., Ph.D., University of Adelaide.

1935. Adam, D. B., B.Agr.Sc., Waite Institute (Private Mail Bag), Adelaide—*Council*, 1939-42; *Vice-President*, 1942; *Librarian*, 1942-.

1927. *Alderman, A. R., Ph.D., D.Sc., F.G.S., Div. Indus. Chemistry, C.S.I.R.O., Box 4331, G.P.O., Melbourne, Victoria—*Council*, 1937-42.

1931. Andrew, Rev. J. R., c/o Methodist Manse, Maitland.

1935. *Andrewartha, H. G., M.Agr.Sc., D.Sc., Waite Institute (Private Mail Bag), Adelaide—*Council*, 1950.

1935. *Andrewartha, Mrs. H. V., B.Agr.Sc., M.S., (nee H. V. Steele), 29 Claremont Avenue, Netherby, S.A.

1929. *Angel, F. M., 34 Fullarton Road, Parkside, S.A.

1939. *Angel, Miss L. M., M.Sc., c/o University of Adelaide.

1945. *Bartlett, H. K., L.Th., 15 Claremont Avenue, Netherby, S.A.

1950. Beasley, A. K., Harris Street, Marden, S.A.

1950. Beck, R. G., B.Ag.Sc., R.D.A., Linewood Park, Mittel, S.A.

1932. Begg, P. R., D.D.Sc., L.D.S., Shell House, 170 North Terrace, Adelaide.

1928. Best, R. J., D.Sc., F.A.C.I., Waite Institute (Private Mail Bag), Adelaide.

1934. Black, E. C., M.B., B.S., Magill Road, Tranmere, Adelaide.

1950. Bonnin, N. J., M.B., B.S., F.R.C.S. (Eng.), F.R.A.C.S., 144 Hill Street, North Adelaide, S.A.

1945. *Bonython, C. W., B.Sc., A.A.C.I., Romalo House, Romalo Avenue, Magill, S.A.

1940. Bonython, Sir J. Lavington, B.A. (Camb.), 263 East Terrace, Adelaide.

1945. *Boomsma, C. D., M.Sc., B.Sc.For., 2 Celtic Avenue, South Road Park, S.A.

1947. Bowes, D. R., Ph.D., B.Sc., 51 Eton Street, Malvern.

Date of Election.

1939. Brookman, Mrs. R. D. (nee A. Harvey), B.A., Meadows, S.A.
1945. Broughton, A. C., Farina, S.A.
1948. Browning, T. O., B.Sc. (Syd.), Waite Institute (Private Mail Bag), Adelaide.
1944. *Burbidge, Miss N. T., M.Sc., C.S.I.R.O., Div. Plant Industry, P.O. Box 109, Canberra, A.C.T.
1923. Burdon, R. S., D.Sc., University of Adelaide—*Council*, 1946.
1922. *Campbell, T. D., D.D.Sc., D.Sc., Dental Dept., Adelaide Hospital, Adelaide—*Council*, 1928-32, 1935, 1942-45; *Vice-President*, 1932-34; *President*, 1934-35.
1944. Casson, P. B., B.Sc., For. (Adel.), 8 Benjafield Terrace, New Town, Hobart.
1929. Christie, W., M.B., B.S., Education Department, Social Services, 51 Pirie Street Adelaide—*Treasurer*, 1933-38.
1950. Coalstad, S. E., B.Sc., 6 Hampton Street, Hawthorn, S.A.
1949. Colliver, F. S., Geology Department, University of Queensland.
1930. *Colquhoun, T. T., M.Sc., 10 French Street, Netherby, S.A.—*Secretary*, 1942-43.
1907. *Cooke, W. T., D.Sc., A.A.C.I., 4 South Terrace, Kensington Gardens, S.A.—*Council*, 1938-41; *Vice-President*, 1941-42, 1943-44; *President*, 1942-43.
1942. *Cooper, H. M., 51 Hastings Street, Glenelg, S.A.
1944. Cornish, Melville, State Bank, Pirie Street, Adelaide.
1929. *Cotton, B. C., S.A. Museum, Adelaide—*Council*, 1943-46, 1948-49; *Vice-President*, 1949-50; *President*, 1950-.
1924. de Crespigny, Sir C. T. C., D.S.O., M.D., F.R.C.P., 219 North Terrace, Adelaide.
1950. Deland, C. M., M.B., B.S., D.P.H., D.J.M., 29 Gilbert Street, Goodwood, S.A.
1941. Dickinson, S. B., M.Sc., 52 Burnside Road, Kensington.
1930. Dix, E. V., Hospitals Department, Rundle Street, Adelaide, S.A.
1944. Dunstone, S. M. L., M.B., B.S., 124 Payneham Road, St. Peters, Adelaide.
1931. Dwyer, J. M., M.B., B.S., 105 Port Road, Hindmarsh, S.A.
1933. *Eardley, Miss C. M., M.Sc., University of Adelaide—*Council*, 1943-46.
1945. *Edmonds, S. J., B.A., M.Sc., 56 Fisher Terrace, Mile End, S.A.
1902. *Edquist, A. G., 19 Farrell Street, Glenelg, S.A.—*Council*, 1949-.
1944. Ferres, Miss H. M., M.Sc., 8 Taylor's Road, Mitcham, S.A.
1927. *Finlayson, H. H., 305 Ward Street, North Adelaide—*Council*, 1937-40.
1923. *Fry, H. K., D.S.O., M.D., B.S., B.Sc., F.R.A.C.P., Town Hall, Adelaide—*Council*, 1933-37; *Vice-President*, 1937-38, 1939-40; *President*, 1938-39.
1932. *Gibson, E. S. H., M.Sc., 297 Cross Roads, Clarence Gardens, Adelaide.
1927. Godfrey, F. K., Box 951H, G.P.O., Adelaide.
1935. †Goldsack, H., Coromandel Valley, S.A.
1925. †Gosse, Sir James H., Gilbert House, Gilbert Place, Adelaide.
1910. *Grant, Prof. Sir Kerr, M.Sc., F.I.P., 56 Fourth Avenue, St. Peters, S.A.
1930. Gray, J. T., Orroroo, S.A.
1933. Greaves, H., 12 Edward Street, Glynde, S.A.
1904. Griffith, H. B., Dunrobin Road, Brighton, S.A.
1948. Gross, G. F., B.Sc., South Australian Museum, Adelaide—*Secretary*, 1950-.
1944. Guppy, D. J., B.Sc., Mineral Resources Survey, Canberra, A.C.T.
1922. *Hale, H. M., Director S.A. Museum, Adelaide—*Verco Medal*, 1946; *Council*, 1931-34, 1950-; *Vice-President*, 1934-36, 1937-38; *President*, 1936-37; *Treasurer*, 1938-1950.
1949. Hall, D. R., Mern Merna, via Quorn, S.A.
1946. *Hardy, Mrs. J. E. (nee A. C. Beckwith), M.Sc., Box 62, Smithton, Tas.
1944. Harris, J. R., B.Sc., 94 Archer Street, North Adelaide, S.A.
1947. Henderson, D. L. W., P.M.B., 20 Bourke, N.S.W.
1944. Herriot, R. I., B.Agr.Sc., Soil Conservator, Dept. of Agriculture, S.A.
1949. Holloway, B. W., B.Sc., 33 Kyre Avenue, Kingswood, S.A.
1924. *Hossfeld, P. S., M.Sc., 132 Fisher Street, Fullarton, S.A.
1950. Howard, P. F., B.Sc., c/o Great Western Consolidated, Bullfinch, W.A.
1944. Humble, D. S. W., 238 Payneham Road, Payneham, S.A.
1947. Hutton, J. T., B.Sc., 18 Emily Avenue, Clapham.
1928. Ifould, P., Kurralta, Burnside, S.A.
1942. Jenkins, C. F. H., Department of Agriculture, St. George's Terrace, Perth, W.A.
1918. *Jennison, Rev. J. C., 7 Frew Street, Fullarton, S.A.
1945. *Jessup, R. W., M.Sc., 3 Alma Road, Fullarton, S.A.
1910. *Johnson, E. A., M.D., M.R.C.S., 1 Baker Street, Glenelg.
1950. Johns, R. K., B.Sc., Department of Mines, Flinders Street, Adelaide, S.A.
1921. *Johnston, Prof. T. H., M.A., D.Sc., University of Adelaide—*Verco Medal*, 1935; *Council*, 1926-28, 1940-; *Vice-President*, 1928-31; *President*, 1931-32; *Secretary*, 1938-40; *Rep. Fauna and Flora Board*, 1932-39; *Editor*, 1943-45.
1939. †Khakhar, H. M., Ph.D., M.B., F.R.G.S., Khakhar Buildings, C.P. Tank Road, Bombay, India.

Date of Election.

1949. *KING, D., M.Sc., 44 Angwin Avenue, Blair Athol, S.A.
1933. *KLEEMAN, A. W., M.Sc., University of Adelaide—*Secretary*, 1945-48; *Vice-President*, 1948-1949, 1950-; *President*, 1949-50.
1922. LENDON, G. A., M.D., B.S., F.R.C.P., A.M.P. Building, King William Street, Adelaide.
1948. LOTHIAN, T. R. N., N.D.H. (N.Z.), Director, Botanic Gardens, Adelaide.
1949. LOWER, H. F., 7 Avenue Road, Highgate, S.A.
1931. *LUDBROOK, MRS. W. V. (nee N. H. Woods), M.A., Elimatta Street, Reid, A.C.T.
1948. MCCULLOCH, R. N., M.B.E., B.Sc. (Oxon.), B.Agr.Sci. (Syd.), Roseworthy Agricultural College, S.A.
1938. MADDERN, C. B., B.D.S., D.D.Sc., Shell House, North Terrace, Adelaide.
1932. MANN, E. A., C/o Bank of Adelaide, Adelaide.
1939. MARSHALL, T. J., M.Agr.Sc., Ph.D., Waite Institute (Private Mail Bag), Adelaide—*Council*, 1948-.
1905. *MAWSON, PROF. SIR DOUGLAS, O.B.E., D.Sc., B.E., F.R.S., University of Adelaide—*Verco Medal*, 1931; *President*, 1924-25, 1944-45; *Vice-President*, 1923-24, 1925-26; *Council*, 1941-43.
1950. MAY, L. H., B.Sc., 691 Esplanade, Grange, S.A.
1920. MAYO, THE HON. MR. JUSTICE, LL.B., K.C., Supreme Court, Adelaide.
1950. MAYO, G. M. E., B.Ag.Sc., Waite Institute (Private Mail Bag), Adelaide, S.A.
1943. MCCARTHY, MISS D. F., B.A., B.Sc., 70 Halton Terrace, Kensington Park.
1945. †*MILES, K. R., D.Sc., F.G.S., Mines Department, Flinders Street, Adelaide.
1939. MINCHAM, V. H., Hammond, S.A.
1925. †MITCHELL, PROF. SIR W., K.C.M.G., M.A., D.Sc., Fitzroy Ter., Prospect, SA.
1933. MITCHELL, PROF. M. L., M.Sc., University, Adelaide.
1938. MOORHOUSE, F. W., M.Sc., Chief Inspector of Fisheries, Flinders Street, Adelaide.
1936. *MOUNTFORD, C. P., 25 First Avenue, St. Peters, Adelaide.
1944. MURRELL, J. W., Engineer ng and Water Supply Dept., Port Road, Thebarton, S.A.
1944. NEAL-SMITH, C. A., B.Agr.Sci., 16 Gooreen Street, Reid, Canberra, A.C.T.
1944. NINNES, A. R., B.A., 62 Sheffield Street, Malvern, S.A.
1945. *NORTHCOTE, K. H., B.Agr.Sc., A.I.A.S., Waite Institute (Private Mail Bag), Adelaide.
1930. OCKENDEN, G. P., B.A., c/o Flinders Street Practising School, Flinders St., Adelaide.
1947. *OPHEL, I. L., 65 Fifth Avenue, St. Peters, S.A.
1913. *OSBORN, PROF. T. G. B., D.Sc., Department of Botany, Oxford, England—*Council*, 1915-20, 1922-24; *President*, 1925-26; *Vice-President*, 1924-25, 1926-27.
1937. *PARKIN, L. W., M.Sc., c/o North Broken Hill Mining Co., Melbourne, Victoria.
1949. PARKINSON, K. J., B.Sc., 8 Mooreland Avenue, Beverley, S.A.
1945. PATTISON, G., 68 Partridge Street, Glenelg, S.A.
1929. PAULL, A. G., M.A., B.Sc., 10 Milton Avenue, Fullarton, S.A.
1926. *PIPER, C. S., D.Sc., Waite Institute (Private Mail Bag), Adelaide—*Council*, 1941-43; *Vice-President*, 1943-45, 1946-47; *President*, 1945-46.
1948. POWRIE, J. K., B.Sc., C.S.I.R.O., Division of Biochemistry, University, Adelaide.
1947. POYNTON, J. O., M.D., M.A., Ch.B., M.R.C.S., L.R.C.P., Institute Medicine, Vet. Science, Frome Road, Adelaide.
1949. PRAITE, R. G., 81 Park Terrace, North Unley, S.A.
1925. *PRESCOTT, PROF. J. A., C.B.E., D.Sc., A.I.C., Waite Institute (Private Mail Bag), Adelaide—*Verco Medal*, 1938; *Council*, 1927-30, 1935-39; *Vice-President*, 1930-32; *President*, 1932-33.
1926. PRICE, A. G., C.M.G., M.A., Litt.D., F.R.G.S., 46 Pennington Terrace, North Adelaide.
1945. PRYOR, L. D., M.Sc., Dip.For., 32 La Perouse Street, Griffith, N.S.W.
1950. *RATTIGAN, J. H., B.Sc., Bureau of Mineral Resources, Melbourne Building, Canberra, A.C.T.
1944. RICEMAN, D. S., M.Sc., B.Agr.Sc., C.S.I.R.O., Division of Nutrition, Adelaide.
1947. RIEDEL, W. R., B.Sc., Oceanographic Institute, Gottenburg, Sweden.
1948. *RIMES, G. D., B.Sc., 24 Winston Avenue, Clarence Gardens, S.A.
1947. RIX, C. E., 42 Waymouth Avenue, Glandore, S.A.
1946. *ROBINSON, E. G., M.Sc., 42 Riverside Drive, Sudbury, Ontario, Canada.
1950. RUDD, PROF. E. A., B.Sc., A.M., University, Adelaide, S.A.
1945. RYMILL, J. R., Old Penola Estate, Penola, S.A.
1944. *SANDARS, MISS D. F., M.Sc., University of Queensland, Brisbane, Queensland.
1950. SAUNDERS, F. L., 79 Winchester Street, Malvern, S.A.
1933. SCHNEIDER, M., M.B., B.S., 175 North Ter., Adelaide.
1946. *SEGNIT, E. R., M.Sc., C.S.I.R.O., Division of Industrial Chemistry, Box 4331, G.P.O., Melbourne, Victoria.

Date of Election.

1924. *SEGNIT, R. W., M.A., B.Sc., Engineering and Water Supply Department, Victoria Square, Adelaide—*Secretary*, 1930-35; *Council*, 1937-38; *Vice-President*, 1938-39, 1940-41; *President*, 1939-40.

1925. *SHEARD, H., Port Elliot, S.A.

1936. *SHEARD, K., Fisheries Research Div. C.S.I.R.O., University of W.A., Nedlands, W.A.

1945. SHEPHERD, J. H., M.Sc., B.A., c/o Anglo-Westralian Mining Pty. Ltd.

1934. SHINKFIELD, R. C., Salisbury, S.A.

1924. SIMPSON, F. N., Pirie Street, Adelaide.

1949. SIMPSON, D. A., M.B., B.S., 42 Lockwood Road, Burnside, S.A.

1941. *SMITH, T. LANGFORD-, B.Sc., Department of Post-War Reconstruction, Canberra, A.C.T.

1941. SOUTHCOTT, R. V., M.B., B.S., 12 Avenue Road, Unley Park, S.A.

1936. SOUTHWOOD, A. R., M.D., M.S. (Adel.), M.R.C.P., Wootoona Ter., Glen Osmond, S.A.

1947. *SPECHT, R. L., M.Sc., 15 Main Road, Richmond, S.A.

1936. *SPRIGG, R. C., M.Sc., Mines Department, Flinders Street, Adelaide.

1947. SPURLING, M. B., B.Ag.Sc., Agricultural College, Roseworthy, S.A.

1949. *SPRY, A. H., B.Sc., 63 LeFevre Terrace, North Adelaide, S.A.

1938. *STEPHENS, C. G., D.Sc., Waite Institute (Private Mail Bag), Adelaide.

1935. SRRICKLAND, A. G., M.Agr.Sc., 11 Wootoona Terrace, Glen Osmond, S.A.—*Council*, 1947.

1932. SWAN, D. C., M.Sc., Waite Institute (Private Mail Bag), Adelaide—*Secretary*, 1940-42; *Vice-President*, 1946-47, 1948-49; *President*, 1947-48.

1948. SWANN, F. J. W., 38 Angas Road, Lower Mitcham, S.A.

1934. SYMONS, I. G., 35 Murray Street, Lower Mitcham, S.A.—*Editor* 1947-.

1929. *TAYLOR, J. K., B.A., M.Sc., Waite Institute (Private Mail Bag), Adelaide—*Council*, 1940-43, 1947-.

1950. TAYLOR, G. H., B.Sc., Department of Mines, Old Legislative Council Building, North Terrace, Adelaide, S.A.

1948. *THOMAS, I. M., M.Sc. (Wales), University, Adelaide—*Secretary*, 1948-50; *Council*, 1950-.

1938. *THOMAS, MRS. I. M. (nee P. M. Mawson), M.Sc., 36 King Street, Brighton.

1940. THOMSON, CAPT. J. M., 135 Military Road, Semaphore South, S.A.

1923. *TINDALE, N. B., B.Sc., South Australian Museum, Adelaide—*Secretary*, 1935-36; *Council*, 1946-47; *Vice-President*, 1947-48, 1949-50; *President*, 1948-49.

1945. TIVER, N. S., M.Sc., B.Agr.Sc., Waite Institute (Private Mail Bag), Adelaide.

1937. *TRUMBLE, PROF. H. C., D.Sc., M.Agr.Sc., Waite Institute (Private Mail Bag), Adelaide—*Council*, 1942-1945; *Vice-President*, 1945-46, 1947-48; *President*, 1946-47.

1925. TURNER, D. C., Brookman Buildings, Grenfell Street, Adelaide.

1950. VIETCH, S. T., Port Lincoln, S.A.

1912. *WARD, L. K., I.S.O., B.A., B.E., D.Sc., 22 Northumberland Avenue, Tusmore—*Council*, 1924-27, 1933-35; *Vice-President*, 1927-28; *President*, 1928-30.

1941. *WARK, D. C., M.Agr.Sc., Div. Plant Industry, C.S.I.R.O., Canberra, A.C.T.

1936. WATERHOUSE, MISS L. M., 35 King Street, Brighton, S.A.

1939. *WEEDING, REV. B. J., 5 York Street, Henley Beach.

1949. *WEGENER, C. F., B.Sc., Department Mines, Flinders Street, Adelaide, S.A.

1946. WHITTLE, A. W. G., B.Sc., Mines Department, Flinders Street, Adelaide.

1950. WILLIAMS, L. D., "Dumosa," Meningie, S.A.

1946. *WILSON, A. F., M.Sc., University of W.A., Nedlands, W.A.

1938. *WILSON, J. O., C.S.I.R.O., Division of Nutrition, Adelaide.

1930. *WOMERSLEY, H., F.R.E.S., A.L.S. (*Hon. causa*), S.A. Museum, Adelaide—*Verco Medal*, 1943; *Secretary*, 1936-37; *Editor*, 1937-43, 1945-47; *President*, 1943-44, *Vice-President*, 1944-45; *Rep. Fauna and Flora Protection Committee*, 1945.

1944. *WOMERSLEY, H. B. S., M.Sc., University of Adelaide.

1944. WOMERSLEY, J. S., B.Sc., Lae, New Guinea.

1923. *WOOD, PROF. J. G., D.Sc., Ph.D., University of Adelaide—*Verco Medal*, 1944; *Council*, 1938-40; *Vice-President*, 1940-41, 1942-43; *Rep. Fauna and Flora Board*, 1940-; *President*, 1941-42; *Council*, 1944-48.

1950. WOODARD, G. D., 20 Kensington Road, Leabrook, S.A.

1943. WOODLANDS, HAROLD, Box 989 H, G.P.O., Adelaide.

1945. WORTHLEY, B. W., B.A., M.Sc., A. Inst. P., University, Adelaide.

1948. *WYMOND, A. P., B.Sc., 4 Woodley Road, Glen Osmond, S.A.

1949. YEATES, J. N., L.S., A.M.I.E., A.M.I.M.E., Richards Buildings, 99 Currie Street, Adelaide, S.A.

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[Names in italics denote that the forms described are new to science]

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