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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

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CECIL THOMAS MADIGAN, M.A., B.E., D.Sc., F.G.S.

TRANSACTIONS OF THE ROYAL SOCIETY
OF SOUTH AUSTRALIA INCORPORATED

OBITUARY NOTICE

CECIL THOMAS MADIGAN

Cecil Thomas Madigan, M.A., B.E., D.Sc., F.G.S., a leading Australian geologist and geographer, a member of this Society for the past 25 years, and a Past President, died at the early age of 57 years on 14 January 1947.

Curtailement of his span of life was doubtless the result of heart strain resulting from exceptional exertions in the field of sport, exploration and war.

His earlier education was received at the Adelaide High School, Prince Alfred College and the University of Adelaide, where he graduated in Mining Engineering in 1910. As a Rhodes Scholar from South Australia, he then proceeded to Magdalen College, Oxford, to continue with geological studies, which were, however, to be postponed, for late in 1911 he joined the Scientific Staff of the Australasian Antarctic Expedition of 1911-14.

Dr. Madigan's record during more than two years in Antarctica was outstanding. It includes leadership of a sledging party which reconnoitred the ice plateau in winter time under record adverse climatic conditions. In the summer of 1912-13 he successfully led a sledge journey, charting a great length of new coast line of the territory thereafter known as King George Land. On return to winter quarters, he was selected to be in charge of all land operations pending the return of the Expedition Leader, who at that time had failed to return from a journey across the plateau ice.

His graphic account of the summer sledge journey forms a section of the popular story of the Expedition, published as "The Home of the Blizzard." He was chiefly responsible for the meteorological record of the Cape Denison Station, which is published as an important section of the Expedition's Scientific Reports issued from the Government Printing Office, Sydney.

On the advent of war when again in England in 1914, he joined the Royal Engineers and served throughout the whole period with rank of Captain. Later, having finally graduated at Oxford, he was appointed Assistant Government Geologist in the Soudan. This post he relinquished in 1922 to join the staff of the University of Adelaide.

With the outbreak of the Second World War, Dr. Madigan was appointed chief instructor in the School of Military Field Engineering (Liverpool, N.S.W.), attaining the rank of Lieut.-Colonel.

During his long term as lecturer in Geology, he found time to execute a number of important geological investigations dealing with problems relating to South Australia and to Central Australia. It is in the latter field that his work has received most recognition. His explorations in the MacDonnell Ranges and neighbourhood, and in the Simpson Desert, have established him as the leading authority on the Geography and Geology of Central Australia. For this work he was the recipient of wide recognition in scientific circles both in Australia and abroad. He is also well remembered for his zeal in furthering the good work of the Legacy Club and the University Graduates' Association.

His published scientific works additional to those dealing with his Antarctic activities mentioned above are the following:—

- "A Description of some Old Towers in the Red Sea Province, North of Port Soudan." *Soudan Notes and Records*, 5 (1922), 78-82.
- "The Geology of the Fleurieu Peninsula, Part I — The Coast from Sellick's Hill to Victor Harbour." *Proc. Roy. Soc. S. Aust.*, 49 (1925), 198-212.
- "Organic Remains from below the Archaeocyathinae Limestones at Myponga Jetty, South Australia." *Trans. Roy. Soc. S. Aust.*, 50 (1926), 32-33.
- "The Geology of the Willunga Scarp." *Proc. Roy. Soc. S. Aust.*, 51 (1927), 398-409.
- A.N.Z.A.A.S. Reports of the Glacial Research Committee (with D. Mawson), 19 (1928), 97-99.
- "Preliminary Notes on New Evidence as to the Age of Formations on the North Coast of Kangaroo Island." *Trans. Roy. Soc. S. Aust.*, 52 (1928), 213-214.
- "An Aerial Reconnaissance into the South-Eastern Portion of Central Australia." *Proc. Roy. Geog. Soc. (S. Aust. Branch)*, 30 (1929), 83-108.
- "Lake Eyre, South Australia." *Geog. Jour.*, 76 (1930), 215-240.
- "Pre-Ordovician Rocks of the MacDonnell Ranges, Central Australia" (with D. Mawson). *Qld. Jour. Geog. Soc.*, 86 (1930), 415-428.
- "Geology of the Western MacDonnell Ranges, Central Australia." *Qld. Jour. Geog. Soc.*, 88 (1932), 672-711.
- "The Geology of the Eastern MacDonnell Ranges, Central Australia." *Trans. Roy. Soc. S. Aust.*, 56 (1932), 71-117.
- "The Physiography of the Western MacDonnell Ranges, Central Australia." *Geog. Jour.*, 78 (1932), 417-433.
- A.N.Z.A.A.S.—Reports of the Glacial Phenomena Committee, 21 (1932), 464.
- "The Geology of the MacDonnell Ranges and Neighbourhood, Central Australia." *Reports A.N.Z.A.A.S.*, 21 (1933), 75-86.
- "The Australian Sand-ridge Deserts." *Geog. Rev.* (1936), 26, (2), 205-227.
- "Central Australia." Oxford University Press, 1936 and (2nd ed.) 1946.
- S. Aust. Royal Society Centenary Address: "The Past, Present and Future of the Society, and its Relation to the Welfare and Progress of the State." *Proc. Roy. Soc. S. Aust.*, 60 (1936), I-XV
- "Additions to the Geology of Central Australia." *A.N.Z.A.A.S. Reports*, 23 (1937), 89-92.
- "A Review of the Arid Regions of Australia and their Economic Potentialities." *A.N.Z.A.A.S. Reports—Presidential Address, Section P*, 23 (1937), 375
- "The Boxhole Crater and the Huckitta Meteorite." *Proc. Roy. Soc. S. Aust.*, 61 (1937), 187-190.
- "The Huckitta Meteorite, Central Australia" (with A. R. Alderman). *Min. Mag.*, (1939), 25, (165), 353-371.
- "The Boxhole Meteoritic Iron, Central Australia" (with A. R. Alderman). *Min. Mag.*, (1940), 25, (168), 481-486
- "Simpson Desert Expedition, 1939: Scientific Reports—Introduction, Narrative, Physiography and Meteorology." *Proc. Roy. Soc. S. Aust.*, 69 (1945), 118-139.
- "Simpson Desert Expedition, 1939: Scientific Reports—No. 6—Geology: The Sand Formations." *Proc. Roy. Soc. S. Aust.*, 70 (1946), 45-63.

NEW GENERA AND SPECIES OF TROMBICULIDAE FROM THE PACIFIC ISLANDS

By H. WOMERSLEY AND G.M. KOHLS

Summary

Description of Larvae-Shape ovate. Length (engorged) to 450, width to 300. Scutum pentagonal, as figured, with the anterior margin lightly sinuous, posterior angle rounded. Sensillae ciliated on distal half, with the sensillae bases nearer to each other than to PL and placed slightly anterior of line of PL. Eyes 2+2, on distinct ocular shields, the posterior eyes the smaller. Chelicerae not serrated on inner (dorsal) edge, with the usual small apical tricuspid cap forming the apical tooth, a small subapical dorsal tooth, and a small subapical ventral tooth. Galeal setae nude. Palpi stout, tibial claw bifurcate; seta on palpal femur 2-3-branched; on genu nude, on tibia only the ventral seta branched; tarsi short, with basal and subapical rods, and five or six ciliated setae, one of which is much stronger than the rest and over-reaches the tip of the tibial claw by the claw's length.

TRANSACTIONS OF THE ROYAL SOCIETY
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NEW GENERA AND SPECIES OF TROMBICULIDAE
FROM THE PACIFIC ISLANDS

By H. WOMERSLEY⁽¹⁾ and G. M. KOHLES⁽²⁾

[Read 10 October 1946]

Eutrombicula gymnodactyla n. sp.

Fig. 1 A-F

Description of Larvae—Shape ovate. Length (engorged) to 450 μ , width to 300 μ . Scutum pentagonal, as figured, with the anterior margin lightly sinuous, posterior angle rounded. Sensillae ciliated on distal half, with the sensillae bases nearer to each other than to PL and placed slightly anterior of line of PL. Eyes

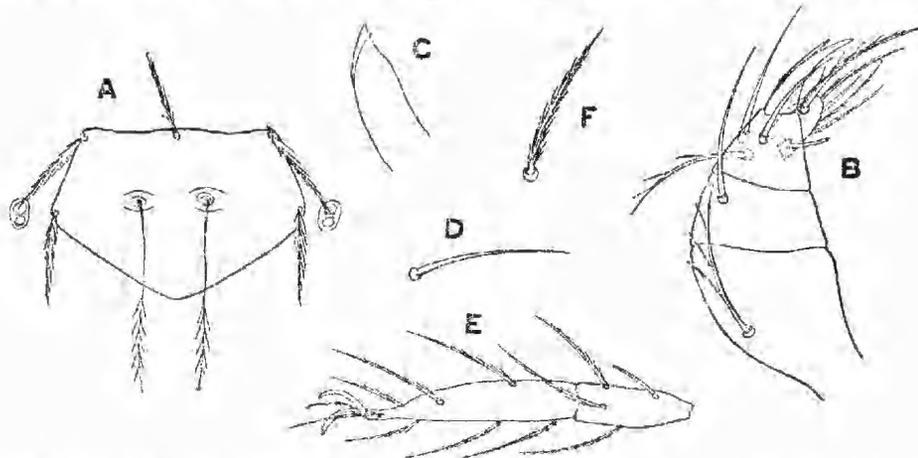


Fig. 1 *Eutrombicula (Ascariscus) gymnodactyla* n. sp. A, dorsal scutum (x500); B, palp in dorsal view (x860); C, tip of chelicera (x860); D, galeal seta; E, tarsus and metatarsus III (x450); F, dorsal seta (x860).

2+2, on distinct ocular shields, the posterior eyes the smaller. Chelicerae not serrated on inner (dorsal) edge, with the usual small apical tricuspid cap forming the apical tooth, a small subapical dorsal tooth, and a small subapical ventral tooth. Galeal setae nude. Palpi stout, tibial claw bifurcate; seta on palpal femur 2-3-branched; on genu nude, on tibia only the ventral seta branched; tarsi short, with basal and subapical rods, and five or six ciliated setae, one of which is much stronger than the rest and over-reaches the tip of the tibial claw by the claw's length.

Dorsal setae 24 in number, to 30 μ long, ciliated and arranged 2,6,6,4,4,2. Ventrally with a pair of branched setae on gnathosoma, one on each coxa, a pair between coxae I and between coxae III, thereafter uncertain as all specimens

⁽¹⁾ Entomologist, South Australian Museum.

⁽²⁾ Major S. C., United States of America Typhus Commission, now Entomologist, U.S. Public Health Service, Rocky Mountain Laboratory, Hamilton, Montana.

were heavily infested with sporozoa but approximately to $20\ \mu$ in length. Legs: I $210\ \mu$ long, II $195\ \mu$, III $210\ \mu$; tarsi I and II with the usual dorsal sensory rods; tarsi III without any long nude seta.

The Standard Data (see Womersley and Heaslip 1943) in microns for the type and three paratypes.

	Mean	Standard Deviation	Theoretical Range	Observed Range	Coeff. of Variation
AW ...	45.75 ± 0.75	1.50 ± 0.50	41.25—50.25	45.0—48.0	3.2
PW ...	60.0	No variation recorded			
SB ...	16.5 ± 0.87	1.73 ± 0.61	11.3—21.7	15.0—18.0	10.5
ASB ...	18.0	No variation recorded			
PSB ...	23.25 ± 0.75	1.50 ± 0.53	18.75—23.75	21.0—24.0	6.4
SD ...	41.25 ± 0.75	1.50 ± 0.53	36.75—45.75	39.0—42.0	3.6
A-P ...	19.5 ± 0.87	1.73 ± 0.61	14.3—24.7	18.0—21.0	8.8
AM ...	24.0	No variation recorded			
AL ...	25.5 ± 0.87	1.73 ± 0.61	20.3—30.7	24.0—27.0	6.8
PL ...	27.0	No variation recorded			
Sens. ...	47.0 ± 1.0	1.73 ± 0.71	41.8—52.2	45.0—48.0	3.7

Loc.—This species is described from four specimens from *Gymnodartylus lausiedensis* from Sansapor, Dutch New Guinea (G. M. K., Sansapor, No. 3, 26 Aug. 1944).

Remarks.—In the pentagonal scutum this species would fall into Sig Thor's subgenus *Pentagonella* 1935, but the bifurcate palpal claw puts it into Ewing's *Entrombicula* 1938, and the number of dorsal setae into *Ascariscus* Ewing 1943. We concur, however, with Michener 1946 (*Annals. Ent. Soc. America*, 29, (1), 101-118, in regarding *Ascariscus* as a synonym of *Entrombicula*.

The type and one paratype in the South Australian Museum, and two paratypes in the U.S. National Museum.

Genus *Novotrombicula* nov.

Larvae.—As in *Trombicula* Berl. s.l., with the dorsal scutum furnished with paired filamentous sensillae and the usual five setae (one AM, two AL, and two PL), but produced posteriorly and tongue-like, so as to include, in addition to the above, some of the median setae of some of the dorsal rows as in the genus *Gahrleipia*.

Genotype *Novotrombicula owiensis* n. sp.

Novotrombicula owiensis n. sp.

Fig. 2 A-H

Description of Larvae.—Shape subrotund. Size small; length (unfed) $255\ \mu$, width $180\ \mu$. Dorsal scutum large, tongue-shaped and produced posteriorly to take in the two median setae of the third dorsal row, in addition to the AM, AL and PL setae; sensillae long and filamentous with ciliations on the distal half, bases wide apart and about midway between lines of AL and PL. Eyes 2+2, on distinct ocular shields placed close to the lateral scutal margin; posterior eyes the smaller. Chelicera with only the usual apical tricuspid cap, but on the inner margin below the cap with a rather prominent subapical angle. Galeal setae long and nude. Palpi rather slender, with rather long slender and bifurcate tibial claw, the dorsal prong of which is small and indistinct; palpal femur and genu with a long slender, shortly ciliated seta; all three setae on tibia long and apparently nude; tarsi moderately long and conical, with a long subbasal sensory rod and five or six long ciliated setae.

Dorsal setae rather thick, slightly tapering, shortly ciliated and of two sizes, arranged 2.4.4|2|.4.2.2; the second row with the medial pair just off the scutum and to $57\ \mu$ long; the inner members of the third row are on the scutum and are



Fig 2 *Novotrombicula owlensis* n. g. and n. sp. A, dorsal view; B, ventral view; C, dorsal scutum ($\times 500$); D, palp in dorsal view ($\times 860$); E, tip of chelicera ($\times 860$); F, galeal seta; G, dorsal seta ($\times 860$); H, tarsus and metatarsus III ($\times 450$).

short to $24\ \mu$. Ventrally with a pair of branched or ciliated setae on the gnathosoma, one on each coxa, a pair between coxae I and between coxae III and thereafter 6.2.2.2.2. to $24\ \mu$ long. All three pairs of coxae touching. Legs: I $255\ \mu$ long, II $240\ \mu$, III $275\ \mu$; tarsi I and II with the usual sensory rod-like seta, III without any long nude seta.

The Standard Data in microns for type and two paratypes are:

	Mean	Standard Deviation	Theoretical Range	Observed Range	Coeff. of Variation
AW ...	89.3 ± 1.20	2.08 ± 0.85	83.1—95.5	87.0—91.0	2.3
PW ...	95.5 ± 1.33	2.31 ± 0.94	88.0—102.2	94.0—98.0	2.4
SB ...	61.0 ± 1.00	1.73 ± 0.71	55.8—66.2	60.0—63.0	2.8
ASB ...	16.0 ± 1.0	1.73 ± 0.71	10.8—21.2	15.0—18.0	10.9
PSB ...	112.0	No variation recorded			
SD ...	128.0 ± 1.00	1.73 ± 0.71	122.8—133.2	127.0—130.0	1.3
A-P ...	20.7 ± 0.31	0.54 ± 0.22	19.1—22.3	20.0—21.0	2.6
AM ...	40.3 ± 0.88	1.53 ± 0.62	35.7—44.7	39.0—42.0	3.8
AL ...	30.0	No variation recorded			
PL ...	45.0	No variation recorded			
Sens. ..	67.0 ± 1.0	1.73 ± 0.71	61.8—72.2	66.0—69.0	2.6

Loc.—Six specimens collected from the soil at the base of a large tree on Owi Island, North Coast of Dutch New Guinea, 15 Aug. 1944 (G. M. K., Owi 22 C.).

Remarks—But for the prolongation of the dorsal scutum to include some of the medial dorsal setae, this interesting species would fall into *Trombicula* s.l. The form of the scutum, however, is parallel to that found in the genus *Gahrlepiea* of the group of genera with clavate sensillae and justifies the erection of a new genus.

The type and two paratypes in the South Australian Museum, three paratypes in the collection of the Rocky Mountain Laboratory.

Schongastia philipi n. sp.

Fig. 3 A-G

Description of Larvae—Shape an elongate oval. Length (unfed) $236\ \mu$, width $182\ \mu$. Scutum more or less hexagonal, with the posterior margin 3-sided and deep behind line of PL with a slight concavity medially; AM seta very much shorter than AL and PL, AL the longest; sensillae more capitate than clavate with their bases in line with PL. Eyes $2 + 2$, apparently not on ocular shields, the posterior eyes the smaller. Chelicerae not unusually slender, with apical tricuspid cap and on the inner (dorsal) margin with three to four strong and some smaller teeth. Galeal setae nude. Palpi stout, with trifurcate tibial claw; seta on palpal femur ciliated or branched; on genu nude; on tibia dorsal and lateral nude, ventral branched; tarsus short, with basal and subapical sensory rods and several ciliated setae.

Dorsal setae $36-40\ \mu$ long, ciliated, 28 in number and arranged 2.8.6.6.4.2. Ventrally with paired branched setae on gnathosoma, a ciliated seta on each coxa, a pair between coxae I and between coxae III, and thereafter 4.6.6.6.2.2. to $25\ \mu$ long. Legs: I $256\ \mu$ long, II $228\ \mu$, III $256\ \mu$; tarsi I and II with dorsal sensory rod, III with a long nude seta arising subbasally and dorsally.

The Standard Data for type and four paratypes are:

	Mean	Standard Deviation	Theoretical Range	Observed Range	Coeff. of Variation
AW ...	48.6±1.12	2.51±0.80	41.1-56.1	45.0-51.0	.5-1
PW ...	69.6±0.40	0.89±0.28	66.9-72.3	68.0-70.0	1.3
SB ...	18.4±0.40	0.89±0.28	15.7-21.1	18.0-20.0	4.8
ASB ...	24.0	No variation recorded			
PSB ...	21.0	No variation recorded			
SD ...	45.0	No variation recorded			
A P ...	23.6±0.40	0.89±0.28	20.9-26.3	22.0-24.0	3.8
AM ...	22.2±0.73	1.64±0.52	17.3-27.1	21.0-24.0	7.4
AL ...	59.2±0.49	1.04±0.34	55.9-62.5	58.0-60.0	1.8
PL ...	42.6±1.12	2.51±0.79	35.1-50.1	39.0-45.0	5.9
Sens. ...	30.0	with head 15/18			

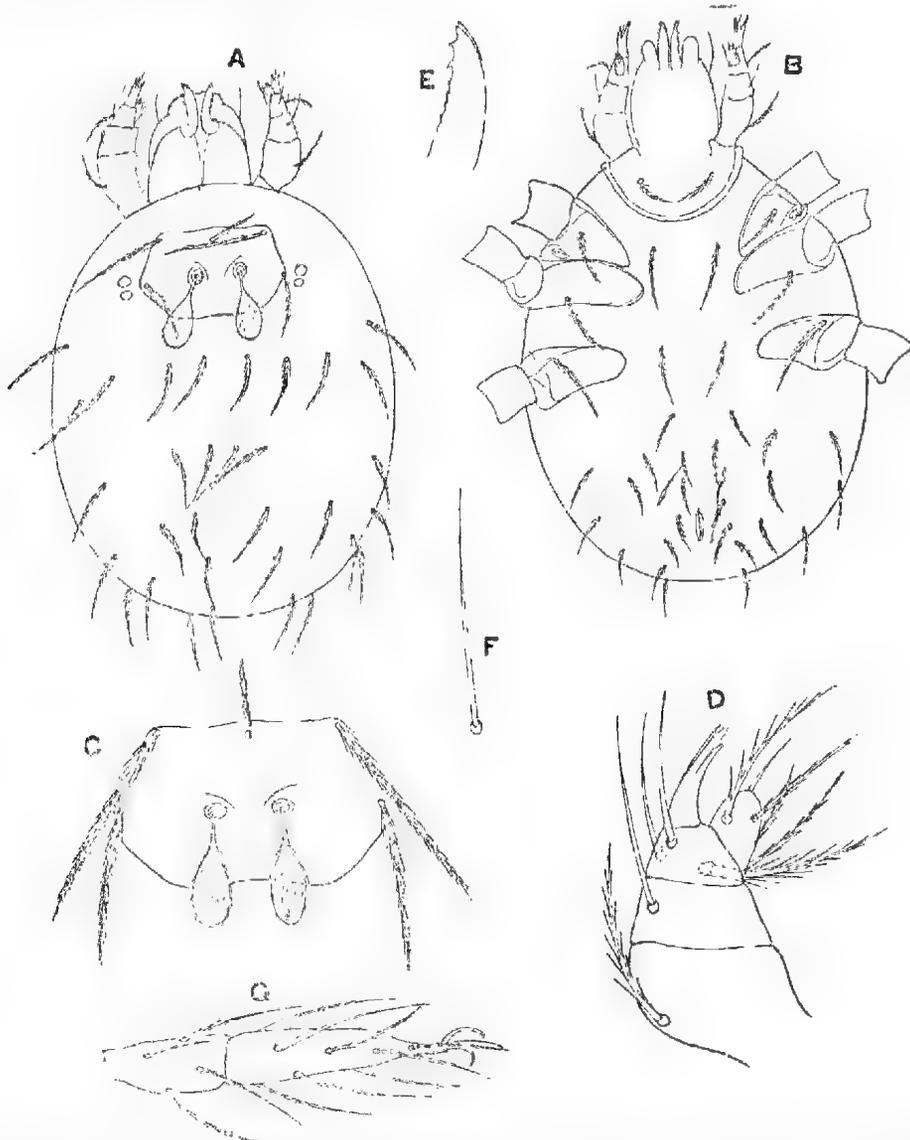


Fig. 3. *Schöngastia philipi* n.sp. A, dorsal view; B, ventral view; C, dorsal scutum (x 500); D, palp in dorsal view (x 860); E, tip of chelicera (x 860); F, galeal seta; G, tarsus and metatarsus III (x 450).

Loc.—Type and nine paratypes from a lizard *Leiolopisma albertisii* from Goodenough Island, New Guinea, 17 Jan. 1944 (G. M. K., No. 486).

Remarks.—The dentition of the chelicerae in this species is somewhat different from the many small teeth found in other species of *Schöngastia*, but this is not sufficient to warrant generic separation.

The type and four paratypes in the South Australian Museum, and one paratype to be deposited in the British Museum; one paratype to be deposited in the U.S. National Museum and in the Rocky Mountain Laboratory.

Genus *Oenoschongastia* nov.

Allied to *Schöngastia* but the chelicerae are short, curved and stumpy with the apex divided into two terminal blunt and thick teeth, with a pair (sometimes three) of rather smaller teeth subapically. Palpal claw short and stout, trifurcate. Median tarsal claw (empodium) longer than the laterals but equally thick. Sensillae clavate or capitate.

Oenoschongastia cana n. sp.

Fig. 4 A-G

Description of Larvae.—Shape an elongate oval. Length (unfed) 252 μ , width 162 μ . Dorsal scutum roughly hexagonal with indistinct and fine pitting; with the usual five normal ciliated setae, of which AL are the longest and AM the shortest, AM with short branches, AL and PL with long outstanding branches; sensillae broadly clavate, the head indistinctly and very shortly setulose, sensillae bases about in line with PL; anterior scutal margin convex, posterior laterally angular. Eyes 2 + 2, large, on well-developed ocular shields and closely adjacent to scutum, posterior eyes the smaller. Chelicerae of peculiar form, short, stout and curved, apex truncate and divided into two strong, broad and blunt teeth, and two (sometimes three) smaller teeth placed subapically on the inner edge. Galeal setae nude. Palpi stout, tibial claw short, stout and trifurcate; femur with a long strong seta with long branches; genu with a nude seta; tibia with the dorsal and lateral setae nude, ventral branched; tarsi short with basal and subapical sensory rods and three or four ciliated or branched setae. Dorsal setae strong with strong ciliations, 36 in number and arranged 2.8.10.6.6.4., to 40-50 μ long. Ventrally with the usual pair of branched setae on gnathosoma, a single seta on each coxa, a pair between coxae I and between coxae III, and thereafter 6.6.6.4.2, more slender and with longer ciliations than the dorsal setae, to 30 μ long. Legs: I 324 μ long, II 252 μ , III 380 μ ; tarsi I and II with the usual dorsal rod-like setae, tarsi III with a long outstanding nude seta*; median claw (empodium) longer than but as thick as the laterals.

The Standard Data in microns derived from 22 specimens are:

	Mean	Standard Deviation	Theoretical Range	Observed Range	Coeff. of Variation
AW ...	62.85 \pm 0.56	2.65 \pm 0.40	54.9 - 70.8	60.0 - 69.0	4.2
PW ...	78.7 \pm 0.71	3.34 \pm 0.50	63.7 - 83.7	75.0 - 87.0	4.2
SB ...	31.85 \pm 0.49	2.30 \pm 0.35	24.95 - 38.75	30.0 - 39.0	7.2
ASB ...	28.9 \pm 0.33	1.53 \pm 0.23	24.3 - 33.5	27.0 - 32.0	5.3
CSB ...	23.8 \pm 0.30	1.32 \pm 0.21	19.6 - 28.0	21.0 - 27.0	5.8
SD ...	52.8 \pm 0.45	2.11 \pm 0.32	46.5 - 59.1	48.0 - 57.0	4.0
A 2 ...	29.2 \pm 0.33	1.50 \pm 0.23	24.7 - 33.7	27.0 - 33.0	5.2
AM ...	32.45 \pm 0.46	2.15 \pm 0.32	25.0 - 38.9	27.0 - 36.0	6.6
AL ...	74.3 \pm 0.50	2.34 \pm 0.35	67.3 - 81.3	70.0 - 80.0	3.0
PL ...	59.5 \pm 0.39	1.81 \pm 0.28	51.0 - 65.0	55.0 - 65.0	3.1
Sens.	36.0 with head 20/24				

* Unfortunately omitted from fig. 4 G.

Loc.—The type and 72 paratypes from the moulting of a brush turkey, Dobodura, New Guinea, 18 May 1944 (G. M. K., No. 325).

The type and 22 paratype deposited in the South Australian Museum, 35 paratypes in the collection of the Rocky Mountain Laboratory, five paratypes in the U.S. National Museum and five in the British Museum.

Remarks.—This genus and species in the peculiar and characteristic chelicerae and the palpal claw is very distinct from *Schöngastia*, *Neoschöngastia* and *Ascoshöngastia*.

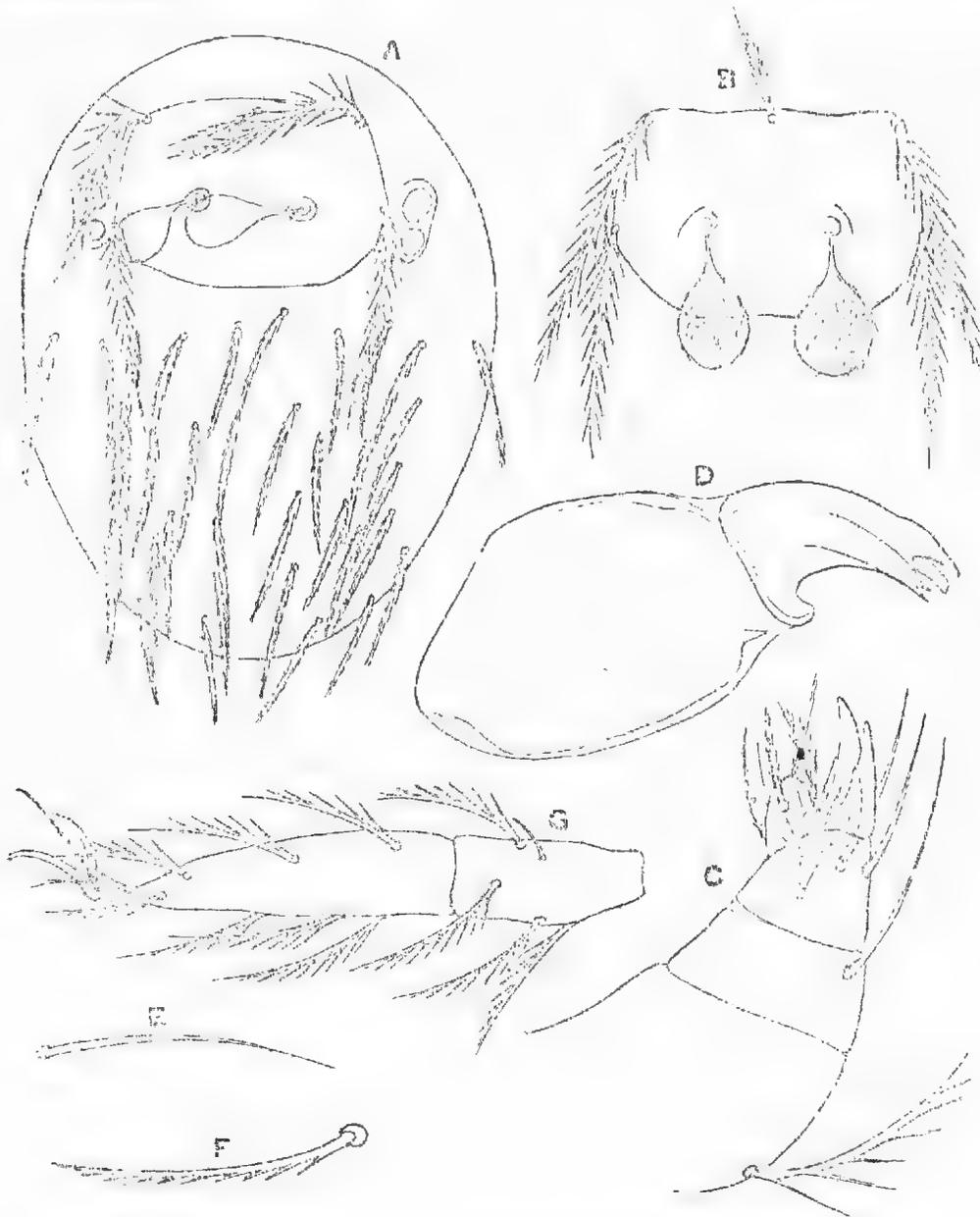


Fig. 4 *Oenoschöngastia cana* n.g. and n.sp. A, dorsal view; B, dorsal scutum (x500); C, palp in dorsal view (x860); D, chelicera (x860); E, galeal seta; F, dorsal seta (x860); G, tarsus and metatarsus III (x450).

Ascoshongastia⁽³⁾ *uromys* n. sp.

Fig. 5 A-F

Description of Larvae—Shape oval. Length (unengorged) 300 μ , width 200 μ . Scutum roughly rectangular with fairly well produced posterior margin, AM short and normally ciliated, AL and PL lanceolate or foliate, to 16 μ wide.

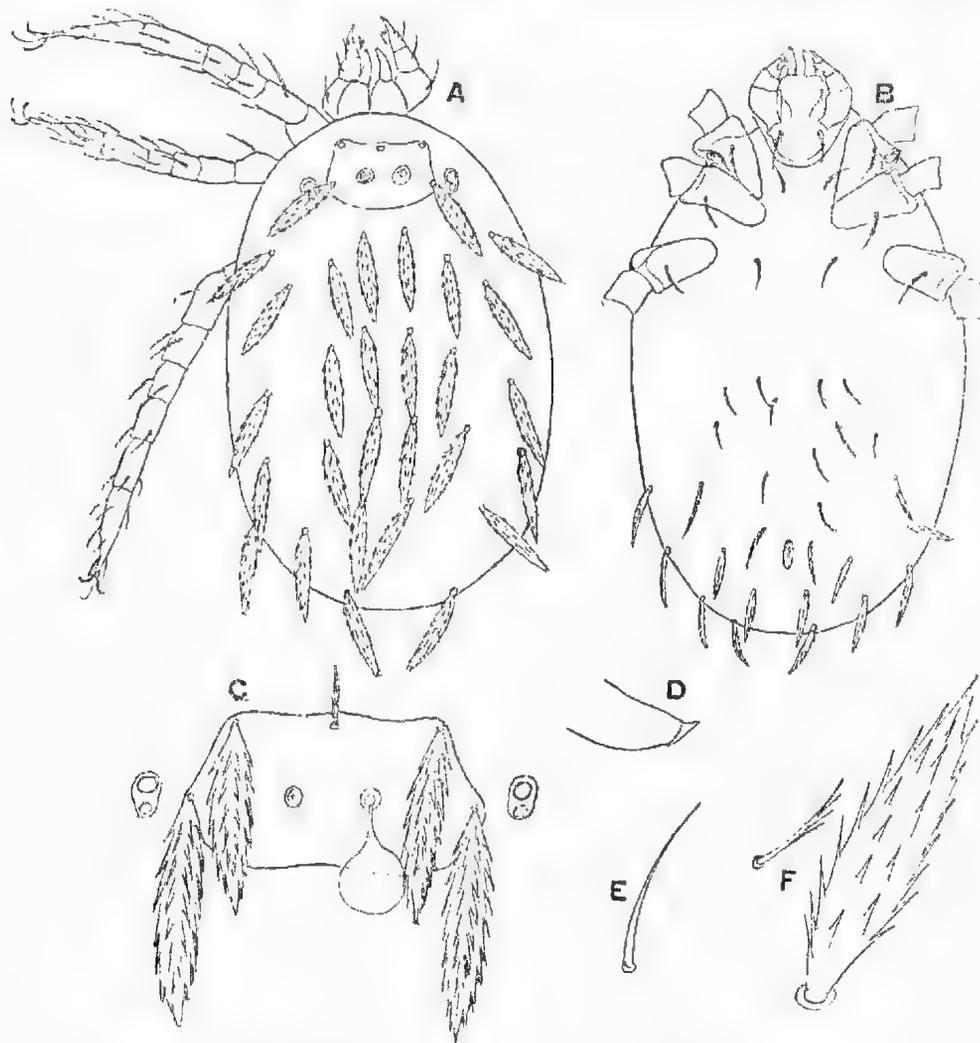


Fig. 5 *Ascoshongastia uromys* n. sp. A, dorsal view; B, ventral view; C, dorsal scutum (x500); D, tip of chelicera (x860); E, galeal seta; F, dorsal and ventral setae (x860).

with longitudinal rows of strong dentures. Sensillae globose, apparently nude, with their bases only slightly in advance of line of PL. Eyes 2—2, on distinct ocular shields; posterior the smaller. Chelicerae with only the usual apical tricuspid

⁽³⁾ Ewing (Proc. Biol. Soc. Washington, 59, 1946, p. 70-71) has recently shown that the genus *Paraschongastia* Wom. is synonymous with *Neoschongastia* Ewing 1929 (genotype *N. americana*), and for the remainder of the species of *Neoschongastia* not conspecific with *americana* has proposed the name of *Ascoshongastia* with *N. mulloyensis* Gater as genotype. The choice of this species as genotype is, however, somewhat unfortunate, as it is a rather aberrant species with PL distinctly off the scutum.

cap. Galeal setae nude. Palpi fairly stout, with bifurcate tibial claw. Setae on palpal femur, genu and tarsi apparently all nude. Dorsal setae all foliate or lanceolate with strong dentures (cf. fig. 5 D), to $64\ \mu$ long and $16\ \mu$ wide, 28 in number, and arranged 2,6,6,6,6,2. Ventrally with usual pair of branched setae on gnathosoma, a single ciliated seta on each coxa, a pair between coxae I and between coxae III, and thereafter 5,6,6, anterior of anus, and of which the outer two of the second six approach the dorsal setae in form; then posterior of anus 4,2, foliate and dentate as on dorsum; the anterior non-foliate ventral setae to $20\ \mu$ long. Legs: I $270\ \mu$ long, II $220\ \mu$, III $270\ \mu$; tarsi I and II with the usual dorsal sensory rod, III without any long nude seta.

The Standard Data derived from the type and seven paratypes are as follows:

	Mean	Standard Deviation	Theoretical Range	Observed Range	Coeff. of Variation
AW ...	50.6 ± 1.74	4.92 ± 1.23	35.8-65.4	45.0-60.4	9.7
PW ...	69.5 ± 0.71	2.60 ± 0.50	63.5-75.5	66.0-75.0	2.9
SB ...	17.0 ± 0.50	1.41 ± 0.35	14.8-23.2	18.0-21.0	7.4
ASB ...	21.0	No variation recorded			
PSB ...	18.0	No variation recorded			
SD ...	39.0	No variation recorded			
A-P ...	21.6 ± 0.42	1.19 ± 0.30	18.0-25.2	21.0-24.0	5.5
AM ...	16.5 ± 0.67	1.64 ± 0.47	11.6-21.4	15.0-18.0	9.9
AL ...	49.5 ± 0.67	1.64 ± 0.47	44.6-54.4	48.0-51.0	3.3
PL ...	60.0 ± 0.57	1.60 ± 0.40	55.2-64.8	57.0-63.0	2.7
Sens. ...	28.0	with head 17/17.	Only one determination		

Loc.—The type and seven paratypes from *Uromys lamington* from Dobodura, New Guinea, 16 May 1944 (No. 315, G. M. K.).

The type and two paratypes in the South Australian Museum, three paratypes in the Rocky Mountain Laboratory, one paratype each in the U.S. National Museum, and the British Museum (N. H.).

Remarks.—This species falls into the small group with foliate scutal and dorsal setae comprising *A. lasiata* (Gater), *maccullochi* (Wom.), *foliata* (Günther) and another species at present unpublished.

It is close to *maccullochi* but can be distinguished by the different number and arrangement of the dorsal and ventral setae, and by the dentations of the setae, although strong, being nowhere so large as in *maccullochi*.

Ascoshongatia eehymipera n. sp.

Fig. 6A-C

Description of Larvae.—Shape oval. Length (engorged) to $460\ \mu$, width to $350\ \mu$. Scutum roughly rectangular, rather small, and fairly long, with the posterior margin very shallow behind PL and lightly sinuous; AM the shortest, AL the longest but only a little longer than PL. Sensillae globose with short distinct ciliations; the sensillae bases about midway between AL and PL. Eyes 2-|-2, on distinct ocular shields and well separated from scutal margin; the posterior eyes very much the smaller. Chelicerae with only the apical trienspid cap. Galeal setae nude. Palpi stout, tibial claw trifurcate; setae on palpal femur and genu branched, on tibia all three nude. DS 34-38 in number, arranged 2,8,6,6,6,4,5(2),2(0), to $30\ \mu$ long. Ventrally with a pair of branched setae on

gnathosoma, a single ciliated seta on each coxa, a pair between coxae I and between coxae III, and thereafter ca. 6.6.6.4.4.4.2, to $26\ \mu$ long. Legs; I $213\ \mu$ long, II $186\ \mu$, III $226\ \mu$; tarsi I and II with the usual dorsal sensory rod, III without any long nude seta.

The Standard Data from the type and 12 paratypes and three other specimens are:

	Mean	Standard Deviation	Theoretical Range	Observed Range	Coeff. of Variation
AV	45.3 ± 0.29	1.16 ± 0.20	41.3-48.8	43.0-48.0	2.5
WT	61.5 ± 0.33	2.12 ± 0.37	55.1-67.9	57.0-66.0	3.4
SB	20.4 ± 0.39	1.17 ± 0.21	17.0-23.9	18.0-21.0	5.7
DSB	21.0	No variation recorded			
DSG	15.0	No variation recorded			
SD	36.0	No variation recorded			
A-P	31.3 ± 0.37	1.49 ± 0.25	26.8-35.8	30.0-33.0	4.7
AM	26.6 ± 0.36	1.45 ± 0.26	22.2-31.0	24.0-30.0	5.6
AL	45.5 ± 0.59	2.37 ± 0.42	39.4-53.6	42.0-51.0	5.1
PL	42.6 ± 0.39	1.45 ± 0.25	38.2-47.0	40.0-45.0	3.4
Setae	27.0	with head 17/17. No variation recorded			

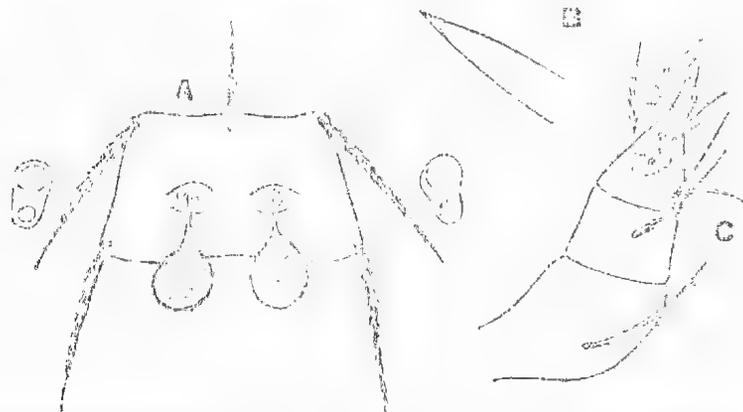


FIG. 6. *Ascoshöngastia echymipera* n. sp. A, dorsal scutum ($\times 500$); B, tip of chelicera ($\times 860$); C, palp in dorsal view ($\times 860$).

Loc.—The type and 12 paratypes from *Echymipera cockerelli* from Dobudura, New Guinea, 29 Nov. 1943 (No. 46, G. M. K.), and another paratype from same host, locality and date (No. 48, G. M. K.); also two other specimens from same host and locality, 8 Dec. 1943 (No. 77, G. M. K.) 10 Dec. 1943 (No. 81, G. M. K.).

The type and four paratypes in the South Australian Museum, two paratypes each in the U.S. Nat. Museum and the British Museum (N. H.); remaining specimens in the Rocky Mountain Laboratory.

Remarks.—In a new key to the species of *Ascoshöngastia* in preparation, *echymipera* will run down close to *coorongense* Hirst and *innisfailensis* Wom. and Heasp., but is easily distinguished by the scutum and the number and arrangement of the DS.

AUSTRALIAN ACANTHOCEPHALA

BY T. HARVEY JOHNSTON AND S.J. EDMONDS

Summary

Parasites of this species were found in the fish *Callionymus calauropomus*, caught in St. Vincent Gulf, South Australia. Five of six fish examined contained this parasite, and in four of them they were abundant. The intestines of all these fish contained crustacean material, especially amphipods and cyprids. The collections examined contained both males and females, the latter being slightly longer and broader than the males. In all the specimens examined the proboscis was protruded, but in no case was the copulatory bursa of the male everted.

AUSTRALIAN ACANTHOCEPHALA

No. 5

By T. HARVEY JOHNSTON and S. J. EDMONDS, Department of Zoology,
University of Adelaide

[Read 10 October 1946]

HYPOECHINORHYNCHUS ALALOPIS Yamaguti 1939

(Fig. 1-9)

Parasites of this species were found in the fish *Callionymus calanrotomus*, caught in St. Vincent Gulf, South Australia. Five of six fish examined contained this parasite, and in four of them they were abundant. The intestines of all these fish contained crustacean material, especially amphipods and cyprids. The collections examined contained both males and females, the latter being slightly longer and broader than the males. In all the specimens examined the proboscis was protruded, but in no case was the copulatory bursa of the male everted.

The length of the male is 1.3 to 2.7 mm., and the female 1.6 to 2.8 mm. The maximum width of the male is 0.45 to 0.70 mm., and the female 0.50 to 0.91 mm. The body in both sexes is curved ventrally and devoid of spines. The proboscis is globular to spherical in shape and is attached to the trunk ventro-terminally (fig. 1). The proboscis of the male is 0.10 to 0.14 mm. long and 0.10 to 0.15 mm. in its widest part. The corresponding measurements in the female are 0.12 to 0.16 mm. The neck portion of the proboscis is very short. The proboscis is armed with 25 hooks arranged in ten longitudinal rows, consisting of five rows each of three hooks alternating with five rows each of two hooks (fig. 4, 5). The lengths of the hooks, measured along the curve from the point of extrusion to the tip of the hook, are shown in the following table:—

Male				Anterior	Middle	Posterior
Row of three	....	....	....	78-101 μ	30-35 μ	21-28 μ
Row of two	..	..	..	71-89 μ		25-32 μ
Female				Anterior	Middle	Posterior
Row of three	....	....	....	81-110 μ	38-42 μ	28-32 μ
Row of two	....	....	....	74-90 μ		29-35 μ

The proboscis sheath is bulb-like and in the male measures 0.12 to 0.22 mm. long and 0.11 to 0.14 mm. in its widest part. The corresponding measurements of the female are 0.12 to 0.20 mm. and 0.11 to 0.16 mm. The sheath, which is inserted at the base of the proboscis, is double-walled. The maximum thickness of each layer in both sexes is 10 to 15 μ . A spindle-shaped ganglion is situated at the posterior end of the sheath, and the retinacula arise from the side walls at about this level. A strongly developed retractor is present in both sexes. The lemnisci are short, stout and cylindrical, and contain a well-developed lacunar system. The hypodermis is thick and the lacunae of the body wall anastomose freely.

Male system—There are two spherical to oval-shaped testes placed one behind the other but usually pressed close together. They lie in the anterior part of the worm. The anterior testis is slightly larger than the posterior, the dimensions of the former being 0.21 to 0.38 mm. long and 0.20 to 0.26 mm. wide; and of the posterior 0.20 to 0.32 mm. long and 0.18 to 0.25 mm. wide. Two vasa efferentia unite near the anterior end of the Sacculiger's pouch to form a common duct, which in most specimens is swollen at its base to form a seminal vesicle. This terminates in a penis which projects into the atrium of the bursa

and which is enclosed in a capsule or genital papilla. There are six cement glands which are elliptical to pyriform. In most cases they lie pressed closely together. The ducts of the six glands unite to form two lateral ducts, which join at their bases to form a U-shaped cement reservoir. Two well-developed diverticula project anteriorly from the bursa. The genital pore is terminal.

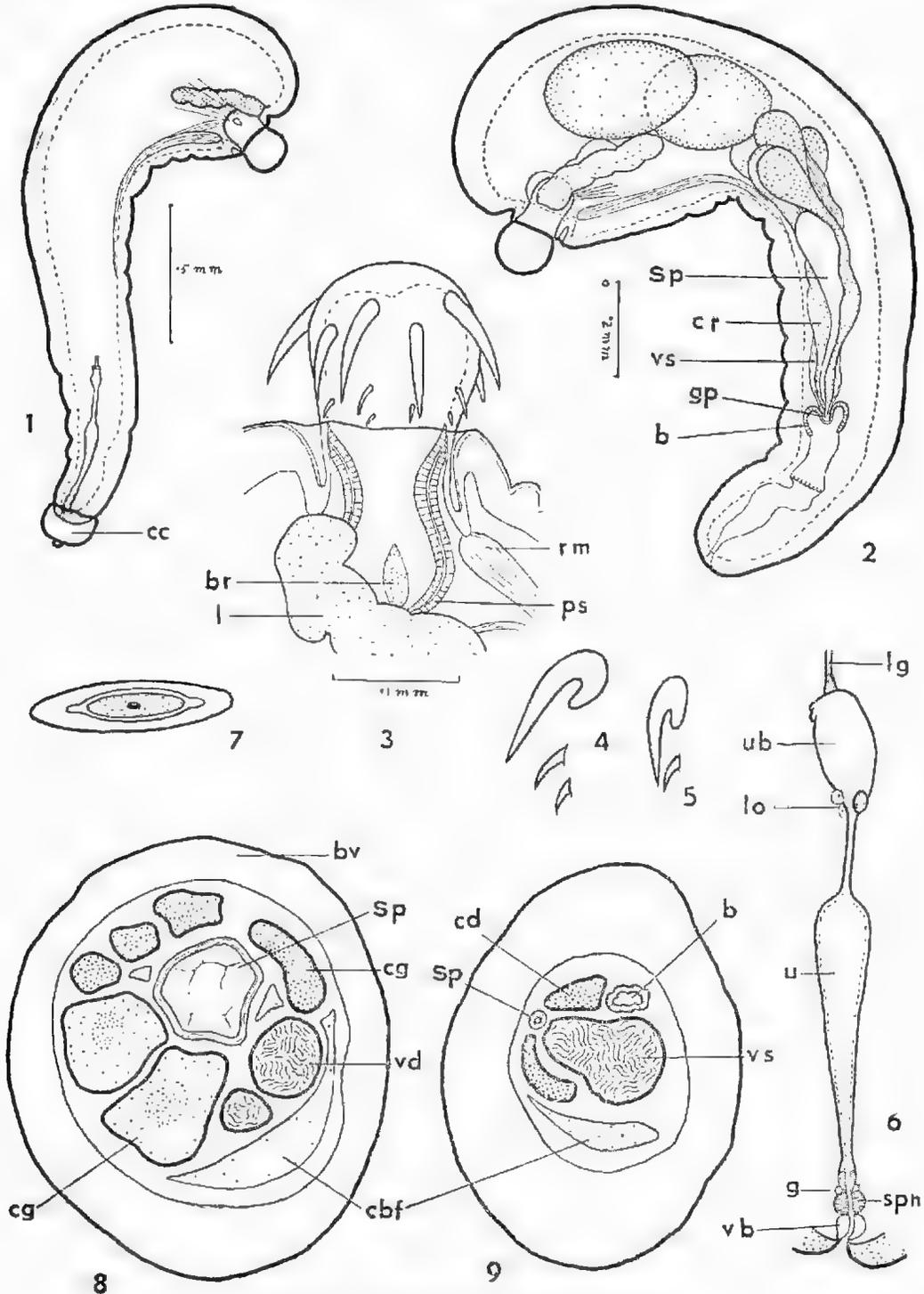


Fig. 1-9 *Hypocoelatorhynchus alacophis*:

Female system—The general anatomy of the female system is shown in fig. 6. In a typical specimen the uterine bell is 0.15 mm. long and is separated from the uterus by a narrow constriction, 0.12 mm. in length. The uterus in the same specimen is 0.35 mm. long and 0.07 mm. wide at the anterior end. Some of the female specimens contain floating ovaries, while the others have both ovaries and eggs. Mature eggs, when mounted in methyl salicylate, measure 50 to 54 μ long and 13 to 16 μ wide. The polar extrusions of the middle shell are well developed. A number of females bear a copulatory cap at their posterior extremity.

Systematic position—We consider that this parasite belongs to the species *Hypocchinorhynchus alticopsis*, described by Yamaguti (1939, 325), from a Japanese fish. Our measurements agree very closely with those given by him. The hooks of our specimens, however, seem slightly longer, and the testes somewhat smaller than in his material. We regard *Hypocchinorhynchus* as a valid genus of the family Echinorhynchidae. The form of the proboscis, as well as the shape, number and arrangement of its hooks, are suggestive of those of *Neocchinorhynchus*, but the characters of the cement glands are quite different.

Although the parasites described by Yamaguti were taken from *Alacops flintus*, he stated that a single immature female specimen was collected from *Collionymus altivelis*.

Parathadinorhynchus mugilis n. gen., n. sp.

(Fig. 10-22)

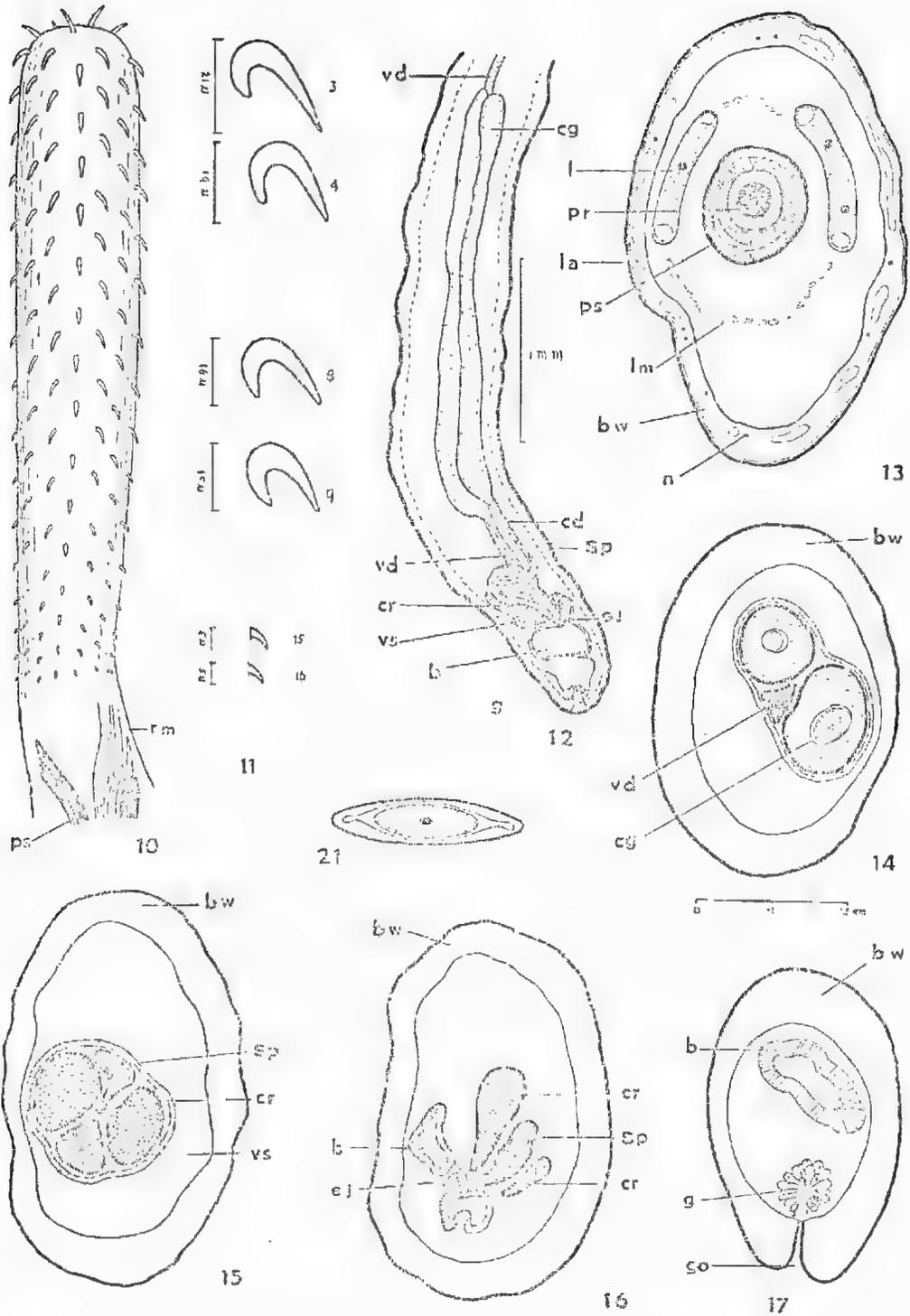
This species occurs in the mullet, *Mugil cephalus*. Five of six fish examined from Port Willunga in March, 1939, were parasitised, in one case heavily. The intestine of all the fish contained much plant debris with occasional molluscs and small crustaceans. Two other fish taken at American River, Kangaroo Island, by Mr. H. M. Cooper in January, 1945, also contained the same species of parasite in considerable numbers. In the stomach of these fish were gastropods and numerous crustaceans (prawns, amphipods and copepods). Both male and female specimens were collected. The worms are long and cylindrical, the female being longer and slightly broader than the male. Both sexes are devoid of body spines. The length of the male ranges from 3.1 to 11.4 mm., and the minimum width from 0.23 to 0.61 mm. The females are from 3.9 to 19.2 mm. long and from 0.22 to 0.69 mm. wide. The posterior half or third of the female is twisted in most cases into two or three spiral-like convolutions (fig. 19). This may be due to the fixing processes. All measurements were made on animals cleared in methyl salicylate.

Although the collection consists of a considerable number of both sexes, in only two is the proboscis fully extended. It is therefore difficult to give a range of values for the length and breadth of that organ. The proboscis in most adult specimens is about 0.9 mm. long and 0.2 mm. wide in the broadest part. It appears to taper slightly towards the base. It bears 18 longitudinal rows of hooks, most of which are firmly attached by rooting processes to the cuticle. Each row consists of 16 to 17 hooks. The form of the proboscis is shown in fig. 10, and

DESCRIPTION OF FIG. 1-9

1, male; 2, female; 3, proboscis; 4, 5, rows of hooks; 6 female organs; 7, egg; 8, T.S. male, through cement glands; 9, T.S. male, through cement ducts.

b, bursa; br, brain; bw, body wall; cc, copulatory cap; cd, cement duct; cf, coagulated body fluid; cg, cement gland; cr, cement reservoir; ej, ejaculatory duct; g, ganglion; go, genital opening; gp, genital papilla; l, lemniscus; la, lactaria; lg, ligament; lm, longitudinal muscle; lo, lateral opening of uterine bell; n, nucleus; pr, proboscis; ps, proboscis sheath; rm, retractor muscle; Sp, Sæffigen's pouch; sph, sphincter; t, testis; u, uterus; ub, uterine bell; vb, vaginal bulb; vd, vas deferens; vs, vesicula seminalis.



FIGS. 10-17.—*Parachelipomyia papillata*: 10, proboscis of male; 11, hooks from anterior, middle and posterior regions of proboscis; 12, posterior end of male; 13, T.S. anterior end of male; 14, T.S. through region of cement glands; 15, T.S. through cement ducts; 16, T.S. through region of ejaculatory duct; 17, T.S. region of ganglion of male.

the size and form of the hooks in fig. 11. There is a slight neck region. The proboscis sheath is double-walled and measures from 0.61 to 1.3 mm. long, and from 0.12 to 0.20 mm. wide. The thickness of each wall is about 0.02 mm. A brain is situated towards the base of the proboscis sheath.

The lacunar system of the body wall shows two well-developed longitudinal lacunae, from which anastomosing channels arise (fig. 22). Numerous small nuclei are found in the body wall.

The lemnisci are about 0.8 mm. long and extend usually as far as the posterior portion of the proboscis sheath. Transverse sections of the lemnisci show that they are flat and that two lateral canals and a number of large nuclei are also present in these structures (fig. 15).

Male system.—There are two elongate testes which lie close together, one behind the other, in the posterior half or third of the animal. The anterior testis measures from 0.28 to 1.1 mm. long and from 0.08 to 0.24 mm. wide, and the posterior 0.27 to 1.1 mm. long and 0.08 to 0.23 mm. wide. There are two long, narrow cement glands which range in length from 0.45 to 2.5 mm., and in most specimens they are swollen posteriorly. The ducts from these glands form two long cement reservoirs which usually are constricted in one or two places towards their posterior extremities. A long Saeffigen's pouch lies between the two cement ducts and reaches forward as far as the distal ends of the cement glands. The vas deferens swells slightly towards its posterior part to form a seminal vesicle. There is an ejaculatory duct and a well-developed bursa which bears rays. In none of the specimens examined was the bursa everted. The male aperture is terminal and is surrounded by numerous cells, probably constituting a ganglion.

Female system.—The structure and arrangement of the female system is shown in fig. 20. The uterine bell is about 0.20 mm. long. The uterus proper in mature specimens ranges from 1.1 to 1.4 mm. in length. The genital opening is terminal and the ganglionic complex which surrounds it is about 0.15 mm. long.

Mature eggs, measured in 70% alcohol, range from 56 to 62 μ long and 14 to 18 μ wide and bear polar prolongations of the middle shell.

Systematic position.—This species does not fit very well into Van Cleave's conception (1923; 1940) of the Rhadinorhynchidae, but it resembles most of the members of that family in the form of the proboscis, the shape of the hooks, the double-walled proboscis sheath, the long, tubular cement glands, and the fact that its host is a fish. It differs from the known genera of the family in the lack of body spines, though one such genus, *Leptorhynchoides*, has already been admitted. We propose for the reception of this species a new genus, *Pararhadinorhynchus*, with the following characters: Rhadinorhynchidae; body elongate, cylindrical; proboscis long, with numerous hooks; proboscis sheath double-walled with proboscis ganglion towards the posterior end; body devoid of spines; cement glands two, long, tubular, swollen slightly towards the posterior end; numerous small nuclei in body wall; genital ganglion well developed. In fish. Type, *Pararhadinorhynchus mugilis*. Types have been deposited in the South Australian Museum, Adelaide.

RHADINORHYNCHUS PRISTIS (Rudolphi 1802)

(Figs. 23-25)

One immature female of this species was found in the intestine of the southern tunny, *Thunnus maccoyii*, caught off the Semaphore in St. Vincent Gulf, South Australia. The worm was long and tubular, its length being 17.1 mm. and its maximum breadth 0.60 mm. The proboscis, which was fully retracted, was 1.9 mm. long and bore many hooks. The proboscis sheath was double-walled

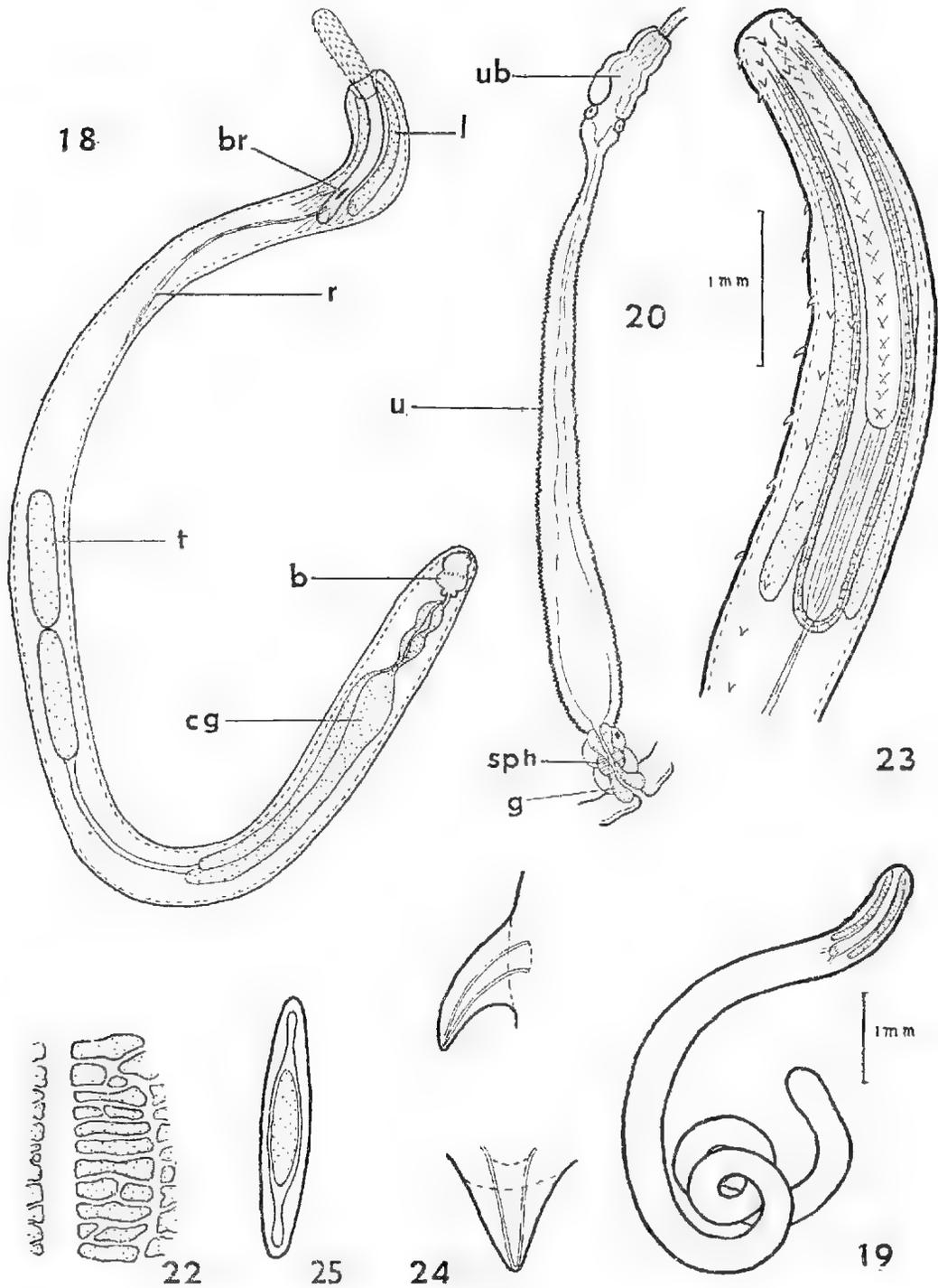


Fig. 18-22—*Pararhadinoxynchus mugilis*: 18, male; 19, female; 20, female organs; 21, egg; 22, part of lacteal system.

Fig. 23-25—*Rhadinoxynchus pristis*: 23, anterior end of female; 24, body hooks; 25, egg.

and 2.8 mm. long. Two lemnisci extended back as far as the posterior part of the proboscis sheath. The extreme anterior part of the body bore two sets of hooks, one group surrounding that part of the body adjacent to the proboscis, and the other group lying on the ventral side of the worm. The shape of the hooks is shown in fig. 24. The specimen was filled with unripe eggs which prevented the examination of the female complex. The largest of the eggs were 0.062 mm. long and 0.012 mm. broad. Three shells were seen, the middle bearing well-developed polar prolongations (fig. 25).

The specimen agreed in all essential details with the figures published by Lühe (1911, 44-46, fig. 58-63) and Meyer (1932, 47-48, fig. 23-25). The latter mentioned several kinds of fish as hosts of the parasite. The species is now recorded for the first time from Australasian waters.

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ADDITIONS TO THE FLORA OF SOUTH AUSTRALIA

By J. M. BLACK

Summary

Acacia euthycarpa desc. Em. Frutex magnus glaber, ramulis teretibus; phyllodia usque ad 8 cm. longa, 1 mm. crassa, teretia et 4-nervia, vel leviter compressa et in quoque latere duobis nervis additiis inconspicuis instructa; capitula gemina vel pauca in racemis brevibus efoliatis; flores ut in *A. calamiformi*; legumen subplanum marginibus strictum, 8-12 cm. longum, 6-8 mm. latum; semina longitudinalia funiculo conduplicato cincta.

Southern district to Flinders Range; Murray lands. Differs from *A. calamiformis* chiefly in the straight-edged margin of the pods, which are not or very slightly narrowed between the seeds. This is a more complete description than was given in these Transactions, 1945, p. 310.

ADDITIONS TO THE FLORA OF SOUTH AUSTRALIA

No. 44

By J. M. BLACK

[Read 10 October 1946]

LEGUMINOSAE

Acacia euthycarpa desc. em. Frutex magnus glaber, ramulis teretibus; phyllodia usque ad 8 cm. longa, 1 mm. crassa, teretia et 4-nervia, vel leviter compressa et in quoque latere duobis nervis additiis inconspicuis instructa; capitula gemina vel pauca in racemis brevibus ciliatis; flores ut in *A. calamiiformis*; legumen subplanum marginibus strictum, 8-12 cm. longum, 6-8 mm. latum; semina longitudinalia funiculo conduplicato cincta.

Southern district to Flinders Range; Murray lands. Differs from *A. calamiiformis* chiefly in the straight-edged margin of the pods, which are not or very slightly narrowed between the seeds. This is a more complete description than was given in these Transactions, 1945, p. 310.

Acacia pinguiifolia nov. sp. Frutex glaber, ramulis teretibus; phyllodia carnea teretia erecta vel recurvata 2-4 cm. longa 2-3 mm. crassa obscure circa 12-nervia mucrone brevi duro terminata ad basin articulata; pedunculi solitarii vel gemini 5-10 mm. longi; capitula circa 25-flora; sepala 5 lineari-spathulata ciliata dimidio breviora quam petala; bracteolae clavuliformes; legumen circa 3 cm. longum 2 mm. latum contortum et super semina longitudinalia convexum; semen nigrum; funiculus filiformis, in arillum crassum album quadruplicem desinens.

Finniss River, near Lake Alexandrina; near Port Lincoln. Near *A. Bynoeana*, Benth., and *A. Menziesii*, but is not viscid and has thicker phyllodes with more numerous nerves.

Differs from *A. sulcata* R. Br. in the fleshy, much thicker and longer phyllodes, and the moniliform pod; from *A. gonophylla* Benth. by the phyllodes not tetragonous or incurved and by the pod which in *A. gonophylla* is flat, straight and not twisted.

Acacia cerenalis nov. sp. Ramuli subangulati; phyllodia glabra, ovato-oblonga vel lato-lanceolata, coriacea, basin versus angustata, 3-4½ cm. longa, 6-15 mm. lata, obtusa, oblique 1-nervia, pennivenia, marginibus nerviformibus; stipulae praecipue spinosae; capitula parva, glabra, 15-20 in quoque racemo axillari disposita, 20-25 flora, tenues, puberuli, pedunculi circa 10 mm. longi, solitarii, gemini vel terni, racemos phyllodii subaequalibus formantes; sepala 5, lineari-spathulata, 1 mm. longa, apice pilosa, petalis duplo breviora; ovarium glabrum, brevissime stipitatum; legumen ignotum.

Crown Point, River Finke, Central Australia. The exact relation to *A. Victoriae*, Benth., cannot be known until the pod is found.

Daviesia nudula nov. sp. Frutex strictus glaber 1-2 m. altus; ramuli longi rigidi sulcati-teretes apice pungentes plerique aphylli, quandoque paucis foliis brevibus (3-9 mm. longis) subulatis spiniformibus divaricatis pungenibus praediti; folia cum ramulis continua; flores 3-12 in racemis solitariis vel congestis 1-2½ cm. longis fere omnibus lateribus; pedicelli capillares patentes 5-12 mm. longi; calyx 4 mm. longus turbinatus in pedicellum paulatim fastigatum, centibus brevibus acutis, duobus superioribus brevioribus approximatisque; carina obtusa; legumen immaturum triangulare.

Berri (River Murray). Perhaps the same as *D. brevifolia*, Lindl. var. *cphedroides*, Benth., of Western Australia. Differs from *D. brevifolia* in its

almost leafless character and in its much longer racemes with capillary pedicels usually two to three times as long as the calyx.

PROTEACEAE

Grevillea umbellifera nov. sp. Fruticulus 60-100 cm. altus, ramis validis, asperis, fuscis, pubescentibus; folia erecta, anguste linearia, rigida, apice pungentia, 5-10 cm. longa, 2 mm. lata, supra glabra, infra puberula et bisulcata, integra aut pauca summa bi- vel tripartita, omnia rigide breviterque petiolata; flores pauci usque 20, pedicellata, in umbellis vel capitulis fere sessilibus, plerumque axillaribus, congregati; perianthium extus roseum, dense puberulum, inferne subturgidum, intus saturate rubrum glabrumque, tubo 10-12 mm. longo; ovarium glabrum; gynophorus ruber, inferne perianthii basi adnatus; glandula nulla; stylus glaber, ruber, 9 mm. longus, disco laterali; pedicellus puberulus, 4-5 mm. longus; fructus globosulus, niger, laevis, circa 12 mm. diametro.

Kooibba, near Fowler Bay, Sept.-Oct., J. B. Cleland.

Near the Western Australian *G. brachystachya* Meisn. in leaves and inflorescence, but differs in a few of the upper leaves divided into two or three linear segments, the flowers larger and the lower part of the gynophore adnate to the base of the perianth.

SOME NEMATODES FROM AUSTRALIAN LIZARDS

BY T. HARVEY JOHNSTON AND PATRICIA M. MAWSON

Summary

Most of the material dealt with in this paper has been collected over a period of very many years by the senior author in New South Wales, Victoria, south-eastern Queensland, Central Australia and South Australia. We are indebted to Professor J. B. Cleland for some of the specimens from New South Wales, and to the late Dr. T. L. Bancroft for those from Eidsvold, Burnett River, Queensland. Acknowledgment is made of assistance from the Commonwealth Research Grant to the University of Adelaide. Types of the new species will be deposited in the South Australian Museum.

SOME NEMATODES FROM AUSTRALIAN LIZARDS

By T. HARVEY JOHNSTON and PATRICIA M. MAWSON,
Department of Zoology, University of Adelaide

[Read 10 October 1946]

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HOST-PARASITE LIST

- VARANUS VARIUS Shaw. *Physaloptera antarctica* Linst. (Burnett R., Queensland). *Physaloptera confusa* J. and M. (S.E. Queensland). *Ophidascaris varani* n. sp. (S.E. Queensland).
- VARANUS BELLI Dum. and Bibr. (Probably only a northern variety of *V. varius*). *Physaloptera confusa* J. and M. (Burnett R.).
- VARANUS GOELDI Gray. *Physaloptera antarctica* Linst. (Burnett R., Queensland; Victoria). *P. confusa* J. and M. (S.E. Queensland; Victoria).
- VARANUS GIGANTEUS Gray. *Physaloptera confusa* J. and M. (Central Australia).
- VARANUS DENTATUS var. ORIENTALIS Fry (Eidsvold, Burnett R.). *Physaloptera* sp.
- TILIQUA SCINCOIDES Shaw. *Pneumocma filiquae* Johnston (New South Wales). *Physaloptera antarctica* Linst. (New South Wales; S.E. Queensland). *Pharyngodon australe* J. and M. (Burnett R., Queensland). *Pharyngodon tiliquae* Baylis (Burnett R.).
- TILIQUA NIGROLUTEA Gray. *Physaloptera antarctica* Linst. *Physaloptera* sp. and *Pharyngodon australe* J. and M. (all from Katoomba, New South Wales).
- TRACHYSAURUS RUGOSUS Gray. *Thelandros trachysauri* n. sp. (Adelaide, South Australia).
- EGERNIA CUNNINGHAMI Gray. *Pharyngodon tiliquae* Baylis (Bathurst, New South Wales).
- EGERNIA STRIOLATA Peters. *Pharyngodon filiquae* Baylis (Sydney and Kendall, New South Wales).
- EGERNIA WHITEI Lacep. *Pharyngodon tiliquae* Baylis (Sydney, New South Wales).
- EGERNIA DAHLI Boulenger. *Pharyngodon tiliquae* Baylis. *Amphibiophilus egerinae* n. sp. (Both from Musgrave Ranges, Central Australia.)
- LYGOSOMA QUOYI D. and B. *Physaloptera* sp. (Lower Hawkesbury River, New South Wales).
- OEDURA ROBUSTA Boulenger. *Physaloptera* sp.; *Parathelandros acdurae* n. sp. (both from West Burleigh, S.E. Queensland).

Amphibiophilus egerniae n. sp.
(Fig. 1-3)

Two males and one female trichostrongylid worms were taken from the intestine of *Egernia dahli*, Ernabella, Musgrave Ranges, Central Australia. The males are 3.9-4.4 mm. long, and the female 8.3 mm. The body is spirally coiled, and narrow lateral alae are present. The mouth leads to a small buccal cavity in which is one tooth. The oesophagus, .3 mm. long in the male, is somewhat wider in its posterior third, and is surrounded by the nerve ring just before this level.

The vulva lies near the posterior end, .2 mm. in front of the anus. The tail is .07 mm. long. The egg nearest the vulva is oval and measures $65 \mu \times 30 \mu$.

The bursa is tightly folded in both male specimens available, but the lateral lobes appear to be symmetrical. The dorsal lobe is hardly demarcated from the lateral lobes. The arrangement of the rays is indicated in the accompanying

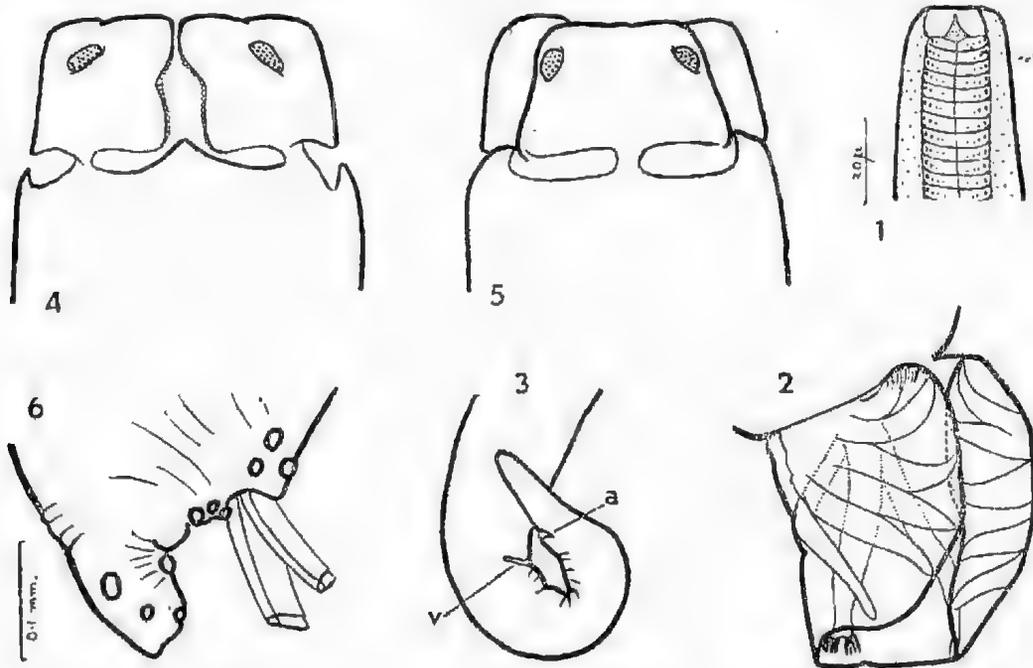


Fig. 1-3. *Amphibiophilus egerniae*; 1, head; 2, male tail; 3, posterior end of female. 4-6, *Ophidascaris varani*; 4, 5, head; 6, male tail. Fig. 3, 4, 5 and 6 to same scale.

fig. (fig. 2). The external dorsal ray appears to arise from beside the base of the dorsal, rather than from the latter. The dorsal gives rise to two branches, each of which has four terminal digits. The spicules are simple, .2 mm. in length, with the proximal half wider than the distal. A gubernaculum, .045-.05 mm. long is present.

The species appears to us to be the nearest to those of the genus *Amphibiophilus*, differing from them, however, in having four, instead of the three, terminal processes on each branch of the dorsal ray.

Ophidascaris varani n. sp.
(Fig. 4-6)

A single male worm belonging to the genus *Ophidascaris* was taken from *Varanus varus* from Toowoomba, Queensland. It measures 7 mm. in length. The very short interlabia are separated from the lips by deep grooves, and both

interlabia and grooves are bordered by a wide continuous cuticular flange. The lips have a very narrow lateral flange, bearing a fine denticular ridge. The oesophagus is 4.8 mm. long. The position of the nerve ring is not clear. The posterior end narrows suddenly at the level of the anus. The tail, .15 mm. long, bears two pairs of lateral and two pairs of sub-median papillae. There are a pair of adanal double-headed papillae, and about 30 pairs of small pre-anal papillae. The presence of median pre- and post-anal papillae is doubtful. The alate spicules are .9 mm. long; their length being much shorter than any hitherto recorded for species of *Ophidascaris*. In addition to this characteristic the present specimen differs from the other species of the genus recorded as occurring in Australia, *O. filaria* (Duj.) and *O. pyrulus* J. and M., in the length of the interlabia and in the number of caudal papillae.

PHYSALOPTERA ANTARCTICA Linst.

This species has been taken in large numbers from *Tiliqua scincoides* (New South Wales and S.E. Queensland); *Varanus gouldi* (Burnett River, Queensland; and Victoria); *T. nigroluta* (Katoomba, New South Wales), and *V. varius* (Burnett River, Queensland).

A very great variation in size has been observed, mature female specimens in some collections being only about 2 cm. long, in others reaching 5 cm.

PHYSALOPTERA CONFUSA J. and M.

This species, which was originally recorded by us (1942) from the tiger snake, *Notechis scutatus*, is very close to *P. antarctica* Linst., as redescribed by Irwin-Smith (1922, 57; 1922, 233) from material from *Tiliqua* spp., and *Varanus varius* (1922, 419). It was suggested by us that *P. confusa* might be restricted to snakes. This, however, does not seem to be the case, since among a large number of Physalopterids now examined from *Varanus* spp. some are determined as *P. antarctica* and some as *P. confusa*. The latter nematode is now recorded from *Varanus gouldi*, Caloundra, South Queensland, and Victoria; *V. varius*, Toowoomba and West Burleigh, Queensland; *V. belli*, Eidsvold, Burnett River, Queensland; and *V. giganteus*, Hermannsburg, Central Australia.

PHYSALOPTERA sp.

In some collections there were Physalopterid worms in an immature condition, or too poorly preserved for satisfactory examination, so that the species could not be determined. Such material was observed in collections from *Tiliqua nigroluta* (Katoomba, New South Wales); *Varanus punctatus* var. *orientalis* (Eidsvold, Burnett River); *Lygosoma quoyi* (Hawkesbury R., New South Wales); and *Oedura robusta* (West Burleigh, Queensland).

PNEUMONEMA TILIIQUAE JOHNSON

Many specimens of this parasite of the lungs were examined from the type host, *Tiliqua scincoides*, from Sydney. As in the original material, females only were present.

Thelandros trachysauri n. sp.

(Fig. 7-8)

From *Trachysaurus rugosus*, Adelaide. Males up to 2 mm., females to 3.5 mm. Vestibule practically absent. Oesophagus .55 mm. long in the male, .6 mm. in the female. Excretory pore post-oesophageal. Nerve ring about .2 mm. from the anterior end in the male. The vulva is 1.4 mm. from the posterior end of the body in a female 3.2 mm. long, i.e., just posterior to the mid-body. Eggs are thin-shelled, 54 μ \times 100 μ . The female tail tapers gradually to a fine point, and measures .4 mm. in length.

The male tail, or dorsal spine, is .1 mm. long and bears one median papilla at about its mid-length. There are a pair of pre-anal and a pair of post-anal papillae, and a median post-anal prominence which is a true papilla. The spicule is .1 mm. long. The species closely resembles *T. kartana* J. and M., from which it is distinguished by the greater length of the spicule and the different shape of the egg.

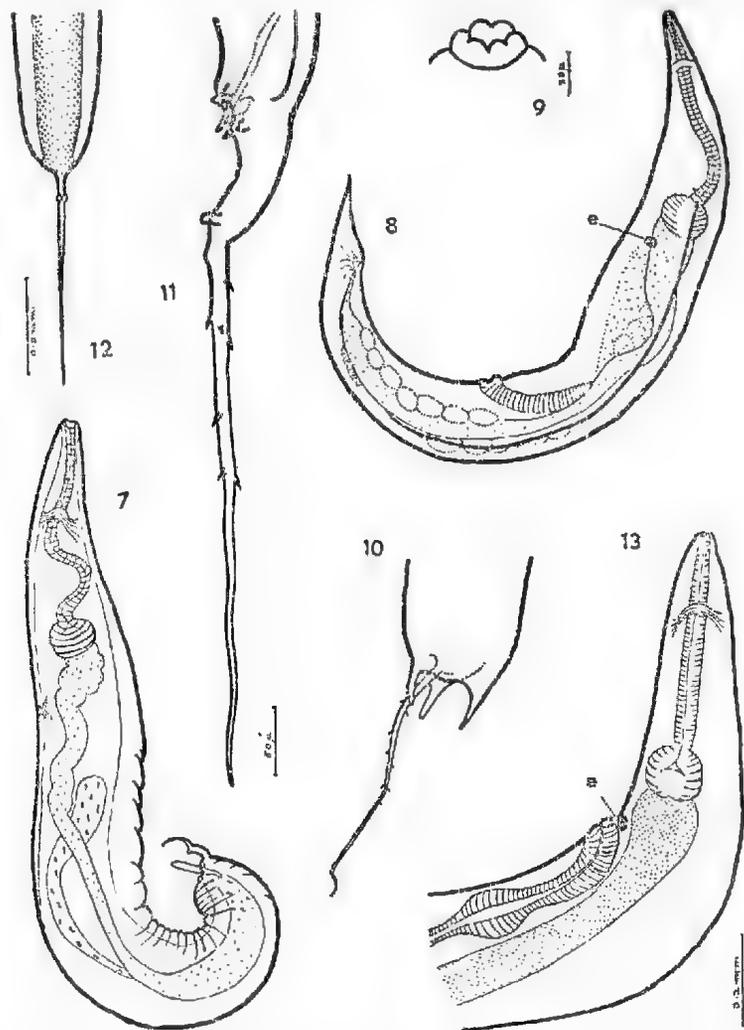


Fig. 7-8. *Thelandros brachysauri*: 7, male; 8, female. 9-13. *Parathelandros oedurae*: 9, head; 10, posterior end of female; 11, posterior end of male; 12, male tail, ventral view; 13, anterior end of female. Fig. 9, 10 and 12 to same scale; fig. 7 and 13 to same scale.

***Parathelandros oedurae* n. sp.**

(Fig. 9-13)

From *Oedura robusta*, from West Burleigh, South-east Queensland. Collections were made from several specimens of this host species. Males up to 1.6 mm. long and .24 mm. wide; females 6 mm. long and .32 mm. wide, inclusive of the tail spike and lateral alae in both cases. Body tapering markedly towards head. Lateral alae present from about posterior end of oesophagus to level of anus,

and relatively very much wider in male than in female. Posterior end in both sexes bears a long, tapering spined spike. In the female the posterior end bears, in addition, three stout backwardly directed "horns" which are strongly cuticularised extensions of the body wall, but are not so long as the tail spike. Oesophagus .3 mm. long in the male, .6 mm. in the female, its anterior part cylindrical, and ending in a large spherical bulb .13 mm. in diameter in the female. In the adult female the rectum is very narrow and quite insignificant. Nerve ring .13 mm. in male and .15 mm. in female from the anterior end of the body. Excretory pore post-oesophageal, just in front of vulva in the female.

Male: Body tapers abruptly at level of cloaca to end in spike .7 mm. long, on which are a pair of papillae and about 12-15 small spines (fig. 11). A pair of pre-anal and a pair of post-anal papillae are present. One spicule, .11 mm. long, and a gubernaculum about .03 mm. long, have been observed; the presence of a second spicule is probable, but was not seen, perhaps owing to the concentration of tissues in this region.

In the female the tail spine is about .9 mm. long, and bears about 16 small spines. The horn-like processes at the posterior end of the body proper are .13 mm. long (fig. 10). Uterus narrow, but very long and much twisted, its loops extending behind the termination of the intestine. Eggs $142 \mu \times 43 \mu$. Vulva at level of oesophageal bulb or just post-oesophageal.

The species differs very little from *P. molis* Chitwood, the distinguishing features in the male of the present species being the absence of a median post-anal papilla, the presence of tail spines, and the presence of a spicule; and in the female, the form of the posterior end of the body and the size of the eggs.

PHARYNGODON Diesing 1861

The genus *Pharyngodon* has been recorded several times from Australian hosts, four species being named from reptiles. These species are not all included in the valuable analysis of, and key to, the genus published by Spaul (1926), since *P. hughesi* Thapar 1925 was the only one of them described prior to 1926. Following that key, all the recorded Australian species fall into the group "Aa", that is, species in which caudal alae of the male include the pair of post-anal papillae, and in which the adanal pair of papillae are forked. We have further differentiated this group as follows:—

- | | | |
|--|---|---|
| 1. Female tail spined.
Female tail naked. | <i>P. kartaya</i> J. and M. | 2 |
| 2. Spike of male tail two to three times length of bursa.
Spike longer than, but not twice length of, bursa.
Spike shorter than length of bursa. | <i>P. tiliquae</i> Baylis
<i>P. hughesi</i> Thapar
<i>P. australe</i> J. and M. | |

Other differences between these species concern the position of the excretory pore and the size of the eggs. It is remarkable that three of them should have been recorded from the same host species, *Tiliqua scincoides*. As far as the information at present available is concerned, all these species appear valid.

PHARYNGODON TILIQUEAE Baylis 1930

This species was originally described from *Tiliqua scincoides*; it is now recorded from that host from Eidsvold, Queensland; *Egernia addisi* (Sydney); *E. striolata* (Kendall, New South Wales); *E. cunninghami* (Bathurst, New South Wales); and *E. dahl* (Musgrave Ranges, Central Australia). *Pharyngodon* sp., described by Thapar (1925) from female specimens from *E. cunninghami* agrees with the description given of *P. tiliquae*, and can now be placed in the synonymy of the latter.

PHARYNGODON AUSTRALE J. and M.

Originally described by us (1942) from *Tiliqua scincoides*, from New South Wales, this species is now recorded from the same host species from Eidsvold, Queensland; and from *Tiliqua nigrolutea*, from Katoomba, New South Wales.

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A REVISION OF THE AUSTRALIAN PHYCITIDAE

BY A. JEFFERIS TURNER

Summary

Mr A. J. T. Janse is at present engaged on a Revision of the whole of the world genera of this large family, and I am much indebted to him for sending me advance copies of some of his work. This has encouraged and helped me in the preparation of this paper. The family is naturally divisible into two subfamilies, the Aneastrianae, which have no tongue, and the Phycitinae, in which the tongue is fully developed.

A REVISION OF THE AUSTRALIAN PHYCITIDAE
PART I

By A. JEFFERIS TURNER

Communicated by H. Womersley, 14 November 1946

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The family is naturally divisible into two subfamilies, the *Anerastrianae*, which have no tongue, and the *Phycitinae*, in which the tongue is fully developed.

Subfam. ANERSTRIANAE

KEY TO GENERA

1. Hindwings with 3 and 4 absent.		2
Hindwings with not both absent.		3
2. Forewings with 5 absent, 3 and 4 stalked.	<i>Staitina</i>	
Forewings with 5 absent, 3 and 4 separate.	<i>Calamotropha</i>	
3. Hindwings with 5 absent.		4
Hindwings with 5 present.		5
4. Hindwings with 6 and 7 stalked.		5
Hindwings with 6 and 7 coincident.	<i>Alloea</i>	
5. Hindwings with cell closed.		6
Hindwings with cell open.	<i>Anaresca</i>	
6. Forewings with 5 absent.		7
Forewings with 5 present.		8
7. Face with conical anterior projection.	<i>Anerastria</i>	
Face not projecting.		8
8. Palpi with terminal joint turned downwards.	<i>Anchylobela</i>	
Palpi not so.	<i>Lioprosopa</i>	
9. Forewings with 4 and 5 stalked.		
Forewings with 4 and 5 not stalked.	<i>Saluria</i>	10
10. Hindwings with cell less than one-half.	<i>Emmalocera</i>	
Hindwings with cell more than one-half.	<i>Creobota</i>	

Gen. STAITINA Rag.

N. Amer. Phycit., 19.

Face with anterior tuft of scales. Palpi long, down-curved. Maxillary palpi minute. Forewings with 3 and 4 stalked, 5 absent. Hindwings with 3 and 4 absent, 6 and 7 stalked. Type, *S. roscoinctella*, from North America.

STAITINA RHODOBAPHELLA Rag.⁽¹⁾

Nov. Gen., 50; Rom. Mem., 8, 417.

Queensland. New Guinea. Celebes.

⁽¹⁾ = Sp. unknown to me.

Gen. CALAMOTROPHIA Hmps.

P.Z.S., 1918, 91.

Face with pointed conical prominence. Palpi long, down-curved. Maxillary palpi dilated. Forewings with 3 and 4 separate, 5 absent. Hindwings with 3 and 4 absent, 6 and 7 stalked. Type, *C. pulverulenta* Hmps.

CALAMOTROPHIA PULVERIVENA Hmps.⁽²⁾

P.Z.S., 1918, 91.

West Australia: Sherlock River.

Gen. ANERASTRIA Hb.

Verz., 367.

Face with conical anterior projection. Palpi long, perfect. Antennae of male with sub-basal dorsal notch. Forewings with 5 absent. 9 and 10 stalked or separate. Hindwings with cell short, 3 and 4 stalked, 5 absent. Type, *A. lotella* Hb., from Europe.

ANERASTRIA MIRABILELLA Meyr.

Proc. Linn. Soc. N.S.W., 1878, 213.

Sydney.

ANERASTRIA ERASMIA Turn.

Proc. Roy. Soc. Qld., 1912, 117.

Atherton, Injune, Carnarvon Range.

ANERASTRIA VIRGINELLA Meyr.

Proc. Linn. Soc. N.S.W., 1880, 233; *neurica* Turn., Proc. Roy. Soc. Qld., 1912, 113.

Darwin, Brocks Creek, Cape York, Cairns, Atherton, Duinga, Lismore.

Anerastria rhodochros n. sp.*ῥοδαχρως, rosy.*

♂ ♀. 18-22 mm. Head and thorax dark reddish or rosy-grey. Palpi 6; rosy-grey. Antennae pale grey; in male with a sub-basal dorsal notch followed by a fusiform glandular swelling. Abdomen grey-whitish, base of dorsum ochreous. Forewings with costa rather strongly arched, apex rounded; bright rosy with slender white lines on veins confluent towards base; cilia white, partly rosy-tinged. Hindwings grey-whitish; cilia white. Forewings broader than in *A. virginella* Meyr., with apices more broadly rounded.

North Queensland: Cape York in September and April (W. B. Barnard); three specimens. Type in Queensland Museum.

Anerastria albivena n. sp.*albivenus, white-veined.*

♂. 19-20 mm. Head and thorax dull rosy; face with strong conical anterior projection. Palpi 6; dull rosy. Antennae pale grey; in male with basal glandular thickening. Abdomen grey, base of dorsum ochreous; tuft whitish. Forewings with costa gently arched, apex rounded; bright rosy; veins slenderly and discretely outlined with white; cilia rosy. Hindwings and cilia grey.

New South Wales: Murrurundi in October (Dr. B. L. Middleton); one specimen.

⁽²⁾ = Sp. unknown to me.

ANERASTRIA MICRORRHODA Turn.

Proc. Linn. Soc. N.S.W., 1923, 453.

Darwin,

ANERASTRIA METALLACTIS Meyr.

Meyr. Trans. Ent. Soc., 1887, 262.

Darwin, Noosa, Chinchilla, Bathurst.

Anerastia xyloides n. sp.

ξύλωδης, wooden.

♂. 24 mm. Head and thorax fuscous. Palpi 6; pale brownish, Antennae grey. Abdomen ochreous; terminal segments and tuft grey-whitish. Forewings elongate, costa gently arched, apex rounded, termen obliquely rounded; pale brownish; a subcostal whitish stripe from base to two-thirds, edged beneath by a fuscous line; a terminal series of minute dark fuscous dots; cilia pale grey. Hindwings grey; cilia whitish.

North Queensland: Cairns in December (F. H. Taylor); one specimen.

Anerastia clepsiphronica n. sp.

κλεψιφρονικός, deceitful.

♂. 18 mm. Head and thorax rosy. Palpi 4; rosy. Antennae grey. Abdomen pale ochreous, terminal segments and tuft whitish. Forewings with costa gently arched, apex rounded, termen obliquely rounded; 3 and 4 closely approximated at origin; rosy; all veins slenderly outlined with whitish; a submarginal series of minute fuscous dots; cilia pale rosy. Hindwings and cilia whitish. A close mimic of *Lioprosopa chlorogramma* Meyr., but readily distinguished by its shark-like head. There is a slight variation in the forewing from that usual in *Anerastia*.

Queensland: Brisbane in October; one specimen.

Gen. *Lioprosopa* nov.

λεωπροσώπος, smooth-faced.

Face smooth or with an anterior superior tuft. Forewings with 5 absent. Hindwings with cell less than one-half, 3 and 4 stalked, 5 absent. Type, *L. chlorogramma* Meyr.

LIOPROSOPA NIPHOPLEURA Turn.

Proc. Roy. Soc. Qld., 1912, 111.

Darwin, Melville Island, Brocks Creek.

LIOPROSOPA HAPLOSHEMA Turn.

Proc. Roy. Soc. Qld., 1903, 117; *pleurochorda* Turn, Proc. Roy. Soc. Qld., 1912, 117

Yeppoon, Duaringa, Brisbane, Stanthorpe.

LIOPROSOPA NIPHOSEMA Turn.

Proc. Roy. Soc. Qld., 1912, 112.

Darwin, Adelaide River.

LIOPROSOPA HOLOPHIAEA Turn.

Proc. Roy. Soc. Qld., 1923, 42.

Darwin, Brisbane.

LIOPROSOPA ICASMOPIS Turn.

Proc. Roy. Soc. Qld., 1903, 116.

Townsville.

LIOPROSOPA STEREOSTICHA Turn.

Proc. Roy. Soc. Qld., 1904, 41.

Thursday Island, Dalby, Stanthorpe,

LIOPROSOPA EURYSTICHA Turn.

Proc. Roy. Soc. Qld., 1903, 119.

Brocks Creek, Townsville.

Lioprosopa dimochla n. sp.

διμοχλος, two-barréd.

♂. 20 mm. Head and thorax greyish-brown. (Palpi missing.) Antennae in male with sub-basal notch followed by a fusiform glandular swelling. Abdomen whitish-ochreous. Forewings with costa straight, apex rounded; brownish-grey; costal edge fuscous; a whitish costal stripe from base to apex; a similar dorsal stripe from base to tornus, interrupted by fuscous dots at one-third and two-thirds; cilia grey, bases whitish. Hindwings and cilia whitish.

North Australia: Brocks Creek in January (T. G. Campbell); one specimen.

Lioprosopa phaulodes n. sp.

φαιλωδης, paltry.

♂. 16 mm. Head and thorax grey. Palpi 2 and a half; grey. Antennae pale grey; in male with a sub-basal dorsal notch followed by a fusiform glandular swelling. Abdomen whitish-grey, base of dorsum ochreous. Forewings with costa slightly arched, apex rounded; grey-whitish with sparsely scattered fuscous scales; a terminal series of blackish dots; cilia grey-whitish. Hindwings and cilia whitish.

North Queensland; Dunk Island in May; one specimen.

Lioprosopa pelopa n. sp.

πελωπος, dusky.

♀. 18 mm. Head and thorax dark brown. Palpi 4; dark brown, base beneath white (Antennae missing.) Abdomen fuscous, base of dorsum brownish; tuft white. Forewings with costa slightly arched, apex rounded; brown; dorsum broadly fuscous; costal edge white; two slender outwardly oblique white lines from costa before apex; a blackish terminal line; cilia white, apices except on tornus fuscous, a short blackish median line at apex. Hindwings pale grey; cilia white.

North Australia: Darwin in December (G. F. Hill); two specimens.

Lioprosopa phaeochiton n. sp.

φαιοχιτων, dark-robed.

♀. 18 mm. Head and thorax fuscous. (Palpi missing.) Antennae grey-whitish. Abdomen pale grey. Forewings with costa straight, apex rounded; dark fuscous; a broad whitish costal stripe from base to apex, narrower towards base, containing very fine longitudinal fuscous lines; a terminal series of minute blackish dots; cilia grey with fuscous antemedian line. Hindwings and cilia whitish.

North Queensland: Cape York in October (W. B. Barnard); one specimen.

Lioprosopa pachyzancla n. sp.

παχυζανκλος, with thick sickles.

♀. 16-18 mm. Head and thorax greyish-brown. Palpi ascending, recurved, thickened with appressed scales, apex pointed; dark fuscous. Antennae grey. Forewings narrow, costa almost straight, apex rounded; grey; a broad white dorsal streak, narrowing towards base and apex, containing very fine fuscous longitudinal lines and a dot at two-thirds; cilia grey. Hindwings and cilia grey.

North Queensland: Cape York in October and November (W. B. Barnard); five specimens. Type in Queensland Museum.

LIOPROSOPA SYSSEMA Turn.

Proc. Roy. Soc. Qld., 1912, 113.

Darwin, Chinchilla, Kimberley.

LIOPROSOPA ZOPIOPLEURA Turn.

Proc. Roy. Soc. Qld., 1903, 117.

Darwin, Brooks Creek, Claudie River, Townsville, Brisbane.

Lioprosopa sporadica n. sp.

σποραδικος, sprinkled.

♂, ♀. 16-20 mm. Head and thorax whitish. Palpi 3; whitish. Antennae pale grey. Abdomen whitish, base of dorsum ochreous-tinged. Forewings with costa straight to middle, thence strongly arched; whitish lightly sprinkled with fuscous and brownish; sometimes a dark fuscous dot in disc at two-thirds; a terminal series of dark fuscous dots; cilia grey. Hindwings and cilia white. Hindwings grey-whitish; cilia whitish.

North Queensland: Cape York in October and November (W. B. Barnard); two specimens.

Lioprosopa rhadinodes n. sp.

ραδινοδης, slender.

♂. 9 mm. Head and thorax white. Palpi 3; white. Antennae whitish; in male with sub-basal dorsal notch. (Abdomen missing.) Forewings with costa slightly arched, apex rounded; white; cilia white. Hindwings and cilia white.

North Queensland: Dunk Island in May; one specimen.

Lioprosopa tanybela n. sp.

τανυβελος, with long palpi.

♂, ♀. 14-17 mm. Head and thorax grey. Palpi in male 5, in female 8; grey. Abdomen pale grey, base of dorsum ochreous. Forewings slightly arched, apex rounded; whitish or grey-whitish; sometimes a few subdorsal or subterminal blackish dots; 2 terminal series of blackish dots; cilia concolorous. Hindwings and cilia white.

North Queensland: Lindeman Island in September; four specimens.

Lioprosopa haploa n. sp.

απλοος, simple

♂. 18-20. Head grey; face in male white, in female grey. Palpi in male 3, white; in female 8, grey. Antennae grey; in male denate, with a sub-basal dorsal notch followed by a glandular swelling. Abdomen ochreous; tuft white. Forewings with costa gently arched, apex rounded; grey-whitish; veins outlined with white; sometimes a grey line above middle from base to apex; cilia white. Hindwings pale grey; cilia white.

North Queensland: Lindeman Island in September; four specimens.

LIOPROSOPA MARCIDA Turn.

Proc. Linn. Soc. N.S.W., 1923, 455.
Queensland: Miles.

LIOPROSOPA MACRURRHYNCHIA Turn.

Proc. Linn. Soc. N.S.W., 1923, 456.
Townsville, Milmeran.

Lioprosopa thiomochla n. sp.

θειασμοχλος, sulphur-barred.

♂, ♀. 20-22 mm. Head and thorax grey. Palpi 5; grey. Antennae in male shortly pectinate (1 and a half); grey-whitish. Abdomen whitish-ochreous, base of dorsum brown. Forewings with costa slightly arched, apex rounded; brownish-grey; dorsum suffused with whitish-ochreous; a pale yellowish costal stripe from base to apex; a fuscous dot above two-fifths dorsum; a subterminal line of minute fuscous dots; cilia grey. Hindwings and cilia grey-whitish.

North Australia: Darwin in November. Queensland: Dalby. North-West Australia: Kimberley in February. Three specimens.

Lioprosopa colobela n. sp.

κολοβελος, with short palpi.

♂. 23 mm. Head and thorax pale reddish. Palpi short (1 and a fourth), broad as base, gradually attenuating to an acute apex; reddish-grey. Antennae pale grey; in male shortly laminate, with a shallow posterior excavation clothed with long hairs near base. Abdomen grey; tuft ochreous-whitish. Forewings with costa almost straight, apex obtusely pointed; dull rosy, paler towards terminen; veins slenderly outlined with white; a white costal stripe narrow at base and apex; cilia whitish. Hindwings and cilia whitish.

North Queensland: Gordonvale, near Cairns; one specimen.

Lioprosopa platymochla n. sp.

πλατυμοχλος, broadly striped.

♂, 25 mm. Head and thorax white. Palpi 8; external surface grey; internal white. Antennae fuscous; in male shortly pectinate. Abdomen ochreous; tuft white. Forewings with costa straight, apex round-pointed; grey finely sprinkled with white; a broad white costal stripe from base nearly to apex; costal edge grey-sprinkled; a grey line beneath costal stripe; cilia white; Hindwings and cilia white.

Queensland: Cunnamulla in October; one specimen.

Lioprosopa transecta n. sp.

transectus, cut across.

22 mm. Head, antennae and thorax white. (Palpi missing.) Abdomen ochreous-grey, towards base ochreous-brown. Forewings elongate, costa slightly arched, apex rounded, terminen obliquely rounded; white; a dark fuscous subcostal stripe from base to apex; a subterminal series of small dark fuscous marks; a terminal series of minute terminal dots; cilia white. Hindwings and cilia white.

Queensland: Injune in February (W. B. Barnard); one specimen.

LIOPROSOPA MARCIDA Turn.

Proc. Linn. Soc. N.S.W., 1923, 455.
Miles.

LIOPROSOPA MACRORRHYNCHA Turn.

Proc. Linn. Soc. N.S.W., 1923, 456.
Townsville, Milmerran.

LIOPROSOPA BISERIELLA Hmps.

Rom. Mem., 8, 397. Turn., Proc. Linn. Soc. N.S.W., 1923, 455.
Darwin, Cooktown, Duaringa, Jericho, Brisbane, Sherlock River, Kimberley.

LIOPROSOPA DYSEIMATA Turn.

Proc. Roy. Soc. Qld., 1912, 112; *acrophaea* Turn., Proc. Roy. Soc. Qld., 1912, 117.
Darwin, Dunk Island, Wyndham, Timor Laut.

LIOPROSOPA EURYZONA Meyr.

Ent. Mo. Mag., 19, 256.
South Australia: Wirrabara.

LIOPROSOPA ACIDNIAS Turn.

Proc. Roy. Soc., 1903, 117.
Townsville.

LIOPROSOPA MINIMELLA Hmps.

Rom. Mem., 8, 392; Turn., Proc. Linn. Soc. N.S.W., 1923, 454.
Darwin, Thursday Island, Celebes, Borneo.

LIOPROSOPA CILOROGRAMMA Meyr.

Proc. Linn. Soc. N.S.W., 1899, 1,116; *rhodosticha* Turn., Proc. Linn. Soc. Roy. Soc. Qld., 1903, 116.

Reid River, Duaringa, Brisbane, Tweed Heads, Macpherson Range, Rosewood, Toowoomba, Injune, Milmerran, Murrurundi.

Lioprosopa poliosticha n. sp.

πολιωστιχος, grey-lined.

♂, 22-24 mm. Head and thorax whitish. Palpi 4 and a half; grey-whitish. Antennae whitish; in male with a sub-basal dorsal notch. Abdomen whitish, basal half of dorsum ochreous; tuft white. Forewings with costa gently arched, apex obtuse; white lightly sprinkled with minute grey scales; a pale grey median stripe from base beneath cell to vein 2; cilia white. Hindwings pale grey; cilia white.

North Queensland: Herberton in September; four specimens.

Lioprosopa rhanstista n. sp.

αντιστος, sprinkled.

♂, 24-26 mm. Head and thorax grey. Palpi 3; whitish. Antennae whitish; in male with a sub-basal comb of long hairs. Abdomen ochreous or fuscous; tuft white. Forewings with costa rather strongly arched, apex rounded; white very lightly sprinkled with pale grey except on veins; cilia white. Hindwings grey-whitish; cilia white.

North Queensland: Lindeman Island in September; two specimens.

LIOPROSOPA LAROPIS Turn.

Proc. Roy. Soc. Qld., 1912, 113.
Darwin.

LIOPROSOPA ARGOSTICHA Turn.

Proc. Roy. Soc. Qld., 1912, 115.
Darwin, Cape York, Dalby.

LIOPROSOPA PSAMATHIELLA Meyr.

Proc. Linn. Soc. N.S.W., 1879, 234; *nitens* Butl., Tr. Ent. Soc., 1886, 440; *baliora* Turn., Proc. Roy. Soc. Qld., 1912, 116.

Cairns, Peak Downs, Brisbane, Dalby, Sydney, Fernshaw.

LIOPROSOPA ANAEMOPIS Turn.

Proc. Roy. Soc. Qld., 1912, 116.
Darwin.

LIOPROSOPA ABLEPTA Turn.

Proc. Roy. Soc. Qld., 1912, 114.

Darwin, Cairns, Dunk Island, Reid River, Nambour, Brisbane, Mount Tamborine, Bunya Mountains.

LIOPROSOPA TALIELLA Hmps.

Rom. Mem., 8, 402.
Queensland.

LIOPROSOPA MINORALIS Low.

Trans. Roy. Soc. S. Aust., 1903, 52.
Mackay.

Gen. *Anchylobela* nov.

ἀγχυλοβελος, with crooked palpi.

Tongue absent. Palpi moderate, porrect; terminal joint bent downwards. Antennae in male with sub-basal dorsal notch, followed by a fusiform swelling. Forewings with cell two-thirds, 2 from before angle, 3 and 4 stalked, 5 absent. Hindwings with cell one-half, 2 from before angle, 3 and 4 stalked, 5 absent.

Anchylobela haplodes n. sp.

ἀπλωδης, simple.

♂. 16-17 mm. Head and thorax pale ochreous grey. Palpi 2 and a half, terminal joint short, pointed; pale ochreous-grey. Abdomen pale ochreous-grey, towards base deep ochreous. Forewings with costa arched, apex rounded, termen obliquely rounded; pale ochreous-grey with very scanty fuscous sprinkling; a terminal series of blackish dots; cilia whitish. Hindwings grey-whitish; cilia whitish.

North Queensland: Kuranda in September (W. B. Barnard), two specimens. Type in Queensland Museum.

Gen. SALURIA Rag.

Palpi long, porrect. Antennae in male with sub-basal dorsal notch. Forewings with 4 and 5 stalked. Hindwings with cell less than one-half, 3 and 4 stalked, 5 absent.

SALURIA ADENOCERA Turn.

Proc. Linn. Soc. N.S.W., 1923, 458.
Cairns, Cunnamulla.

SALURIA RHODOESSA Turn.

Proc. Roy. Soc. Qld., 1903, 120; *distichella* Hmps., Proc. Zool. Soc., 1918, 101.
Brocks Creek, Cairns, Townsville.

SALURIA CALLIRHODA Turn.

Proc. Roy. Soc. Qld., 1903, 120.
Claudie River, Palm Island, Townsville.

SALURIA LEUCONEURA Turn.

Proc. Roy. Soc. Qld., 1912, 118.

Darwin, Cape York, Innisfail, Townsville, Ayr.

SALURIA HOLOCHROA Turn.

Proc. Roy. Soc. N.S.W., 1903, 121.

Duaringa, Emerald, Birchip.

SALURIA PLEUOSTICHA Turn.

Proc. Roy. Soc. Qld., 1903, 115.

Brocks Creek, Townsville.

SALURIA CTENUCHA

Proc. Roy. Soc. Qld., 1912, 118.

Darwin, Townsville, Injune.

SALURIA GRAMMIVENA Hmps.

Proc. Zool. Soc., 1918, 99; Turn., Proc. Linn. Soc. N.S.W., 1923, 459.

North Australia: Alexandria, Sherlock River.

Saluria stereochorda n. sp.*στερεοχορδας*, straight-barred.

♂, ♀. 24-26 mm. Head white. Palpi in male 3 and a half, in female 5; grey, lower edge white. Maxillary palpi in male short, ending in a terminal tuft of long white hairs; in female filiform; grey. Antennae grey. Thorax white; bases of tegulae grey. Abdomen in male grey; in female ochreous; in both with base and tuft white. Forewings with costa straight, apex rounded; white, in female sprinkled with grey; a straight subcostal grey bar from base to apex in male, in female a median suffused bar extending to angle of cell; veins 2 to 5 grey; in male cilia white, but on apex grey; in female grey with white apices. Hindwings grey; cilia white.

Queensland: Bunya Mountains in September; two specimens.

Saluria pelochroa n. sp.*πελοχροος*, dusky.

♀. 28 mm. Head, thorax, abdomen, and antennae fuscous. Palpi 3, ascending; fuscous. Forewings with costa straight, apex rounded; fuscous; a whitish line sprinkled with fuscous on costa from base to apex.

Tasmania: Burnie in January; one specimen.

SALURIA DESERTELLA Hmps.

Proc. Zool. Soc., 1918, 977; Turn., Proc. Linn. Soc. N.S.W., 1923, 459.

Alexandria, Injune, Carnarvon Range, Charleville, Cunnamulla, Sherlock River, Wyndham.

SALURIA XIPHOMELA Low.

Trans. Roy. Soc. S. Aust., 1903, 52.

Cooktown.

SALURIA NEOTOMELLA Meyr.

Proc. Linn. Soc. N.S.W., 1879, 226.

Sydney.

SALURIA NEURICELLA Hmps.

Proc. Zool. Soc., 1918, 98.

Peak Downs.

SALURIA LEUCONEURELLA Hmps.

Rom. Mem., 8, 339.
Cooktown.

Gen. EMMALOCERA Rag.

Nouv. Gen., 38; Turn., Proc. Linn. Soc. N.S.W., 1923, 460. Type, *E. leucocincta* Wlk., from Archipelago.

EMMALOCERA LONGIRAMELLA Hmps.

Rom. Mem., 8, p. 460.

Darwin, Brocks Creek, Townsville, Ayr, Brisbane.

EMMALOCERA LATILIMBELLA Rag.

Bull. Soc. Ent. Fr., 1869, 220; *radiatella* Hmps., Rom. Mem., 8, 315; *rhabdota* Turn., Proc. Roy. Soc. Qld., 1903, 122; *achrosta* Turn., Proc. Roy. Soc. Qld., 1903, 122.

Cape York to Tweed Heads, Bunya Mountains, Stanthorpe, Tabulum, Ben Lomond, New Guinea.

EMMALOCERA ACHROMATELLA Hmps.

Proc. Zool. Soc., 1918, 126.

Dalby, Charleville, Broken Hill.

Emmalocera crossospila n. sp.

κροσσαπιδος, with marginal dots.

♀. 24 mm. Head and thorax pale ochreous-grey. Palpi 8; pale grey. Antennae grey. Abdomen grey-whitish, partly ochreous-tinged; tuft whitish. Forewings with costa gently arched, apex acute, termen straight, oblique; whitish-ochreous; a blackish discal dot above middle at three-fifths; a terminal series of blackish dots; cilia white with a grey median line. Hindwings and cilia white. Queensland: Yelarbon in November; one specimen.

Gen. *Anaresca* nov.

αναρσκος, unattractive.

Palpi slender, porrect. Forewings with 2 from well before angle, 3 from angle, 4 and 5 approximated at origin, 8 and 9 stalked, 10 from near end of cell. Hindwings with cell open, 3, 4, 5, stalked out of 2, 7 anastomosing with 12.

Anaresca xuthochroa n. sp.

ξουθοχροα, yellowish.

♀. 24 mm. Head and thorax whitish-ochreous. Palpi 2; grey. Antennae grey. Abdomen ochreous; tuft whitish. Forewings with costa straight, apex rounded-rectangular; ochreous; a whitish median line from base expanded towards termen; a terminal series of blackish dots; cilia whitish with a grey median line.

North Queensland: Lindeman Island in September; one specimen.

Gen. *Alloea* nov.

αλλοιας, different.

Labial palpi short, obliquely ascending. Maxillary palpi about half length of labial. Face with acute conical projection. Forewings with 2 from before angle, 3 from angle, 4 and 5 stalked, 8 and 9 connate or short-stalked, 10 from near end of cell. Hindwings with 5 absent, 3 and 4 approximated from angle of cell, 6 and 7 coincident and anastomosing with 12; cell two-thirds.

Alloea xylochroa n. sp.

ξύλοχρσος, wood-coloured.

♀. 26-28 mm. Head and thorax pale brownish-ochreous. Palpi 2; pale brownish-ochreous, lower edge white. Antennae grey. Abdomen pale ochreous; extreme basal and apical segments white; tuft ochreous. Forewings with costa slightly arched, apex rounded; pale ochreous with fuscous markings; sometimes an interrupted sub-basal transverse line; sometimes an interrupted postmedian blackish line; a white dot beneath two-thirds costa; a dentate subterminal line, sometimes interrupted, sometimes broadly suffused anteriorly; followed by a dentate whitish line; a triangular subapical fuscous spot narrowly prolonged to near tornus; a terminal series of dark fuscous dots; cilia whitish with a median fuscous line. Hindwings grey-whitish; cilia whitish.

North-West Australia: Wyndham in January (T. G. Campbell); two specimens.

Gen. CREOBOTA Turn.

Proc. Linn. Soc. N.S.W., 1931, 342.

Tongue absent. Labial palpi obliquely ascending, slightly curved upwards; second joint with appressed scales, rather slender; terminal joint short, conical, obtusely pointed. Maxillary palpi large, in male ending in a tuft of long hairs. Forewings with cell two-thirds, discocellulars incurved, 2 from angle well separated from 3, 3 much nearer 4 than 2 at origin, 4 and 5 stalked. Hindwings with cell one-half, discocellulars incurved, the lower very oblique, 2 from three-fourths, 3 from angle, connate with 4, 5, which are stalked. Monotypical.

CREOBOTA COCCOPHTHORA Turn.

Proc. Linn. Soc. N.S.W., 1931, 343.

Canberra.

Subfam. PHYCITINAE

KEY TO GENERA

- | | | |
|---|---------------------|----|
| 1. Hindwings with 4 and 5 absent. | | 2 |
| Hindwings with 4 and 5 not both absent. | | 4 |
| 2. Forewings with 8 and 9 coincident, hindwings with cell open. | <i>Ernophthora</i> | |
| Forewings with 8 and 9 stalked, hindwings with cell closed. | | 3 |
| 3. Forewings with 3 and 4 stalked. | <i>Dialepta</i> | |
| Forewings with 3 and 4 connate. | <i>Abarys</i> | |
| 4. Hindwings with 4 present, 5 absent. | | 5 |
| Hindwings with 4 and 5 present. | | 26 |
| 5. Forewings with 9 absent. | | 6 |
| Forewings with 8 and 9 stalked. | | 10 |
| 6. Forewings with 5 absent. | | 7 |
| Forewings with 5 present. | | 8 |
| 7. Palpi ascending. | <i>Ephesia</i> | |
| Palpi porrect. | <i>Plodia</i> | |
| 8. Forewings with 8 and 10 stalked. | <i>Echletodes</i> | |
| Forewings with 8 and 10 separate. | | 9 |
| 9. Palpi ascending. | <i>Homocosoma</i> | |
| Palpi porrect. | <i>Syntypica</i> | |
| 10. Forewings with 5 absent. | | 11 |
| Forewings with 5 present. | | 16 |
| 11. Forewings with 3 and 4 stalked. | | 12 |
| Forewings with 3 and 4 separate. | | 13 |
| 12. Hindwings with cell one-fifth. | <i>Cryptodia</i> | |
| Hindwings with cell one-third to one-half. | <i>Euzopherodes</i> | |

13. Palpi ascending, recurved. Palpi straight.	14 15
14. Hindwings with cell one-half. Hindwings with cell open.	<i>Unadilla</i> <i>Scythrophanes</i>
15. Palpi swollen to enclose penicillate maxillary palpi. Palpi not swollen, maxillary palpi filiform.	<i>Ancylodes</i> <i>Crocodyporu</i>
16. Hindwings with 3 and 4 connate or stalked. Hindwings with 3 and 4 separate.	17 <i>Eucampyla</i>
17. Forewings with 2 and 3 stalked. Forewings with 2 and 3 not stalked.	<i>Meseimiadia</i> 18
18. Hindwings with 2 from well before angle of cell, which is long. Hindwings with 2 from or from near angle of cell, which is short.	19 21
19. Forewings with 4 and 5 stalked. Forewings with 4 and 5 separate.	20 <i>Caleremna</i>
20. Palpi ascending. Palpi porrect.	<i>Eusophera</i> <i>Euogeta</i>
21. Forewings with 4 and 5 stalked. Forewings with 4 and 5 separate.	<i>Tylochaes</i> 22
22. Forewings with 5 from above angle of cell well separated from 4. Forewings with 4 and 5 approximated at origin.	<i>Pempelia</i> 23
24. Palpi ascending. Palpi porrect.	<i>Trissonca</i> 25
25. Maxillary palpi filiform. Maxillary palpi in male penicillate.	<i>Ancylosis</i> <i>Hypergrysphia</i>

Gen. ERNOPHTHORA Meyr.

Trans. Ent. Soc., 1887, 263.

Palpi ascending, recurved. Forewings with cell from near angle, cell open, 3 and 4 stalked, 5 absent, 8, 9, 10 stalked. Hindwings with cell open, 4 and 5 absent. Type, *E. phoenicias* Meyr.

ERNOPHTHORA PHOENICIAS Meyr.

Trans. Ent. Soc., 1887, 263.

Queensland.

ERNOPHTHORA MILICHA Turn.

Proc. Linn. Soc. N.S.W., 1931, 342.

Yeppoon, Macpherson Range.

Gen. DIALEPTA Turn.

Proc. Roy. Soc. Qld., 1912, 119.

Palpi ascending, recurved. Forewings with 3 and 4 stalked, 5 absent, 8 and 9 coincident. Hindwings with cell closed, 4 and 5 absent. Type, *D. micropolia* Turn.

DIALEPTA MICROPOLIA Turn.

Proc. Roy. Soc. Qld., 1912, 119.

Cairns, Brisbane.

Gen. Abarys nov.

abarys, light.

Palpi ascending, recurved. Forewings with 3 and 4 connate, 5 absent, 8 and 9 stalked. Hindwings with cell closed, 3 and 4 absent, 2 and 5 widely separate.

Abarys amaurodes n. sp.

ἀμαυροδης, obscure.

♀. 16 mm. Head, palpi, antennae, and thorax fuscous. Forewings narrow, posteriorly dilated, apex round-pointed, termen straight, oblique; grey lightly sprinkled with fuscous; markings dark fuscous; an outwardly oblique fascia at two-fifths, paler in centre; a transverse subcostal mark at two-thirds; a terminal suffusion and cilia fuscous. Hindwings and cilia grey.

Queensland: Brisbane in September; one specimen.

Gen. EPHESTIA Gn.

Fur. Micro., 81.

Palpi ascending, recurved. Forewings with 5 absent, 9 absent. Hindwings with cell nearly reaching middle, 3 and 4 closely approximated or stalked, 5 absent. Type *E. elutella* Hb.

EPHESTIA ELUTELLA Hb.

Meyr. Rev. Hdbk. Brit. Lep., 373.

Sydney, Gisborne, Melbourne.

EPHESTIA PICULELLA Barrett

Meyr. Rev. Hdbk. Brit. Lep., 388.

Darwin, Cairns, Gladstone, Brisbane, Dalby, Brunswick Heads, Deloraine. South Australia: Kadina. Africa. Europe. America.

Ephestia pelopis n. sp.

πελωπις, dusky.

♂. 19 mm. Head, palpi, and thorax greyish-brown. Antennae grey. (Abdomen missing.) Forewings with costa straight to middle, thence arched, apex round-pointed, termen slightly rounded, moderately oblique; greyish-brown; a faint suffused transverse line at two-fifths; a similar but narrower line from beneath two-thirds costa oblique to mid-dorsum; a terminal series of minute fuscous dots; cilia pale grey. Hindwings grey-whitish; cilia grey-whitish, apices whitish; cell one-fourth.

North Queensland; Kuranda in October (F. P. Dodd); one specimen.

EPHESTIA CAUTELLA Wlk.

Meyr. Rev. Hdbk. Brit. Lep., 388.

Darwin, Atherton, Lindeman Island, Townsville, Maryborough, Brisbane, Birchip, Kangaroo Island, Perth.

EPHESTIA KUEHNJELLA Zcl.

Meyr. Rev. Hdbk. Brit. Lep., 388.

Brisbane, Dunkeld, Launceston, Adelaide. Africa. Europe. America.

Gen. PLODIA Gn.

Meyr. Rev. Hdbk. Brit. Lep., 386.

Palpi porrect, Forewings 2 and 3 sometimes stalk, 5 absent, 9 absent. Hindwings cell nearly reaching middle, 3 and 4 connate, 5 absent. Type, *P. interpunctella* Gn.

PLODIA INTERPUNCTELLA Gn.

Meyr. Rev. Hdbk. Brit. Lep., 386.

Mackay, Brisbane, Toowoomba, Stanthorpe, Milmerran, Charleville, Sydney, Birchip, Adelaide, Perth.

Gen. ECBLETODES Turn.

Proc. Roy. Soc. Qld., 1903, 124.

Palpi ascending, recurved. Forewings with 4 and 5 stalked, 9 absent, 8 and 10 stalked. Hindwings with cell one-half, 2 from before angle, 3 and 4 stalked, 5 absent. Type, *E. psephenias* Turn. *Enchryphodes* Turn., Proc. Roy. Soc. Qld., 1912, 123, is a synonym.

ECBLETODES PSEPHENIAS Turn.

Proc. Roy. Soc. Qld., 1903, 125.

Brisbane, Lismore.

ECBLETODES AENICTA Turn.

Proc. Roy. Soc. Qld., 1912, 120. *E. aenictopa* Turn., Proc. Roy. Soc. Qld., is a synonym.

Cairns, Atherton, Palm Island, Darwin.

ECBLETODES OTOPTILA Turn.

Proc. Roy. Soc. Qld., 1912, 120.

Darwin.

Gen. HOMOEOSOMA Curt.

Ent. Mag., 1, 190; Hmps. Moths Ind., 4, 66.

Palpi, ascending, recurved. Forewings with 4 and 5 stalked, 9 absent. Hindwings with cell short, 3 and 4 approximated or connate, 5 absent. Type, *H. sinuella* Fab., from Europe.

HOMOEOSOMA VAGELLA Zel.

Isis, 1848, 863. Meyr. Proc. Linn. Soc. N.S.W., 1878, 214.

Cairns to Victoria, Hughenden, Cunnamulla, Broken Hill, Birchip, Adelaide, Western Australia.

HOMOEOSOMA FORNACELLA Meyr.

Proc. Linn. Soc. N.S.W., 1880, 219.

Cairns, Macpherson Range, Ben Lomond, Ebor, Sydney, Tasmania.

Homocosoma centrosticha n. sp.

κεντροστιχος, with central line.

♂, ♀. 18-20 mm. Head and thorax grey. Palpi and antennae fuscous. Abdomen grey; tuft whitish. Forewings narrow, costa straight, apex pointed; grey; markings dark fuscous; a line from base to end of cell, connected by an inwardly oblique line with one-third costa; a white subcostal line from base to end of cell; two fuscous dots placed transversely at end of cell; some minute terminal dots; cilia whitish. Hindwings grey-whitish; cilia whitish.

Queensland: Brisbane in October; Bunya Mountains in February. New South Wales: Murrurundi in March. Three specimens.

Homocosoma rhapta n. sp.

ρᾶπτος, embroidered.

♀. 18-20 mm. Head grey; face white. Palpi grey; second joint with postmedian and terminal fuscous bars. Antennae pale grey. Abdomen grey, towards base dark fuscous. Forewings with costa nearly straight, apex obtuse; grey with some fuscous sprinkling; markings dark fuscous; a triangular spot on base of costa; a narrow transverse fascia at two-fifths, becoming broader towards termen; a minute subcostal dot at two-thirds; a subterminal line obtusely angled in middle

and again between this and dorsum, edged posteriorly whitish; a terminal series of dots; cilia grey. Hindwings pale grey; cilia whitish with sub-basal grey line.

Queensland: Aramac in June; Stanthorpe in November from larva on *Acacia* (H. Jarvis).

***Homoeosoma euryleuca* n. sp.**

μυλευκος, broadly white.

♂. 17 mm. Head fuscous-brown. Palpi exceeding vertex; brown. Antennae grey. Abdomen whitish-ochreous; tuft whitish. Forewings with costa slightly arched, apex pointed; brownish-grey; a white costal stripe from base, gradually increasing in breadth to middle, thence broad to termen; two minute fuscous dots placed transversely at two-thirds; cilia white. Hindwings whitish-grey; cilia white.

North Queensland: Cape York in October (W. B. Barnard); one specimen.

***Homoeosoma contracta* n. sp.**

contractus, narrow.

♀. 17 mm. Head and thorax grey. Palpi fuscous, upper edge whitish. Antennae fuscous. Abdomen dark fuscous, towards apex grey; tuft ochreous-whitish. Forewings narrow, slightly dilated posteriorly, costa slightly arched, apex obtuse, termen straight, oblique; fuscous sprinkled with white; a narrow white line above middle from one-fifth to three-fifths; a dark fuscous median line through cell; suffused fuscous dots above dorsum at one-sixth and one-third; a slender oblique subterminal line parallel to termen; cilia grey. Hindwings pale grey; cilia white with faint grey sub-basal line.

New South Wales: Murrurundi in February (Dr. B. L. Middleton); one specimen.

***Homoeosoma pelosticta* n. sp.**

πελοστικτος, dusky-spotted.

♂, ♀. 12-16 mm. Head, thorax, and abdomen grey. Palpi and antennae fuscous. Forewings narrow, costa almost straight, apex obtuse; grey with a few minute fuscous dots; one median and sub-basal; another, sometimes double, at end of cell; several in subterminal area; cilia white. Hindwings grey-whitish; cilia white.

Queensland: Biloela (foodplant *Sorghum*), in October. New South Wales: Ebor in December. Three specimens.

***Homoeosoma ochropasta* n. sp.**

ωχροπαπτος, pale-sprinkled.

♀. 16 mm. Head, antennae, thorax, and abdomen grey-whitish. Palpi grey, extreme base and apex white. Forewings narrow, costa nearly straight, apex obtuse; whitish finely sprinkled with pale grey; a terminal series of minute terminal dots; cilia grey-whitish. Hindwings and cilia white.

North Queensland: Kuranda, in May (F. P. Dodd); one specimen.

***Homoeosoma atchyna* n. sp.**

ατεχνος, simple.

♀. 21 mm. Head, thorax, and abdomen grey. Palpi and antennae fuscous. Forewings with costa slightly arched, apex rounded; grey-whitish; cilia grey-whitish. Hindwings and cilia grey-whitish.

Tasmania: Derwent Bridge, in January; two specimens.

HOMOEOSOMA STENOPIS Turn.

Proc. Roy. Soc. Qld., 1903, 126.

Birchip.

HOMOEOSOMA MELANOSTICTA LOW.

Trans. Roy. Soc. S. Aust., 1903, 58.

Cairns, Atherton, Brisbane, Mount Tamborine, Toowoomba, Carnarvon Range, Sydney.

Homoeosoma lechriosema n. sp.

λεχραιοσωμος, obliquely marked.

♂. 24 mm. Head, palpi, and thorax grey. (Antennae missing.) Abdomen pale ochreous-grey, towards apex whitish. Forewings dilated posteriorly, costa straight, apex obtusely pointed; fuscous densely sprinkled with white; a basal fuscous suffusion edged posteriorly by a slender oblique line from costa near base to one-third dorsum, and itself edged posteriorly by a fuscous line; a fuscous subcostal dot at three-fifths; a slender oblique white line from costa near apex to three-fourths dorsum, edged anteriorly by a fuscous line; cilia grey-whitish sprinkled with white. Hindwings and cilia whitish.

Queensland: Tweed Heads, in September; one specimen.

HOMOEOSOMA FARINARIA TURN.

Proc. Roy. Soc. Qld., 1903, 126.

Cairns, Eungella, Tweed Heads, Mount Tamborine, Macpherson Range, Toowoomba, Bunya Mountains, Stanthorpe, Lismore, Ebor, Sydney, Strahan, New Zealand.

Gen. SYNTYPICA TURN.

Proc. Linn. Soc. N.S.W., 44.

Palpi long, porrect. Forewings with 4 and 5 absent, 9 absent. Hindwings with 3 and 4 separate, 5 absent. Type *S. aleurades* Turn.

SYNTYPICA ALEURODES TURN.

Proc. Roy. Soc. Qld., 1904, 45.

Birchip.

Gen. CRYPTADIA TURN.

Proc. Roy. Soc. Qld., 121. Type, *C. xuthobela* Turn.

Palpi ascending, recurved. Forewings with 3 and 4 stalked, 5 absent, 8 and 9 stalked. Hindwings with cell short (one-fifth), 5 absent. Type, *C. xuthobela* Turn.

CRYPTADIA XUTHOBELA TURN.

Proc. Roy. Soc. Qld., 1912, 121.

Cairns.

Gen. EUZOPHERODES Hmps.

J. Bombay Soc., 1897, 475; Rom. Mem., 8, 79.

Palpi short, ascending, recurved. Forewings with 3 and 4 connate or stalked, 5 absent, 8 and 9 stalked. Hindwings with cell one-third to one-half, 2 from before angle, 3 and 4 approximated, connate, or stalked from angle, 5 absent. Type, *E. albicans* Hmps.

EUZOPHERODES ALBICANS Hmps.

J. Bombay Soc., 1897, 475.

15-16 mm. Head and thorax ochreous-whitish tinged with grey. Palpi, antennae, and abdomen grey. Forewings elongate-triangular, costa slightly arched, termen nearly straight, oblique; whitish lightly sprinkled with fuscous; markings fuscous; a white line from one-third costa to one-third dorsum edged

fuscous posteriorly; a slightly waved white subterminal line; cilia white. Hindwings grey-whitish; cilia white.

For early stages see Proc. Roy. Soc. Qld., 1903, 127.

Townsville, Brisbane, Brunswick Heads, Ceylon, India.

Euzopherodes concinella n. sp.

cancinellus, neat.

♀. 16 mm. Head, palpi, thorax and abdomen whitish-ochreous. Antennae and abdomen grey. Forewings narrow, costa gently arched, apex subrectangular, termen straight, slightly oblique; ochreous-whitish slightly sprinkled with fuscous; markings dark fuscous; basal dots on costa and dorsum almost meeting; an oval dot on fold at one-fourth; three minute dots in a transverse line at one-third; a subcostal dot at three-fifths with another slightly beneath and beyond; a subterminal line; cilia ochreous-whitish. Hindwings and cilia grey.

Cape York in October (W. B. Barnard); one specimen.

Euzopherodes allocrossa Low.

Trans. Roy. Soc. S. Aust., 1903, 57.

Mackay.

Euzopherodes spodoptila Turn.

Proc. Roy. Soc. Qld., 1912, 121.

Darwin.

Euzopherodes leptocosma Turn.

Proc. Roy. Soc. Qld., 1903, 127; *poliocrana* Low., Trans. Roy. Soc. S. Aust., 1905, 104.

Townsville, Milmerran, Broken Hill.

Euzopherodes homophaea n. sp.

ὁμοφαῖος, uniformly dusky.

♀. Head and thorax fuscous. Palpi pale brownish. Abdomen grey; tuft grey-whitish. Forewings narrow, slightly dilated posteriorly, costa gently arched, apex rounded; fuscous-brown; markings obscure, fuscous; an outwardly curved subterminal line of dots not reaching costa; some terminal dots; cilia grey. Hindwings grey-whitish; cilia whitish.

North Queensland: Kuranda, in March (F. P. Dodd); one specimen.

Euzopherodes homocapna n. sp.

ὁμοκαπνος, uniformly dark.

♀. 16 mm. Head, palpi, antennae, thorax, and abdomen fuscous. Forewings narrow, costa straight, apex rounded; dark fuscous; cilia fuscous. Hindwings with cell open, 3 and 4 stalked to near termen; grey, cilia grey.

Queensland: Cunnamulla, in October; one specimen.

Euzopherodes schematica n. sp.

σχηματικός, well designed.

♂. ♀. 15-16 mm. Head, thorax, and abdomen fuscous; face sometimes partly white. Palpi fuscous, base and a median ring on second joint white. Antennae fuscous. Forewings narrow, costa straight; apex subrectangular; white with dark fuscous markings; an outwardly oblique basal fascia; a second fascia from one-fourth costa to mid-dorsum; a dot beneath midcosta; an oblique line from apex to second fascia; a subterminal line followed by some suffusion; a terminal series of minute dots; cilia grey. Hindwings and cilia pale grey.

North Queensland: Cape York, in November (W. B. Barnard); five specimens. Type in Queensland Museum.

Euzopherodes phaulopa n. sp.

φαιλωπος, mean-looking.

♀. 26 mm. Head, antennae, thorax, and abdomen grey; pectus white. Palpi fuscous. Forewings elongate, costa gently arched, apex rounded, termen obliquely rounded; pale grey sprinkled with fuscous; a transverse fuscous line at one-fourth, angled inwards beneath costa, between this and dorsum finely dentate; some terminal dots; cilia grey. Hindwings with cell one-fourth; grey-whitish; cilia whitish.

New South Wales: Scone, in September (H. T. Nicholas); one specimen.

Gen. Scythrophanes nov.

σκυθροφανής, gloomy.

Palpi ascending, recurved. Forewings with 3 and 4 separate, 5 absent, 8 and 9 stalked. Hindwings with cell open, 5 absent. Type, *U. apatelia* Turn.

SCYTHROPHANES APATELIA TURN.

Proc. Roy. Soc. Qld., 904, 45.

Brisbane.

SCYTHROPHANES TRISSOMITA TURN.

Proc. Roy. Soc. Qld., 1912, 122.

Cairns.

SCYTHROPHANES ATECMARTA TURN.

Proc. Roy. Soc. Qld., 1912, 122.

Cairns.

Gen. UNADILLA Hulst.

Trans. Amer. Ent. Soc., 1890, 197.

Palpi ascending, recurved. Maxillary palpi filiform. Forewings with 3 and 4 separate, 5 absent, 8 and 9 stalked. Hindwings with cell one-half, 3 and 4 stalked, 5 absent.

UNADILLA DISTICHELLA MEYR.

Proc. Linn. Soc. N.S.W., 1878, 215.

Brisbane to Gisborne, Glen Innes, Tasmania.

Gen. ANCYLODES Rag.

Ann. Soc. Ent. Fr., 1887, 250.

Palpi straight, ascending, exceeding vertex; second and terminal joints strongly dilated, apex obtuse. Maxillary palpi of male ending in a pencil of long hairs. Antennae in male with scape dilated, base of shaft strongly dilated antero-posteriorly. Forewings with 2 from before angle, 3 and 4 from angle, 5 absent. Hindwings with 3 and 4 connate, 5 absent.

ANCYLODES PENICILLATA TURN.

Proc. Roy. Soc. Qld., 1907, 46.

Murtoa.

Gen. EUCAMPYLA MEYR.

Proc. Linn. Soc. N.S.W., 1882, 159.

Palpi moderate, porrect. Forewings with 4 and 5 stalked, 7 and 8 stalked. Hindwings with 3 and 4 approximated at origin, 5 absent. Type, *E. etherella* Meyr.

EUCAMPYLA ETHEIELLA MEYR.

Proc. Linn. Soc. N.S.W., 1882, 171.

Sydney.

Gen. CROCYDOPORA Meyr.

Proc. Linn. Soc. N.S.W., 1882, 158. Type, *C. cinigerella* Meyr.

Palpi long, porrect. Maxillary palpi filiform. Forewings with 2 from before angle, 3 and 4 closely approximated from angle, 5 absent, 8 and 9 stalked. Hindwings with 2 from before angle, 3 and 4 connate, 5 absent; cell sometimes open,

CROCYDOPORA CINIGERELLA Wlk.

35, 1719; *stenopectrella* Meyr., Proc. Linn. Soc. N.S.W., 1878, 200.

Atherton, Mackay, Duaringa to Victoria, Glen Innes, Charleville, Ebor, Broken Hill, Birchip, Strahan, Mount Lofty, Western Australia, Norfolk Island, New Zealand.

Gen. MESEINIADIA

Palpi ascending, recurved. Forewings with 2 and 3 stalked, 4 and 5 stalked, 8, 9, 10 stalked. Hindwings with 2 from near angle, 3 and 4 stalked, 5 absent. I am unable to give the origin of this name, which I received from Sir Geo. Hampson.

MESEINIADIA INFRACTALIS Wlk.

30, 958.

12-13 mm. Head, palpi, antennae, thorax, and abdomen ochreous-whitish. Forewings narrow, costa straight, apex obtuse, termen obliquely rounded; ochreous-whitish with fuscous markings; a dot on base of costa; a short dorsal streak from base; a longer streak on fold; a slender oblique streak from two-fifths costa, sometimes connected with a longitudinal streak above middle; sometimes another streak below middle; both ending in a large terminal suffusion; cilia fuscous. Hindwings grey-whitish; cilia whitish.

North Queensland: Cairns, Innisfail.

Gen. EUZOPHERA Zel.

Trans. Ent. Soc., 1867, 453.

Palpi ascending, recurved. Forewings with 4 and 5 stalked, 8 and 9 stalked. Hindwings with 3 and 4 stalked, 5 absent. Type, *E. bivittata* Zel., from Europe.

EUZOPHERA SUBARQUELLA Meyr.

Proc. Linn. Soc. N.S.W., 1878, 211.

Darwin, Cape York to Victoria, Glen Innes, Injune, Adavale, Sea Lake, Mount Lofty, Ardrossan, Perth.

EUZOPHERA HOLOPIRACMA Meyr.

Trans. Ent. Soc., 1887, 255.

Carnarvon.

Euzophera albicosta n. sp.

albicostus, with white costa.

♂, ♀. 18-22 mm. Head fuscous with narrow lateral margins. Palpi fuscous, basal half white. Antennae and thorax fuscous. Abdomen grey; apices of segments and tuft white. Forewings narrow, costa straight, apex rounded; grey; a white costal line from base to near apex; more or less broadly suffused and sprinkled with grey; a transverse fuscous fascia at one-third; an oblique fascia from apex to three-fourths dorsum, edged with white posteriorly; cilia grey. Hindwings and cilia pale grey.

Western Australia: Dennmark in March; Yanchep in September; four specimens

Euzophera flavicosta n. sp.

flavicostus, with yellow costa.

♀. 18-20 mm. Head, palpi, thorax and abdomen brown. Antennae fuscous. Forewings with costa straight, apex rounded, termen obliquely rounded; fuscous-brown; a broad yellowish costal line from base to near apex, interrupted by a yellowish dot at three-fifths; a slender slightly dentate subterminal line; terminal edge yellowish interrupted by a series of fuscous dots; cilia grey. Hindwings grey-whitish; terminal edge fuscous; cilia grey-whitish with a sub-basal grey line.

North Queensland: Cape York in October (W. B. Barnard); four specimens. Type in Queensland Museum.

Euzophera ischnopa n. sp.

ισχνοπτος, thin.

♀. 18 mm. Head and thorax dark fuscous. Palpi much exceeding vertex; dark fuscous, extreme base whitish. (Antennae missing.) Abdomen ochreous; tuft paler. Forewings narrow, slightly dilated posteriorly, costa gently arched, apex obtuse; fuscous-brown; three fuscous dots in cell and two placed transversely at its end; cilia fuscous. Hindwings pale grey; cilia grey-whitish with a faint sub-basal grey line.

North Queensland: Cape York in October (W. B. Barnard); one specimen.

Euzophera arrhythmopis n. sp.

ἀρρυθμοπις, disorderly.

♀. 12-14 mm. Head, palpi, antennae, and thorax grey. Abdomen fuscous; tuft whitish. Forewings dilated posteriorly, costa straight to three-fourths, thence arched, apex rounded; grey; an outwardly curved whitish line from one-third costa to mid-dorsum preceded by some fuscous suffusion; a fine whitish subterminal line indented in middle, preceded by a fuscous costal dot; cilia grey. Hindwings and cilia grey.

North Queensland: Cairns in December. Queensland: Redland Bay, near Brisbane, in November. Two specimens.

Gen. Euageta nov.

εὐαγητος, clear bright.

Palpi long, porrect. Forewings with 4 and 5 stalked, 8 and 9 stalked. Hindwings with cell long, 2 from before angle, 3 and 4 stalked to near termen, 5 absent. Distinguished from *Euzophera* by the porrect palpi.

Euageta arestodes n. sp.

ἀρεστωδης, pleasing.

♂, ♀. 14-16 mm. Head and thorax pale fuscous. Palpi 4; grey, base beneath white. Antennae and abdomen grey. Forewings with costa straight, apex rounded, termen oblique; pale fuscous; a white costal stripe from near base to near apex, broad in middle, narrow at each end; costal edge pale fuscous; a slender or suffused white subterminal line; some minute terminal dark fuscous dots; cilia white. Hindwings grey-whitish; cilia white.

Queensland: Injune in April (W. B. Barnard); two specimens. Type in Queensland Museum.

Gen. CATEREMNA Meyr.

Hdbk. Brit. Lep., 375.

Palpi ascending, recurved. Forewings with 4 and 5 separate, 8 and 9 stalked. Hindwings with 3 and 4 stalked, 5 absent. Type, *C. terebella* Zinck., from Europe.

CATEREMNA MICRODOXA Meyr.

Proc. Linn. Soc. N.S.W., 1880, 231.
Darwin, Darwinia, Launceston.

CATEREMNA ATÉRPNES Tutt.

Proc. Roy. Soc. Qld., 1912, 125.
Darwin.

CATEREMNA SEMIFICTILIS Tutt.

Trans. Roy. Soc. Qld., 1912, 125.
Stradbroke Island.

CATEREMNA QUADRIGUTTELLA Wik.

35, 1,711.

13-18 mm. Head, palpi, and thorax fuscous. Antennae grey. Abdomen grey, bases of segments sometimes fuscous. Forewings rather narrow, posteriorly dilated, costa almost straight, apex obtuse, termen almost straight, slightly oblique; white with fuscous markings; a broad oblique bar from base of costa to dorsum, a bar from one-third costa to mid-dorsum, where it joins a large suffusion broadening to termen and connected to apex; two blackish dots placed transversely in disc at two-thirds; a slender subterminal line edged posteriorly white followed by some grey suffusion, a terminal series of blackish dots; cilia grey-whitish. Hindwings grey; cilia whitish.

Darwin, Cape York to Lismore, Milmeran, Mount Lofty, Western Australia.

Cateremna cataxutha n. sp.

κατάξουθος, tawny posteriorly.

♂, ♀. 14-16 mm. Head, palpi, antennae, and thorax grey. Abdomen fuscous; apices of segments and tuft pale ochreous. Legs fuscous with whitish rings; posterior tibiae whitish. Forewings with costa moderately arched, apex round-pointed; termen straight, slightly oblique; grey-whitish sprinkled with fuscous; a slender median dark fuscous line forming the anterior margin of a broad transverse fuscous fascia and preceded by a fuscous dorsal spot; a slender wavy fuscous subterminal line edged posteriorly with whitish; an interrupted fuscous subterminal line; cilia grey, bases whitish. Hindwings pale ochreous; cilia grey-whitish.

North Australia: Darwin in December. Queensland: Toowoomba in October. Ten specimens.

Cateremna mediolinea n. sp.

mediolineus, with central line.

♀, 16-18 mm. Head, palpi, thorax, and abdomen white. Antennae grey. Forewings narrow at base, costa gently arched, apex obtuse, termen slightly rounded, moderately oblique; pale brownish yellow; a median white line from base of costa to termen above middle, its margins sprinkled with blackish above and beneath; an obscure white subdorsal line sprinkled with blackish; a narrow grey-whitish terminal fascia sprinkled and margined with blackish; cilia grey-whitish. Hindwings and cilia grey.

North Queensland: Cape York in April and June (W. B. Barnard); two specimens. Type in Queensland Museum.

Cateremna leptoptila n. sp.

λεπτωπιλος, narrow-winged.

♀, 14 mm. Head, palpi, thorax, and abdomen fuscous. Antennae grey. Forewings narrow, dilated posteriorly, costa slightly arched, apex obtuse, termen

oblique; whitish sprinkled with fuscous; markings fuscous; a line from base of costa to two-thirds dorsum; a postmedian square uniting this with costa; a very fine line from costa near apex to two-thirds dorsum; some terminal suffusion; a terminal series of dots; cilia fuscous. Hindwings and cilia pale grey.

New South Wales: Broken Hill in March; one specimen.

CATEREMNA LEUCARMA Meyr.

Proc. Linn. Soc. N.S.W., 1880, 230.

Brisbane, Cunnamulla, Sydney, Birchip.

CATEREMNA ALBICOSTALIS Luc.

Proc. Roy. Soc. Qld., 1891, 93.

Cairns, Atherton, Townsville, Mackay, Bundaberg, Brisbane, Stradbroke Island, Lismore.

CATEREMNA METALLOPA Low.

Proc. Linn. Soc. N.S.W., 1898, 46.

Mackay.

Cateremna melanomita n. sp.

μελανομιτος, with blackish lines.

♂. 18 mm. Head and thorax grey. Palpi grey; second joint with postmedian whitish ring. Antennae grey. Abdomen fuscous; extreme base of dorsum and tuft whitish. Forewings dilated posteriorly, costa slightly arched, apex rectangular, termen almost straight, slightly oblique; grey densely sprinkled with fuscous to middle, thence slightly; a sinuate blackish line from midcosta to mid-dorsum; a similar doubly sinuate subterminal line; a terminal series of blackish dots; cilia grey. Hindwings and cilia grey.

North Queensland: Mackay in October; one specimen.

CATEREMNA PAMPHAES Turn.

Proc. Roy. Soc. Qld., 1904, 47.

Darwin, Townsville.

CATEREMNA MEMIBAPHES Turn.

Proc. Roy. Soc. Qld., 1904, 47.

Sea Lake, Hobart, Quairading, Perth.

CATEREMNA APODECTA Turn.

Proc. Roy. Soc. Qld., 1903, 129.

Brisbane, Scone, Sydney.

CATEREMNA THERMOCHIROA Low.

Trans. Roy. Soc. S. Aust., 1896, 160.

Darwin, Brisbane, Cardiff, W. Aust.

CATEREMNA ODONTOSEMA Turn.

Proc. Roy. Soc. Qld., 1912, 126.

Cairns, Imbil.

Gen. TYLOCHARES Meyr.

Ent. Mo. Mag., 1883, 256.

Palpi ascending, recurved. Forewings with 4 and 5 stalked, 8 and 9 stalked. Hindwings with cell short (one-fifth to one-fourth), 2 from near angle, 3 and 4 stalked, 5 from angle.

TYLOCHARES COSMIELLA Meyr.

Proc. Linn. Soc. N.S.W., 1878, 212.

Duaringa, Brisbane, Sydney, Moruya, Broken Hill, Melbourne, Birchip, Murtoa, Wirrabara, Mount Liebig, Perth, Rottnest Island.

Tylochaes epaxia n. sp.

επαξίος, handsome.

♀. 23 mm. Head brown; face whitish. Palpi and antennae grey. Thorax grey; patagia whitish. Abdomen ochreous with a series of central fuscous dots. Forewings with costa almost straight, apex subrectangular, termen slightly rounded, scarcely oblique; grey, a well-marked straight white sub-basal line, followed by a broad fuscous transverse fascia suffused posteriorly; an outwardly curved slender whitish subterminal line, indented beneath costa and above dorsum, edged posteriorly by a series of confluent fuscous dots, an interrupted fuscous terminal line preceded by whitish suffusion; cilia grey, apices whitish. Hindwings bright ochreous; cilia grey, apices white.

North Queensland: Lake Barrine, Atherton Tableland, in January (E. J. Dumigan); one specimen.

Tylchaes prays n. sp.

πρᾶος, gentle.

♀. 24 mm. Head, antennae, and thorax grey. Palpi grey; apices of second and terminal joints white. Forewings dilated posteriorly, costa rather strongly arched, apex obtuse, termen slightly rounded, slightly oblique; grey sprinkled with whitish; a fuscous basal patch containing an oblique outwardly curved blackish transverse line; closely following this a slender outwardly curved grey line from one-fourth costa to two-fifths dorsum; a grey median dot above middle and another beneath two-thirds costa; a suffused grey spot above three-fifths dorsum; a broadly suffused grey submarginal line not reaching tornus; a terminal series of grey or fuscous dots; cilia grey; apices white. Hindwings pale grey; cilia white with a grey median line.

Queensland: Bunya Mountains in January; Stanthorpe in March. Two specimens.

TYLOCHARES SCEPTUCHA Turn.

Proc. Roy. Soc. Qld., 1903, 130.

Stanthorpe, Gisborne,

Tylochaes gypsotypa n. sp.

λιψοτυπος, with white marking.

♂, ♀. 18-21 mm. Head, antennae, and thorax grey. Palpi long, notch exceeding vertex, in male 2 and a half, in female 4; grey, towards base white. Abdomen ochreous, towards base grey. Forewings narrow, costa slightly arched, apex obtuse, termen obliquely rounded; grey; a broad white stripe, sprinkled with grey, narrow at each end, from base to apex; sometimes a series of minute fuscous terminal dots; cilia grey. Hindwings pale grey with darker terminal line; cilia white.

North Queensland: Cape York in October and November (W. H. Barnard); two specimens. Type in Queensland Museum.

Tylochaes anaxia n. sp.

ἀναξίος, of little worth.

♂, ♀. 16-17 mm. Head, palpi, antennae, thorax, and abdomen grey. Forewings dilated posteriorly, costa slightly arched, apex obtuse, termen slightly

oblique; grey; a fine whitish transverse line at one-third, angled outwards in middle, preceded and followed by more or less fuscous suffusion; short fuscous streaks on veins in terminal area; a terminal series of fuscous dots; cilia grey-whitish. Hindwings and cilia grey-whitish.

North Queensland: Cape York in November, Dunk Island in May; three specimens.

Tylochares paucinotata n. sp.

paucinotatus, scantily marked.

♀: 16 mm. Head and thorax fuscous-brown; face pale brownish. Antennae fuscous. (Abdomen missing.) Forewings narrow, dilated posteriorly, apex rounded, termen obliquely rounded; greyish-brown with some fuscous dots; three placed transversely at one-third; a median dot; an outwardly curved sub-terminal line of dots; cilia grey. Hindwings grey-whitish; cilia whitish with a faint sub-basal grey line.

Cape York in October (W. B. Barnard); one specimen.

TYLOCHARES EREMÓNOMA TURN.

Proc. Roy. Soc. Qld., 1912, 125.

Adavale.

TYLOCHARES PROLEUCA LOW.

Trans. Roy. Soc. S. Aust., 1903, 58.

Brisbane, Deniliquin.

TYLOCHARES HEMICHIÓNĒA TURN.

Proc. Roy. Soc. Qld., 1912, 226.

Caloundra, Brisbane.

Tylochares chionopleura n. sp.

χαιτοπλευράς, with snow-white costa.

♂, ♀: 16-20 mm. Head, palpi, antennae, and thorax fuscous. Abdomen pale grey. Forewings narrow, costa straight, apex rounded; fuscous; a snow-white costal stripe from near base to near apex; costal edge fuscous; cilia white, on tornus grey, but sometimes wholly grey. Hindwings and cilia pale grey.

Queensland: Warwick in December, from larvae feeding in *Acacia* galls; two specimens.

Tylochares endophaga n. sp.

ἐνδοφαγός, feeding internally.

♀: 21 mm. Head, palpi, and antennae grey. Palpi not exceeding vertex; grey, towards base white. Abdomen with basal half ochreous, terminal half grey. Forewings with costa slightly arched, apex rectangular, termen straight, not oblique; grey; a white stripe, sprinkled with grey, from base to near apex; cilia grey. Hindwings grey-whitish; cilia whitish.

Queensland: Bribie Island, near Caloundra, in October; one specimen from larva feeding in an *Acacia* gall.

Tylochares pastopleura n. sp.

παστόπλευράς, with sprinkled costa.

♂, ♀: 15-16 mm. Head, antennae, and thorax grey. Palpi fuscous. Abdomen whitish, in female slightly ochreous tinged. Forewings narrow, costa slightly arched, apex rounded; grey; a costal stripe from base to apex, over one-third breadth of wing, sprinkled with fuscous; a terminal series of minute fuscous dots; cilia whitish or grey-whitish. Hindwings with cell one-third; grey-whitish; cilia whitish.

North Queensland: Cape York in October and November (W. B. Barnard); two specimens. Type in Queensland Museum.

TYLOCHARES GONIOSTICHA Turn.

Trans. Roy. Soc. S. Aust., 1915, 803.

Musgrave Range.

Gen. PEMPELIA Hb.

Verz., 369.

Palpi ascending, recurved. Forewings with 2 from well above angle, 5 separate, 8 and 9 stalked. Hindwings with cell short (one-fifth), 2 from angle, 3 and 4 stalked, 5 absent.

PEMPELIA OPIMELLA Meyr.

Proc. Roy. Soc. N.S.W., 1878, 201.

Brisbane, Mount Tamborine, Stanthorpe, Miles, Milmerran.

PEMPELIA CANILINEA Meyr.

Proc. Linn. Soc. N.S.W., 1878, 209.

Brisbane, Toowoomba, Castarvon Range, Murrumbidgee, Sydney, Goulburn, Katoomba.

PEMPELIA HEMICHLAENA Meyr.

Trans. Ent. Soc., 1887, 260.

Victoria.

PEMPELIA MICROCOSMA Low.

Trans. Roy. Soc. S. Aust., 1893, 166.

Gen. TRISSONCA Meyr.

Proc. Linn. Soc. N.S.W., 1882, 158.

Palpi ascending, recurved. Forewings with 5 separate, approximated at origin, 8 and 9 stalked. Hindwings with cell short (one-fifth to one-third), 2 from angle, 3 and 4 stalked, 5 absent.

Trissonca clytepa n. sp.

κλυτωπος, noble.

♂, ♀. 14-17 mm. Head fuscous; lower edge of face whitish. Palpi and thorax fuscous. Antennae grey. Abdomen ochreous. Legs fuscous with whitish rings; posterior pair whitish. Forewings rather narrow, posteriorly dilated, costa straight to middle, thence arched, termen straight, scarcely oblique; a fuscous basal patch limited by a slender blackish line posteriorly from two-fifths costa to mid-dorsum, angled outwards beneath costa and again above middle; disc beyond this grey or partly grey-whitish, with some fuscous admixture; an outwardly curved blackish subterminal line; a slender blackish submarginal line preceded by more or less white suffusion; cilia grey, apices whitish.

North Queensland: Kuranda (F. P. Dodd); two specimens.

TRISSONCA IANTHEMIS Meyr.

Trans. Ent. Soc., 1897, 260; *epiterpues* Turn., Proc. Roy. Soc. Qld., 1904, 48.

Darwin, Cairns, Atherton, Townsville, Bowen, Eungella, Yeppoon, Brisbane, Toowoomba, Charleville.

TRISSONCA MELANOPHORA Low.

Trans. Roy. Soc. S. Aust., 1903, 57.

Cooktown, Townsville, Nambour, Brisbane, Tweed Heads.

TRISSONCA MESACTELLA Meyr.

Proc. Linn. Soc. N.S.W., 1879, 225.

Sydney.

Gen. *HYPOGRYPHIA* Rag.

Bull. Soc. Ent. Fr., 1890, 119.

Palpi long, porrect. Maxillary palpi in male penicillate. Forewings with 4 and 5 stalked, 8 and 9 stalked. Hindwings with cell short, 2 from angle, 3 and 4 stalked, 5 absent.

Hypogryphia amictodes n. sp.

ἀμικτωδής, unmarked.

♂, ♀. 22-23 mm. Head and thorax greyish-brown. Palpi 4; grey, near base whitish. Antennae and abdomen grey. Forewings narrow, posteriorly dilated, costa straight to middle, thence gently arched, apex rounded, termen obliquely rounded; greyish-brown; cilia concolorous. Hindwings pale ochreous-grey; cilia whitish.

Queensland: Duaranga in December; Toowoomba in October (W. B. Barnard); two specimens. Type in Queensland Museum.

Gen. *ANCYLOSIS* Zel.

Isis, 1839, 178.

Palpi porrect. Maxillary palpi filiform. Forewings with 5 separate, 8 and 9 stalked. Hindwings with cell short, 2 from angle, 3 and 4 stalked, 5 absent. Type, *A. cinnamomea* Dup., from Europe.

ANCYLOSIS LAPSA Wlk.

29, 829.

♂, ♀. 14-16 mm. Head, palpi, antennae and thorax fuscous. Abdomen pale grey. Forewings with costa slightly arched, apex round-pointed, termen straight, slightly oblique; pale ochreous-grey; a fuscous dot below middle at one-third; a narrow dark fuscous terminal fascia; cilia grey; apices whitish.

North Queensland: Townsville. Queensland: Yeppoon. Also from Ceylon.

ANCYLOSIS RUFIFASCIA Hmps.

Rom. Mem., 8, 193.

♂, ♀. 22-25 mm. Head and thorax whitish-ochreous; patagia and tegulae pinkish. Palpi 6; lower edge white. Antennae pale grey. Abdomen grey-whitish. Forewings with costa straight to middle, thence arched, apex pointed, termen very obliquely rounded; whitish more or less pinkish-tinged with slight grey sprinkling; a median line from base to two-thirds or more, edged above with white, beneath with blackish scales; a terminal series of blackish dots; cilia whitish. Hindwings grey-whitish; cilia whitish.

North Queensland: Townsville. Queensland: Peak Downs, Gayndah, Nambour, Brisbane, Dalby, Injune. New South Wales: Scone.

Ancylosis thlosticha n. sp.

θλοστήχος, sulphur-lined.

♂, ♀. 22-24 mm. Head and thorax ochreous-grey. Palpi 6; grey, lower edge except terminal joint whitish. Antennae grey. Abdomen fuscous. Forewings with costa gently arched, apex obtuse, termen obliquely rounded; grey, in male suffused with whitish; in female a fine pale yellow line from base to apex; near apex, a broader submedian line from base to termen; a similar subdorsal line much narrower except near base; a subcostal fuscous dot at one-third and another at end of cell; a terminal series of blackish dots; cilia grey. Hindwings grey; cilia grey, towards dorsum whitish.

Queensland: Injune in October (W. B. Barnard); two specimens. Type in Queensland Museum.

PRE-CAMBRIAN GRANITES AND GRANITISATION, WITH SPECIAL REFERENCE TO WESTERN AUSTRALIA AND SOUTH AUSTRALIA

BY KEITH R. MILES, DEPARTMENT OF MINES, ADELAIDE

Summary

A review of the Australian Pre-Cambrian Succession reveals occurrences of granites and rocks of granitic appearance encountered over very considerable areas and apparently involving vast periods of geological time. With the changing modern concepts of the origin of granite and of granitic-looking rocks, all evidence concerning the relationships of these rocks in both time and space, both with one another and with other adjacent geological formations, assumes a new significance, from the point of view of both historical geology and the specialized problems of petrogenesis. It is time that such evidence should be brought forth once more and critically re-examined in this new light. Periodical stocktakings are always valuable, and, to the scientific worker, can prove both salutary and encouraging.

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REFERENCE TO WESTERN AUSTRALIA AND SOUTH AUSTRALIA

By KEITH R. MILES, Department of Mines, Adelaide

[Read 14 November 1946]

PLATE I

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INTRODUCTION

A review of the Australian Pre-Cambrian Succession reveals occurrences of granites and rocks of granitic appearance encountered over very considerable areas and apparently involving vast periods of geological time. With the changing modern concepts of the origin of granite and of granitic-looking rocks, all evidence concerning the relationships of these rocks in both time and space, both with one another and with other adjacent geological formations, assumes a new significance, from the point of view of both historical geology and the specialized problems of petrogenesis. It is time that such evidence should be brought forth once more and critically re-examined in this new light. Periodical stocktakings are always valuable, and, to the scientific worker, can prove both salutary and encouraging.

ORIGIN OF GRANITE — MODERN CONCEPTS

Professor H. H. Read in two memorable presidential addresses to the British Geologists Association, entitled "Meditations on Granite, Parts I and II" (Read 1943, 1944), has placed all English-speaking geologists forever deeply in his debt for a clear presentation of the facts of the problem of the origin of granite and of the modern trend of thought, which are thrown into proper perspective by an exceedingly illuminating historical background. This historical review, like all good science, has a truly international flavour and follows the arguments and controversies of the British, French and Pennoskandian masters from the late 18th century up to the present day. It has probably come as a shock to many Australian geologists to learn that ideas very similar to the present conception of "granitisation" were first put forward by the Frenchman (Ami Boué) in 1824, and that the thesis has been steadfastly developed and elaborated by most of the great French geologists from that time onward. Such ideas were diametrically opposed to the principles of igneous geology laid down by leading petrologists of the German School, under whose far-reaching influence British and American thought, unfortunately, remained clouded until well into the 20th century.

The old concept of "igneous" rock based on the fundamental three-fold classification of rocks into Igneous, Aqueous or Sedimentary, and Metamorphic, the first rung of the ladder to which most of our first student steps were guided,

is proving untenable in certain important respects and can no longer fully sustain us on our upward climb. This fact has been amply demonstrated by Read in his review of French and Fennoscandian literature and supported by the latest researches of many workers in both Britain and America. It has become increasingly apparent that there is a fundamental genetic difference between the two main groups of so-called "igneous" rocks, *i.e.*, basalt and granites, and that contrary to past beliefs an understanding of the origin, mechanics of emplacement, trend of differentiation, by-products and so on of the first group in general contributes very little towards the understanding of the same features of the latter group. W. O. Kennedy (in Kennedy and Anderson, 1938), discussing this problem, has advanced the idea of two apparently independent expressions of "magmatic" activity called Volcanic and Plutonic Associations—the former considered to be derived from a universal basaltic magma, which has originated from the remelting of a basaltic earth shell, the intermediate layer. The latter are considered to be derived from a primary universal granodioritic parent magma which has developed by remelting of the so-called "granitic" layer within orogenic zones, where tectonic thickening of the earth's crust has brought the base of the granite within the range of melting. Important differences in the mode of eruption in the two cases have been cited. The granite and granodiorite batholiths appear to penetrate slowly upwards, accompanied by a wave of granitisation and migmatitisation of the country rocks, until arrested by some unknown form of pressure balance akin to hydrostatic control before they reach the surface. The ascent of basaltic magma, however, is believed to be directly towards the surface by way of a system of relatively narrow dyke-like fissures with no large intercrustal reservoirs being formed. The magma is then either extruded as lava flows or forms injected bodies of various sizes, such as sills or laccoliths, which may themselves represent volcanic reservoirs. No large scale migmatitisation or metasomatic replacement of country rocks is ever performed by such basic magmas, whose differentiation and subsequent evolution are controlled largely by fractional crystallisation processes.

Without necessarily conceding the validity of all of Kennedy's conclusions in their entirety, it is apparent that there are certain major irreconcilable differences in the mode of occurrence of these two groups of rocks pointing to two quite distinct forms of so-called "igneous" activity. This is nowhere more clearly demonstrable than from studies of the Archaean granitic rocks throughout the world, from which it is also becoming more and more clear that the division between "Igneous" and "Metamorphic" in the old three fold classification, *i.e.*, as far as Kennedy's "plutonic association" of granitic rocks and the high-grade metamorphic rocks are concerned, is more apparent than real, and that in many cases the distinction between ortho- and para-gneiss completely breaks down. It is from the observation of instances illustrating this last fact and by deductions therefrom that we have reached this modern viewpoint on the origin of granite.

GRANITISATION

The pitch of this viewpoint can probably best be summed up in the word "granitisation," a word which according to Grout (1941) has been loosely used by writers for a number of years and which has recently been defined by Read (1944), after an analysis of definitions from many sources, as "the process by which solid rocks are converted to rocks of granitic character without passing through a magmatic stage." Some French writers apparently use the term *leptothisation* as synonymous with granitisation.

Granitisation of country rock is dependent upon the introduction and metasomatising action of some form of very active emanations—gaseous, fluid or both—whose origin is yet obscure. These emanations, whether vapours or solutions,

are apparently extremely active and tenuous and must be at least heated above the critical point of water (365° C. at approximately 200 atmospheres). The mechanics of introduction of these granitising emanations have been discussed in considerable detail by French and Fenno-Scandinavian authorities. Apparently two chief processes are recognised—lit par lit injection or preferential replacement and a form of bodily chemical replacement through "soaking up" or "imbibition" (to use the French term) without distortion or displacement of the country rock, and migration of material by what has been termed "oil spot" mechanism. In this respect C. E. Wegmann (1931, 1935, 1938) has emphasized the importance of intergranular films in the molecular replacement and migration of material and similar reactions.

One of the most puzzling features of granitisation is why and how the final result of the permeation and replacement process is apparently always the formation of granite or granitic rock, irrespective of the composition of the country rock attacked. This has been explained in the concept of migration and advancing "fingers," developed by Wegmann (*op. cit.*), Backlund (1938), Reynolds (1943, 1944) and others. Material from the granitising emanations is regarded by them as selectively replacing the components of the pre-existing rock, adding here, taking away there, so as to leave remaining material granitic in composition. The displaced material is driven forward with outgoing emanations and fixed in an outer zone or "front." The geochemical relationships involved in granitisation have been expressed in mathematical terms by Holmes (1945) as: "Granite = pre-existing rock plus added material (A) introduced by and abstracted from incoming emanations ($A + x$) minus displaced material (B) driven forward with outgoing emanations ($B + x$)." The remarkable feature about these emanations ($A + x$) is that (x) apparently leaves no trace, from which we may deduce that they cannot represent ordinary magma.

Qualitative geochemical studies of the successive stages of granitisation in the field recently carried out by Dr. Doris L. Reynolds on the Newry Igneous Complex (1943, 1944) have demonstrated that the minimum introductions (A) were Na, Ca and Si, and displaced materials (B) eventually carried forward were Al, Fe, Mg, K, H, Ti, P, Mn. These (predominantly basic) displaced materials were found to have been fixed in an aureole of "igneous looking" basic and ultrabasic rocks, and it is concluded from these studies that before any given mass of country rock was granitised it passed through a preliminary stage of basification. In a very recent paper (1946) (abstract only available at time of writing) Dr. Reynolds has enlarged on this subject and demonstrated that the geochemical changes leading to granitisation in rocks of all types invariably includes an initial enrichment in ferric constituents and alkalis ("basification," "desilication") followed by a stage of feldspathisation or granitisation proper. Details of the stages in metasomatic alteration of pelitic, semi-pelitic, pramitic and basic igneous rocks are given, providing valuable criteria for the recognition of the provenance of xenoliths or "enclaves" in granite.

In considering the origin of granite perhaps the most satisfying feature of the "replacement metamorphism" hypothesis is in connection with the space problem, particularly as it concerns the enormous regionally gneissose granitic masses of the Archaean shields and ancient continental blocks and the major batholiths usually forming cores to folded ranges of periods later than Archaean. In both these cases, if the granite is considered to be strictly intrusive, that is, added to the pre-existing rocks, then the space factor renders this view untenable. There is no evidence of displacement of country rocks on even the smallest fraction of the scale required, nor has there yet been imagined any mechanism of doming, subsidence, block faulting, stoping, etc., that could account

for the entrance of such volumes of magma involved. All the evidence, on the other hand, points to replacement with little or no bulk changes in volume. However, as far as minor granitic intrusions such as dykes, sills and veins of any age are concerned, the actual injection of material as liquid, *i.e.*, magma, into places of weakness would appear to be an equally logical explanation.

Finally, attention may be drawn to the division of granites into the three categories enumerated above, *viz.*: (a) Archaean granite masses, (b) core batholiths of later age, and (c) minor intrusions of all ages, and to the suggestion, for which there appears to be some claim, that there was greater igneous and metamorphic activity in Archaean times than at any later date, with the inference of a possible fundamental difference in origin between the Archaean metamorphic rocks (particularly granitic) and those of later periods.

GRANITISATION AND THE PRE-CAMBRIAN SUCCESSION

We may now come to a consideration of the relationship of the granitisation replacement concept of the origin of granite to the question of the Pre-Cambrian Succession in Australia. In the light of the modern viewpoint, it is necessary to re-examine evidence as to relative age of granite emplacements and the petrogenesis of adjacent rocks. It is now clear that apparently petrographically dissimilar types of granitic rock, *e.g.*, an apparently massive granite, product of the granitisation process, and an adjacent granitic gneiss or schist, product of partial granitisation, and also possibly a more basic type of igneous-looking rock—say diorite or monzonitic, representative of Wegmann's Mg-Fe "front"—may all be closely linked both in age and origin. Furthermore, it is evident that pressure movements resulting from adjustment of minor volume changes in the country rocks during the granitisation process might result in bodily displacements of the already formed plastic or fluid granite mash producing intrusions of massive non-gneissic granite into its own contemporaneous granitisation products.

In such a case it appears conceivable to the present writer that, especially where the granitised sediments show rapidly varying character and composition, the chemical composition and petrographical characters of the intrusive granite and of the more granitic portions of adjacent migmatites might vary to such an extent as to give the impression that the two "granites" were neither consanguineous nor contemporaneous. It is possible, therefore, that limited field and laboratory observations may have in some cases led to entirely erroneous conclusions as to the relative age of granitic magmas. Further, if the granitisation theory is accepted, then the correlation of granite on chemical and mineral composition alone obviously becomes increasingly difficult.

Consequently it is opportune to review such evidence as is available regarding the periods of emplacement of all bodies of Pre-Cambrian plutonic rocks, both the granitic and the more basic types, in the hope that a clearer picture may emerge of the nature and scope of Pre-Cambrian igneous activity throughout the Commonwealth. It is considered that by making studies of this kind, interesting evidence should be obtained to aid the elucidation of some of the mysteries of the Archaean basement complex, the primeval foundation upon which all other geological formations have subsequently been built. It is to be anticipated that such work will also lead to some interesting conclusions regarding relationships of ore deposits to igneous activity and the granitic rocks, and will thus have considerable economic significance.

There is no doubt that there are in Australia numerous areas which would provide excellent scope for studies of the phenomena of granitisation and granite emplacement in rocks of many different ages. Some of these occurrences were described and discussed at the meeting of A.N.Z.A.A.S. held in 1939, but the

published abstracts of papers submitted (Report of 24th Meeting A.N.Z.A.A.S., Canberra, 1939, p. 95-98) shows that the conception of granitisation held at that time differed in several important aspects from the more modern ideas already expressed. The terms "granitisation" and "assimilation" were then apparently used to describe rather similar processes taking place at the margins of and consequent upon granitic magma intrusions. No clear conception of the meaning of "granitisation," in its modern sense, or of its probable role in granitic magma formation was then indicated.

The "Fundamental Complex" rocks—the granites, gneisses and migmatites associated with high-grade schists of the Archaean Shields—provide exposures on the largest scale that are most suitable for these investigations. The greatest areal distribution of these rocks occurs in Western Australia, South Australia, Northern Territory and probably Queensland. Although many such areas are situated in geographically remote regions and in consequence have not received detailed study, there are still numerous occurrences in reasonably accessible localities which are relatively unknown. The present writer's own personal experiences are concerned with areas in Western Australia, and to a lesser extent in South Australia, which are the subjects of this paper. The notes presented in the following sections refer to observations made in such areas, and are confined in particular to the Pre-Cambrian granites.

WESTERN AUSTRALIA

A glance at David's Geological Map of the Commonwealth of Australia reveals the southern half of Western Australia depicted as composed very largely of "granites of Mosquito Creek Series, of Older Proterozoic Age," which enclose scattered "islands" of metamorphic sedimentary and igneous rocks representing the Yilgarn and Kalgoorlie Series, disposed in a general meridional trend. The "granite" areas of this great Archaean Shield in reality comprise strictly limited outcrops of a wide and diverse variety of acid metamorphic and igneous rock types—massive granites, banded or gneissic granites showing every gradation from slight linear arrangement of minerals through more striped types enclosing relics of absorbed schists to obvious hybrids, composite gneisses or migmatites, and to schists in which only minor quantities of interlaminated "igneous" material can be distinguished. Large tracts of country intervening between these "granitic" outcrops, particularly in the central and eastern goldfields areas, are covered with superficial deposits of sand, forming low, broadly undulating scrub-covered plains in which outcrops are rare and comprise low, bare mounds or flat floors of massive granite. The rocks underlying these sandy plains are generally accepted as being granitic or gneissic in character, and are often distinguished in local mapping by the symbol Gr/Gn. (H. A. Ellis 1939).

It seems clear that this great granitic massif, which can be reasonably assumed to extend discontinuously over an area of the order of 200,000 square miles, cannot be regarded as having the generally accepted form of a batholith, nor yet that of a series of batholiths, as this would imply a body or bodies extending to depths of many hundreds of miles into the earth's crust. Rather, it would appear that it may have the form of a great crustal sheet or sheets of considerable horizontal extent, but relatively shallow depth.

The regional geological structure in some of the "islands" forming portions of the Western Australian goldfields with which the writer is familiar, viz., the Yilgarn (Ellis 1939), portions of Coolgardie, North Coolgardie and Mount Margaret Goldfield appears to be relatively simple, comprising in many cases comparatively gentle folding with little evidence that the present remnants of the Kalgoorlie and Yilgarn Series are the roots of original fold mountain chains

or the products of such other major orogenic movements as might be expected to accompany the bodily intrusion of vast masses of magna.

On the contrary, generally speaking the banding of the granite-gneisses over considerable areas coincides perfectly with the regional and local structures found in the schists of adjacent "islands" of Yilgarn or Kalgoorlie Series, whilst on a small scale banding is frequently to be seen reproducing the structure lines of original schists, of which relicts are still preserved unreplaced. It is quite apparent that these granitic rocks have not developed by the forceful intrusion and upward stopping of a granitic magna, but rather by some process of quiet soaking and replacement of the original country rock schists, *vis.*, "granitisation," in which original trend lines were first undisturbed, but as the "granitisation front" moved forward the heated mass became more fluid, pasty and probably culminated locally in magna which could remain in place or move bodily as an intrusive mass, finally crystallising as massive granite such as that whose outcrops are found as the isolated "rocks" within the sandy plains mentioned above.

Some excellent exposures for the detailed investigation of the products of granitisation are to be found in these goldfields regions, more particularly amongst the high-grade schists of the Yilgarn Goldfield in such localities as Yellowline-Mount Palmer district, 24 miles east of Southern Cross, and the Hope's Hill-Corinthian district, running north from Southern Cross. An interesting feature of these and other areas of the Western Australian goldfields is the fact that a great proportion of the original rocks are basic in character—the Kalgoorlie and Yilgarn "greenstones" contain great thicknesses of basic, probably mainly basaltic, lava flows metamorphosed in varying degree, and some bodies of basic and ultra-basic intrusive rocks, dolerites and gabbros. In many areas these rocks, rich in Fe and Mg, are now represented by amphibolites and amphibolite schists. It is obvious that during regional granitisation of the original basic rocks enormous quantities of Fe and Mg must have migrated out of the rocks undergoing alteration, and it is possible that many of the existing amphibolites and amphibolite schists may represent in fact the fixation of calcic material in a basic "front" preceding granitisation as has been outlined above. These amphibolites could then perhaps be more accurately classed as amphibolitic *diabrochites* (after Dunn, J. A., 1942). Similarly it would seem possible that Ellis' Greenstone Series, subdivision of the Yilgarn System, may represent but a broad "front" of basification of the rocks which may have had an original composition similar to his Whitestone Series.

Detailed investigations of areas in the Darling Ranges, near Perth, in recent years by R. T. Prider (1941, 1945), and others, have resulted in an accumulation of evidence for at least two phases of Archaean granite emplacement in this region: (a) development of hybrid granite gneisses and migmatites from granitisation of pre-existing formations (possibly part of the predominantly meta-sedimentary Chittering-Jimperding Series, relicts of which are exposed to the north-east of Perth); (b) emplacement of a younger microcline granite which has engulfed considerable portions of (a). The younger granite is considered by Prider to belong "to a distinctly later period than the granite which gave rise to the hybrid granite gneisses." However, remnants or xenoliths of the original "basement" rocks, comprising Fe-rich hornblende-biotite-epidote hornfels enclosed in the granite gneisses which Prider considers to be derived from pre-existing basic igneous rock, may well represent "*diabrochites*," relicts of an original Mg-Fe "front," and under existing concepts of the processes of granitisation reviewed above it would not appear inconceivable that the granite gneisses and the younger granite are more closely related in age and petrogenesis than has hitherto been supposed.

Another area of particular interest which Prider has recently described (Prider 1945 b) is at Daring, 90 miles east of Perth, where lenticular xenoliths of charnockitic rock types—ranging from ultrabasic (olivine-hornblende and cordierite hypersthénites) to basic (plagioclase-hornblende-pyroxene granulites)—are found enclosed in country rocks of hybrid gneiss or "acid charnockites" (cordierite-hypersthene-quartz-felspar gneiss, etc.). Prider concludes that the acid charnockites have developed by granulisation of pre-existing hypersthene-bearing basic charnockites which are themselves the re-crystallised products of basic intrusions contaminated by assimilation of aluminous sediments. Here again, by application of the theory of advancing fronts, it would appear that the development of the ultrabasic and basic charnockites may have been a necessary preliminary step towards the granulisation of the original basic sediments to form acid charnockite gneisses and may thus have been an integral part of the one process. These occurrences are of particular interest to us in South Australia because of the development of similar rock types amongst the granite gneisses of the Eyre Peninsula originally described by Tilley (1921).

Other areas in Western Australia where excellent exposures of Archaean granite and gneisses suitable for intensive investigations are to be found are in the belt of "peripheral gneisses" extending around the coastline from Cape Naturaliste in the south-west corner of the State to Albany, and thence eastwards for many miles along the south coast, and it is hoped that these studies will be made in the light of recent developments concerning the origin of granites.

SOUTH AUSTRALIA

Here in South Australia contributions towards the petrogenesis of the Pre-Cambrian granitic rocks have been disappointingly few. This can only partly be explained by the relative inaccessibility of many of the more interesting outcrops of these rocks. Rather it would appear that studies of the stratigraphy of the Proterozoic formations have completely over-shadowed consideration of the older "fundamental" rocks.

Keenan's (1937) investigation of the "diorite" inclusions in the granite of Granite Island pointed towards the possibility of replacement of intruded country rock to form granitic rock, whilst Alderman's (1938) study of the chemical and mineralogical changes involved in the production of the augen gneisses of the Humbug Scrub area stands out as a notable contribution to the petrogenesis of these rocks. The augen gneisses, injection gneisses and pegmatitised schists of this region are considered by Alderman to be due to intimate injection or permeation of original sedimentary schists (? phyllites now sericite schists) along bedding and foliation planes by alkali silicate solutions. This is apparently conceived as an additive metasomatism in which it is calculated that volume increases up to approximately double the original volume would be incurred during the reactions. Internal stresses set up in the gneisses as a result are concluded by Alderman to have been responsible for subsequent dynamic metamorphism of the rocks. Unfortunately the value of this work is weakened, in the present writer's opinion, by lack of supporting field evidence. When the considerable body of schists and injection gneisses in the whole area is considered, volume increases of the order indicated might be expected to produce more noticeable effects than mere local granulation or mylonitization zones within the schists.

Rock exposures in portions at least of the Humbug Scrub area, particularly in the vicinity of the South Para River, are excellent, and much of the district, situated as it is within easy distance of Adelaide, should prove a most fruitful subject for detailed field mapping and petrological studies. Numerous other small areas of Archaean schists associated with granitic gneisses—the Barossian

Series—are to be found scattered throughout the Mount Lofty Ranges, *viz.*, at Houghton, Barossa, Aldgate, Yaukalilla (Benson 1909), Meadows Valley (Mawson 1923), Normanville, Myponga Tiers, Mount Compass, Mount Crawford district (England 1935), Tanunda district (Hosfield 1925). Benson (1909) has noted a marked similarity in, and certain characteristics of the "igneous" rocks of many of these widely scattered areas, which moved him to postulate a single petrographic province in which one magna—the Houghton magna—was responsible for these gneisses by injection into the Barossian Schists. In the light of modern ideas on granitisation, the whole subject of the Houghton magna might well be re-examined.

The present writer was recently privileged to make a brief visit of inspection of the Little Gorge area, about $3\frac{1}{2}$ miles south of Normanville. Here metamorphosed ilmenitic grits and conglomerates, presumably basal beds of the Adelaide Series, are found interlaced and injected or replaced *lit-par-lit* by pink pegmatite felspar stringers. Immediately east of these outcrops the rocks grade to phyllitic schists with ilmenite- and magnetite-bearing quartz-felspar veinlets and in places containing porphyroblastic pink felspar and blue opalescent quartz. Nearby the rocks develop a definite granitic gneissic structure and hybrid igneous-looking rock types are developed, *e.g.*, broadly gneissic "epidote syenite." The writer was left with the impression that this district should prove highly instructive for the study of the progressive metamorphism and granitisation of a series of sedimentary rocks.

One of the best known regions of Archaean gneisses in South Australia is in southern and western Eyre Peninsula. Tilley (1921 b) has recognised and described four groups or divisions of rocks from this area which, in descending order of antiquity, are: (i) The Hutchison Series, (ii) The Flinders Series, (iii) The Warraw Series, and (iv) The Dutton Series.

The Hutchison Series is considered to be predominantly of sedimentary origin—dolomites, calc-magnesian silicate rocks, paragneisses and graphite rocks (Tilley 1920, 1921 a.)—and has been invaded and metamorphosed by the granites and gneisses of the Flinders Series, the most wide-spaced member of the group. The Warraw Series comprises metamorphosed sediments and is distinguished from the Hutchison Series by predominance of massive quartzites in the former. A later *lit-par-lit* injection into the Warraw schists of granite characterised by an abundance of tourmaline in its acid differentiates, resulted in development of the Dutton Series injection gneisses.

Tilley (1921 b) has described the rocks of the Flinders Series in detail—hornblende and biotite granite gneisses, charnockitic hypersthene and diopside granites, with aplites and pegmatites, the latter being especially characterised by hornblende. He concludes that the gneissic structure in the granites is a primary structure representing a foliation imparted to the rocks during consolidation. It is significant that the general trend of foliation in the Flinders Range gneisses (north-south, with vertical to steep westerly dips) is similar to the general strike and dip of the Hutchison Series sediments, which are apparently intruded and enclosed by the granite gneisses at certain localities in the Sturt Bay area. Tilley has paid considerable attention to intercalated bands of basic rocks in the acid gneisses, *viz.*, amphibolites, hornblende schists, pyroxene granulites and the like, which he concludes to represent metamorphosed remnants of pre-existing basic igneous rocks "of slightly higher acidity than the normal gabbroid or doleritic types of intrusive" (1921 b, p. 11), products of an earlier consolidation which have been engulfed by the later acid gneisses. He has described and illustrated lenticular drawn-out and contorted bodies of such basic inclusions, whose folding is explained as plastic deformation following *lit-par-lit* injection and

magma flow, *i.e.*, pygmatic folding consequent upon intrusion by the granitic gneiss.

It would appear that a good case for granitisation, *i.e.*, production of Flinders granitic gneisses and migmatites by *replacement* of the original (? Hutchison) Series, could be presented. The presence of the abundant remnants of basic "igneous" rocks—rare components of the normal Hutchison Series—as xenoliths in the migmatites suggests once again the possibility that these amphibolites may represent relicts of the fixation products of a basic "front" which preceded the onset of regional granitisation in the area.

Further studies of the geology of Southern Eyre Peninsula are apparently yet required to confirm the stratigraphic position of the Warrow Series and discover the genetic relation, if any, between the Flinders and the Dutton Series of gneisses. Another region of granitic rocks likely to yield interesting results from a detailed investigation is in eastern Eyre Peninsula, in the belt running northward from Port Lincoln to Iron Knob and beyond.

Finally, brief mention may be made of the granitic rocks of the Flinders Ranges. Probably the most interesting occurrences yet recorded are those in the central igneous and metamorphic complex of the Mount Painter region. Mawson (1923 b) has correlated these with the Archaeozoic Era, but according to recent investigations described by R. C. Sprigg (1945), in an as yet unpublished report, there is here evidence of a Lower Palaeozoic age for the igneous activity, possibly related to Ordovician orogenic movements.⁽¹⁾ Two types of granite have been recognised—a typically stressed or sheared red granite in which all phases of assimilation and granitisation replacement of the adjacent Proterozoic (Adelaide Series) metamorphosed sediments have been recognised, and a white or leucogranite also intrusive into the Proterozoic sediments but thought to be younger than the red granites. The white granite outcrops are typically massive, unstressed and frequently closely associated with the Thick Quartzite horizon of the series, which is commonly found as xenoliths in the granite.

Scattered outcrops of leucocratic granite are also found in the Flinders Ranges outside the Mount Painter area proper. Petrographic details of some of these occurrences near Umberatana have recently been described by Mawson and Dallwitz (1945), who consider these intrusions to be "in the nature of cupola summits above the general plutonic mass of a large scale granitic intrusion" (p. 48) into the thick Proterozoic and Cambrian sediments.

In the Mount Painter area there are numerous good examples of gradational contacts between gneissic red granite and adjacent quartzites and quartzite inclusions in which the strike and dip of gneissosity in the granite and of bedding structures in the quartzites remain sensibly constant, and grade imperceptibly one into the other. Rock exposures in the Mount Painter area are excellent, and, despite the relative inaccessibility and rugged nature of the country, parts of the area would provide wonderful opportunities for detailed field studies and fundamental research into the mechanism of emplacement and petrogenesis of these granites.

In the preceding notes the writer has commented on a few areas of Pre-Cambrian granites, granite gneisses and migmatites which have come to his notice and which, in the light of modern ideas, he considers would well repay further intensive studies. No doubt many South Australian geologists more familiar with the State than he, can recall other areas equally suitable. It is to be hoped that

⁽¹⁾ A recent determination of the lead/uranium ratio on samarskite from Mount Painter (Kleeman, A. W., 1946, *Trans. Roy. Soc. S. Aust.*, 70, 175-177) supports suggestion of a Lower Palaeozoic age.

they, their associates and students will combine to foster a spirit of more searching enquiry into this subject of granitisation and the origin of the granite "magma."

ECONOMIC CONSIDERATIONS

The general problem of the genesis of ore deposits and of the ore-forming fluid, and more particularly the origin of those ore deposits most closely associated with granite or with rocks of the "plutonic association," is still very much a controversial subject. It is a subject very closely allied to the granite problem and naturally theories of granitisation and replacement metamorphism are of special interest to the economic geologist. For those who have not questioned the orthomagnatic nature of granite a reasonably satisfactory explanation of the genesis of certain of the metallic ores typically associated with granite, *e.g.*, tin, tungsten, tantalum, molybdenum, bismuth, etc., has been provided by theories of differentiation from granite magma, and expulsion of ore-bearing solutions together with early phase volatiles, and subsequent deposition under restricted physico-chemical conditions. On the other hand, if a granite can be formed from pre-existing sediments by the action of suitable emanations, then the primary source of any metallic elements which may be found associated with such granite becomes more obscure than ever. Under these circumstances they can represent either material which has migrated forward and out from the original sediment during granitisation, *i.e.*, possibly forming an advancing metaliferous front, or they may be original components of the granitisation emanations. In the former case the apparent restriction of certain metals, *e.g.*, tin, to a granite association becomes more puzzling than ever; since other metals, *e.g.*, platinum and chromium, are found in association only with basic magma.

Rastall has pointed out another very puzzling feature of metallogenesis associated with granites, namely, the sporadic distribution of certain minerals in time and place. For example, the tin-tungsten-tourmaline association with granite is fairly common but is found in Western Europe only with the Hercynian granites, in Malaya with late Mesozoic probably Cretaceous granites, and in Bolivia probably Tertiary (Rastall 1945, p. 27). In Western Australia this association is found in the Pre-Cambrian granites. Discussions such as these may at first appear largely academic, but when consideration is given to the subject from the point of view of developing a working basis for scientific prospecting the economic urgency of the whole problem becomes obvious.

A specific case which immediately springs to mind is that of the search for new ore deposits in the goldfields of Western Australia. Potentially auriferous, the "kindly" country of prospectors is generally accepted to be the "greenstone" country of the "islands" mentioned above. The surrounding granitic and gneissic country, on the other hand, is usually considered to be non-auriferous, despite the frequent presence of quartz reefs within it. Accepting the principle of the formation of the granitic bodies by replacement of pre-existing rocks, there arises the possibility that pre-existing gold also occurred within these rocks and much of the ore found in known auriferous belts in the greenstone areas may represent "throwouts" formed by the forward migration of gold from the granitised areas.

It is conceivable under such circumstances that remnants of such original gold-bearing rocks and local concentrations of auriferous material may have been jammed back or otherwise retarded from migrating out of the area of granitisation and thus may occur within the granite areas, particularly within the marginal gneissic migmatite zones. The ore bodies of the Edna May (W.A.) Amalgamated Gold Mines at Westonia in the Yilgarn Goldfield, containing gold, tungsten and molybdenum, are found in biotite gneiss country. In a number of other scattered

localities in the northern Yügaru Goldfield small gold workings are to be found in what are considered to be relict greenstone lenses either partially or completely enveloped by granitic gneiss (Matheson 1940).

The question of the genesis of iron ore deposits has been a subject for active controversy for many years. In an investigation of iron ores associated with banded hematite quartzites or "jasper bars" in Western Australia several years ago, the writer noted evidence suggesting at least two generations of iron concentration: (a) a molecular replacement of silica bands in original magnetite or hematite quartzites by granular crystalline hematite, and (b) later emplacement of discordant lenticular bodies or veins of coarse crystalline specular or micaceous hematite often intergrown with quartz. At the time of writing this replacement was considered to be a supergene process, though possibly assisted by heated magmatic waters (Miles 1941, p. 197). The iron ores of Koolyanobbing, 35 miles north-east of Southern Cross in the Yügaru Goldfield, show these features in no small degree. The Koolyanobbing Range forms a long narrow belt of vertical dipping banded iron formations in greenstone country fringed both on the east and west by broad areas of granite and/or gneiss. There is reason to believe that large areas of ferruginous rocks—basic schists, lavas and banded iron formations—must have been replaced during the emplacement of all this granitic rock. The writer has seen in other parts of the district excellent examples of granitised or denatured banded iron formations in which all the iron ore has been removed, probably as soluble hydrides, leaving either a bleached white quartzite or in some cases banded fluorite quartzite (Miles 1946). It is possible that the iron migrating forward with the progressive granitisation of country rock at Koolyanobbing has formed an advancing "terric front" which may have been responsible for the coarse quartz-specular hematite bodies, and possibly even for the earlier main granular hematite replacement bodies mentioned above. The tendency for all this iron to concentrate within a restricted zone, *i.e.*, the original banded hematite quartzite horizon, may possibly be explained partly by a chemical affinity of the migrating material for the already highly ferruginous banded sediment, and partly by the structural control (damming action) exerted by these banded ferruginous quartzite beds.

This subject of the relationship (if any) of adjacent granitic bodies to Pre-Cambrian banded iron ore deposits, such as at Yampi Sound, Koolyanobbing, Willie Mia, Tullering Range in Western Australia and in the Mid North Range, South Australia, should be well worth further investigation.

CONCLUSION

Consideration of the granite problem is a most absorbing occupation for both the research student and the economic geologist. This country provides scope for an enormous amount of intensive investigation of the granites, but particularly the Pre-Cambrian granites and their associates. Both field and detailed laboratory studies are required. The writer would particularly stress the necessity for field work with careful recording of facts and preparation of accurate geological maps on both regional and detailed scales as a preliminary to chemical and petrological studies, a prime requirement which has not always been fully appreciated by some academic workers. In carrying out this type of investigation careful and accurate observation of facts is first required, followed by an impartial presentation of these facts, together with a balanced and logical discussion of the implications and deductions to be drawn from them. In this connection it may be not out of place to draw attention to the critical review of some recent works and the suggested specifications for a satisfactory report which were issued a few years ago by F. F. Groat (1941).

By means of researches such as these we in Australia should be able to contribute notably to world knowledge on this most fascinating and contentious of questions. "What is granite?"—and at the same time take a worthy place with other observers in countries in which the granite rocks, especially those of the Archaean shield, are abundantly displayed.

The ideas discussed in the preceding pages are not new, as has been clearly indicated, nor are they proven to be of general application, whilst some of the suggestions put forward by the present writer are frankly admitted to be pure speculation, not based on any personal experience. However, if any of these suggestions are sufficiently arresting to stimulate amongst geological workers, particularly those in South Australia and Western Australia, a renewed interest in, and a fuller awareness of, the problems of the granite of both Pre-Cambrian and later ages, he will feel amply rewarded.

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Air photo of Granite Area, about 7 miles north of Mount Painter, Flinders Range. North at top of photo. Shows leucogranite (lower right half of photo) intruding and replacing portion of the 'Thick Quartzite horizon (upper left). Abundant pegmatite off-shoots are "advancing" ahead of the granite. Numerous oriented remnants of sediment can be seen enclosed in granite (lower left). South-south-easterly directed dark lines in granite represent major jointing planes.

R.A.A.F. Photo (Vertical) No. 102, Run 337. Lat. 30° 07' S., Long. 136° 30' E - 139° 30' E. 12 April 1945. Scale approximately 27.5 chains to the inch.

THE CLIMATOLOGY OF THE INTRODUCTION OF PINES OF THE MEDITERRANEAN ENVIRONMENT TO AUSTRALIA

BY J. A. PRESCOTT AND C. E. LANE POOLE

Summary

Apart from its native grasslands and forests, the continent of Australia originally offered so little in the way of plants of economic value to man that plant introduction has always been of great importance in the development of the country. The botanic gardens, early established in the capital cities of the colonies and at Darwin, were originally essentially acclimatisation centres and testing grounds for introduced species of plants, although they have generally lost their importance in this regard and this function has been replaced by the plant introduction activities of the several State Departments of Agriculture and the Council for Scientific and Industrial Research.

THE CLIMATOLOGY OF THE INTRODUCTION OF PINES OF THE
MEDITERRANEAN ENVIRONMENT TO AUSTRALIA

By J. A. PRESCOTT⁽¹⁾ and C. E. LANE POOLE⁽²⁾

[Read 14 November 1946]

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INTRODUCTION

Apart from its native grasslands and forests, the continent of Australia originally offered so little in the way of plants of economic value to man that plant introduction has always been of great importance in the development of the country. The botanic gardens, early established in the capital cities of the colonies and at Darwin, were originally essentially acclimatisation centres and testing grounds for introduced species of plants, although they have generally lost their importance in this regard and this function has been replaced by the plant introduction activities of the several State Departments of Agriculture and the Council for Scientific and Industrial Research.

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In the early years of colonisation there must have been extensive trial and error in these activities, but the exigencies of quarantine and the exhaustion of the more obvious introductions have made it increasingly necessary to place plant introduction on a more logical footing. Some highly desirable introductions such as the soy bean have proved exceedingly difficult, while there is no doubt that others have failed through a lack of knowledge of soil and climatic requirements.

In a recent discussion on ecology and the study of climate reported in *Nature* by Day⁽¹⁾ (1946) emphasis was placed on the need for the growth-cycles of introduced species to be in phase with the annual seasonal cycle. Two examples are given of such lack of harmony in Britain. The European larch begins its growth much too early, while the Corsican pine continues growth until much too late. Because of this they suffer seriously from frost in many situations. This tends markedly to restrict the areas within which they can be grown successfully.

It is the purpose of the present contribution to review the climatic requirements of a number of species of the genus *Pinus* which thrive in the Mediterranean region or in regions having a similar climate such as California, and to determine how far such climates are reproduced in southern Australia. In the light of actual experience with these species in Australia, the analysis may reveal some general principles which may be of service in such plant introduction work. The species chosen are:

Pinus radiata D. Don, the Monterey pine, from California.

Pinus canariensis C. Smith, the Canary Island pine.

Pinus pinaster Aiton, the cluster pine, of southern France, Portugal and Corsica.

Pinus nigra Arnold or *Pinus laricio* Poiré, the black or Corsican pine, also of the Mediterranean region.

Pinus halepensis Miller, the Aleppo pine of the eastern Mediterranean.

The Monterey and Canary Island pines have very restricted native habitats, so that the climatic conditions of these environments can be very narrowly defined. The other pines are more widely distributed, and the associated climates are therefore not quite so easily determined.

CLIMATIC CONSIDERATIONS

In dealing with perennial plants, temperature and moisture conditions throughout the year are of importance. Tolerance to low or high temperatures may be important, and greater emphasis has therefore been placed in this study on temperature. Rainfall is not, however, completely overlooked.

In dealing with temperatures, use has been made of the convenient method of wave-form analysis adopted by Prescott (1942), which enables the twelve mean monthly temperatures to be reduced to the three values of annual mean, amplitude

DESCRIPTION OF FIG. 1

Maps of the Mediterranean region, showing

- (a) Natural distribution of *Pinus canariensis*, *P. pinaster*, *P. nigra*, *P. halepensis*.
- (b) Mean annual temperature.
- (c) Mean annual amplitude of temperature.
- (d) Temperature phase expressed in terms of lag in days behind solar radiation.

⁽¹⁾ See also Day (1945).

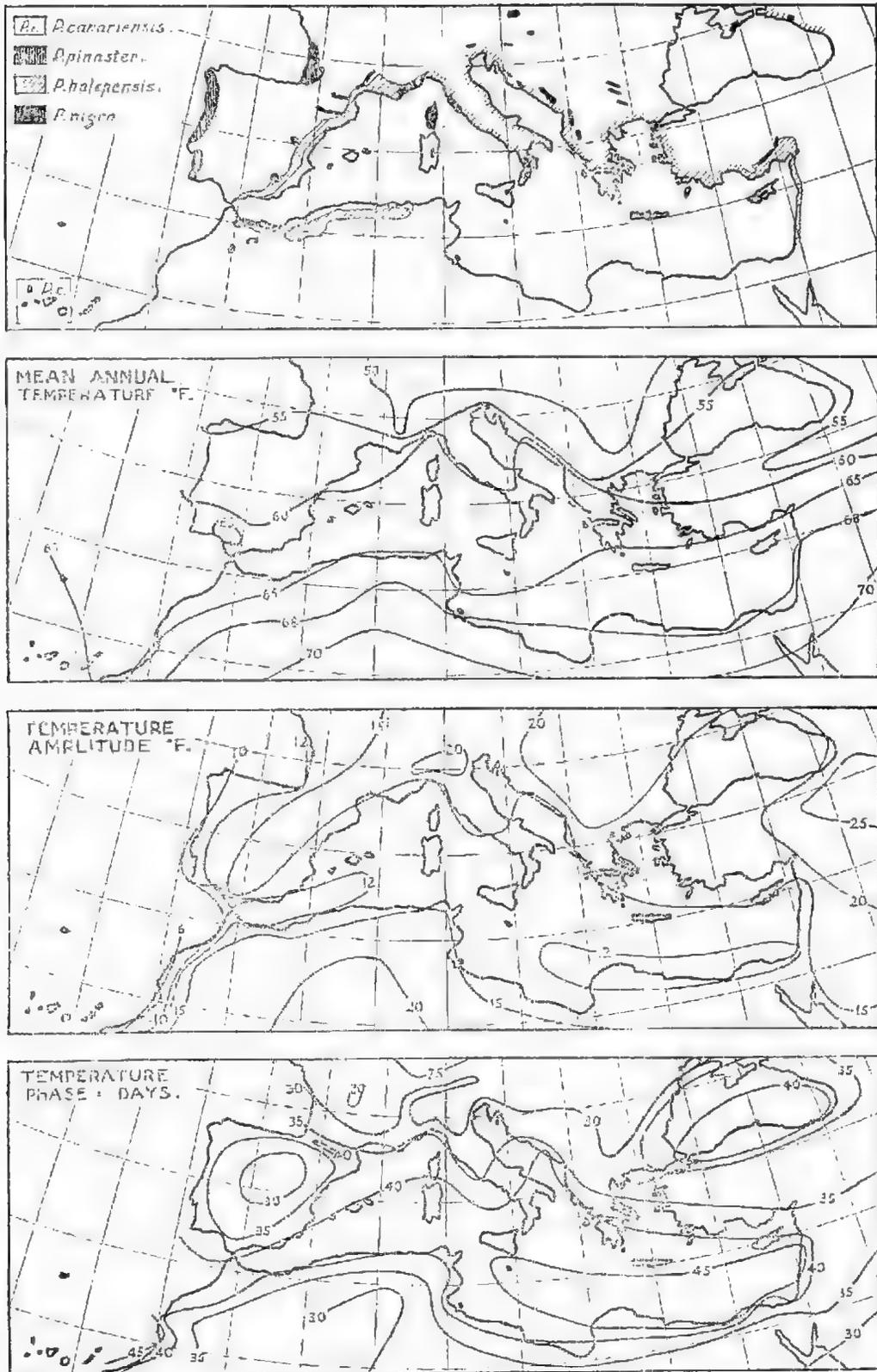


Fig. 1

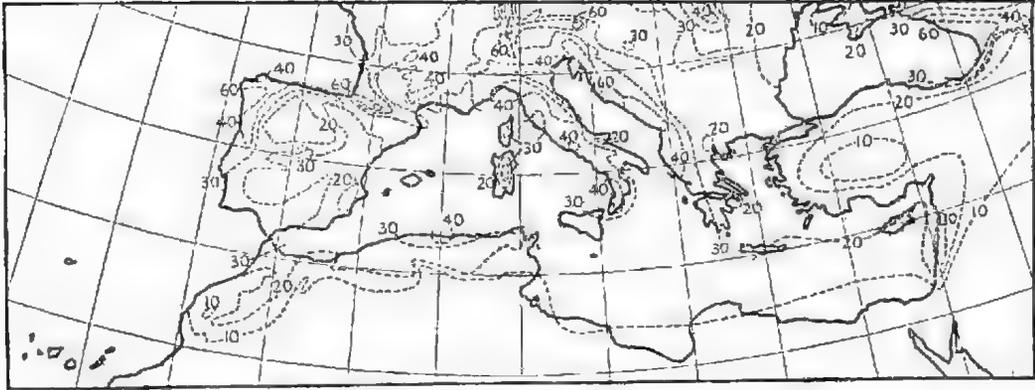


Fig. 2

Map of the Mediterranean region, showing mean annual rainfall in inches based on data of Kendrew (1927), Brooks (1932), and Herbertson (1901).

and phase. It is assumed that there is some correlation between daily amplitudes and annual amplitudes.

Of importance in the case of moisture conditions are the total amount of effective or influential rainfall and its distribution in time. In the Mediterranean climates under consideration, the rainfall has a marked winter incidence and the length of the rainy season becomes an important index. To secure identical combinations of all these factors is not always an easy matter, but it is essential to secure identical combinations of at least mean annual temperature and amplitude with the appropriate seasonal rainfall. One difficulty is to assess the contribution of cloud and fog to moisture supply. This is particularly so in the case of the Canary Island pine and the Monterey pine. It is probable that in these cases, in the Australian environment, somewhat higher rainfall should be allowed than is recorded for the native habitats.

Maps of the Mediterranean region, illustrating the geographical distribution of four of these pines, together with temperature characteristics and annual rainfall, are given in fig. 1 and 2.

PINUS RADIATA (Monterey pine)

Pinus radiata is a native of California and shares with *Cupressus macrocarpa* the very restricted habitat of the Monterey peninsula. Being essentially a coastal species occurring near sea level the temperature conditions can be readily ascertained without interpolation, and the rainfall conditions are similarly reasonably well known. The other habitats of this pine are Año Nuevo Point, San Simeon Bay (Cambria), two of the Santa Barbara Islands and the Island of Guadalupe off the coast of Southern California. The climatic conditions on these islands have not been ascertained, but they are likely to include low amplitudes and a late phase. Attention has necessarily been restricted to the occurrences on the mainland.

In Table I are given the essential data for Californian localities near the zone of natural occurrence of this pine. Santa Barbara and San Luis Obispo have late phases associated presumably with greater oceanic influences. All the amplitudes are quite low. The annual rainfall on the Monterey peninsula has been estimated by Mason (1934) to range from 18.8 inches at Carmel to 25.7 inches on Huckleberry Hill, with almost daily summer fogs.

TABLE 1

Temperature and Rainfall Characteristics of Localities in or near the Californian Zone of Occurrence of *Pinus radiata*.

Locality	Temperature Characteristics			Rainfall Characteristics		
	Annual Mean Amplitude		Phase, lag behind solar radiation	Annual	Seasonal	Length ^(*) of season
	°C.	°F.	days	ins.	ins.	months
San Luis Obispo	58.5	6.2	49	21.9	21	6-7
Santa Barbara	59.8	6.3	50	18.9	18	6-7
Santa Cruz	57.3	6.4	36	27.0	25	7-8
Del Monte	56.4	6.0	35	15.1	14	5-6

For practical purposes, therefore, may be sought zones in southern Australia having the following temperature characteristics:

Mean annual temperature	56-60° F.
Amplitude	5.5-7.0° F.
Phase	35-50 days

Parallel zones (fig. 3 and 4) are found to occur in the south-west of Western Australia and in the coastal regions of South Australia, Victoria and northern Tasmania. Kangaroo Island and the islands in Bass Strait also come within the zone. The climate is thus essentially maritime. Rainfall conditions within this zone are, however, much more favourable than in most of the Californian localities, and it may be assumed that adjacent zones with annual rainfalls of 25 to 30 inches may come within the favourable zone, providing soil conditions are suitable. It is known from Australian experience that this species is rather exacting in its soil requirements, and throughout this discussion it must be borne in mind that edaphic factors are deliberately excluded from consideration. It is of interest to list Australian stations which offer parallels to these Californian stations.

TABLE 2

Temperature and Rainfall Characteristics of Australian Localities having Temperature Regimes similar to those of Californian Stations in or near the Habitat of *Pinus radiata*.

Locality	Mean annual temperature		Phase	Mean annual rainfall	Length of wet season
	° F.	° F.			
Eddystone Point, Tas.	56.6	6.3	42	29.4	12.0
Currie, King Island, Tas.	55.7	5.3	47	34.1	12.0
Albany, W. Aust.	59.9	6.5	45	37.2	11.4
Eclipse Island, W. Aust.	59.5	5.6	52	32.7	12.0
Karridale, W. Aust.	59.8	6.6	44	47.8	9.8
Cape Borda, S. Aust.	58.6	6.6	41	24.8	7.9
Kingscote, S. Aust.	59.1	6.6	41	19.1	8.8
Cape Northumberland, S. Aust.	56.9	6.3	38	26.6	10.6
Robe, S. Aust.	57.9	6.5	37	24.7	9.3
Mount Burr Forest, S. Aust.	58.5	5.7	36	30.7	9.4

(*) The mean length of season in this and the following tables is based on mean monthly values for rainfall and probable evaporation. It would be preferable to use the mean of the lengths of individual seasons, but this information was available in only a few cases. The estimates are likely to be somewhat too high, particularly for the higher values.

It will be seen that the South Australian stations approach most closely the Californian ones in respect both of temperature and rainfall. The close parallel between Kingscote, Kangaroo Island and Santa Barbara may be noted as one example. The Australian stations have also longer rainfall seasons and a greater certainty of summer rainfall. This may well compensate for the absence of summer fogs in the Australian environment.

PINUS CANARIENSIS
(Canary Island pine)

This pine, like the Monterey pine, occurs in a rather restricted zone, but as altitude plays a part in the determination of its habitat, it has proved necessary to interpolate some of the climatic information available in the standard textbooks of climatology and the report of Byles (1932). It has been assumed that this pine finds its optimum temperature conditions at altitudes between 2,000 feet and 6,000 feet, with 4,000 feet as a probable ideal. Although the coastal stations of the Canary Islands have a maritime climate similar to that of coastal California, there appears to be a significant increase in the annual temperature range with increasing height above sea level. No part of Australia shows the sharp changes in topography characteristic of the Canary Islands. Byles assumes a probable annual rainfall of between 12 and 30 inches. The length of the rainy season cannot be precisely determined from the available data, but it appears to be in the neighbourhood of eight months, with a greater certainty than in Australia of absence of rain in the summer months. The temperature data which are appropriate to the discussion are given in Table 3.

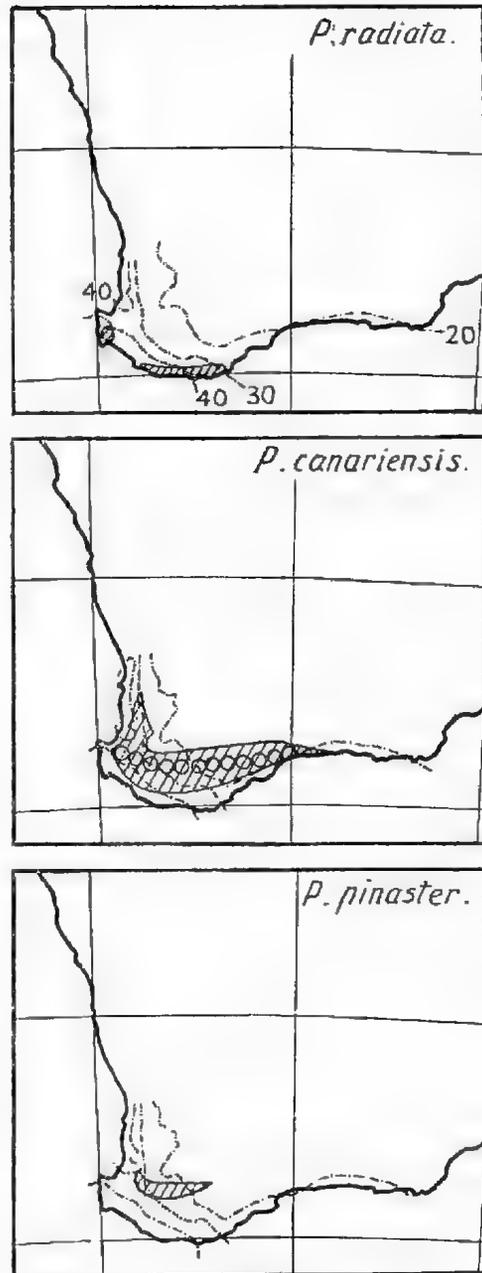


Fig. 3

Maps of the south-west part of Australia, illustrating localities where temperature conditions are similar with respect to mean, amplitude and phase with those of the zones of native occurrence of *P. radiata* and *P. canariensis* and the Portuguese habitat of *P. pinaster*. The numbered lines are isohyets of rainfall in inches. The line of circles parallels temperature conditions with respect to appropriate combinations of mean and amplitude in the case of *P. canariensis*.

TABLE 3
Temperature Characteristics in the Neighbourhood of the Zone of native Occurrence of
Pinus canariensis.

	Height above sea level feet	Annual mean ° F.	Amplitude ° F.	Phase, lag behind solar radiation days
Santa Cruz, Teneriffe	130	67.4	6.3	53
Puerto de Orotova, Teneriffe	70	67.3	6.6	57
Guimar, Teneriffe	366	64.3	7.5	63
(5) Vilaflor, Teneriffe	4,460	54.5	9.8	41
Las Canadas, Teneriffe	6,857	48.9	11.6	32
Las Palmas, Grand Canary	30	67.8	5.4	59
Funchal, Madeira	80	65.0	6.3	59
Agadir, Morocco	—	65.2	7.8	56
Mogador, Morocco	30	63.7	5.6	40

From the data available it may be assumed that the temperature requirements of *Pinus canariensis* approximate to the following conditions on Teneriffe:

	Mean ° F.	Amplitude ° F.	Phase days
At 2,000 feet	60.6	8.3	53
At 4,000 feet	55.8	9.6	44
At 6,000 feet	51.0	11.0	36

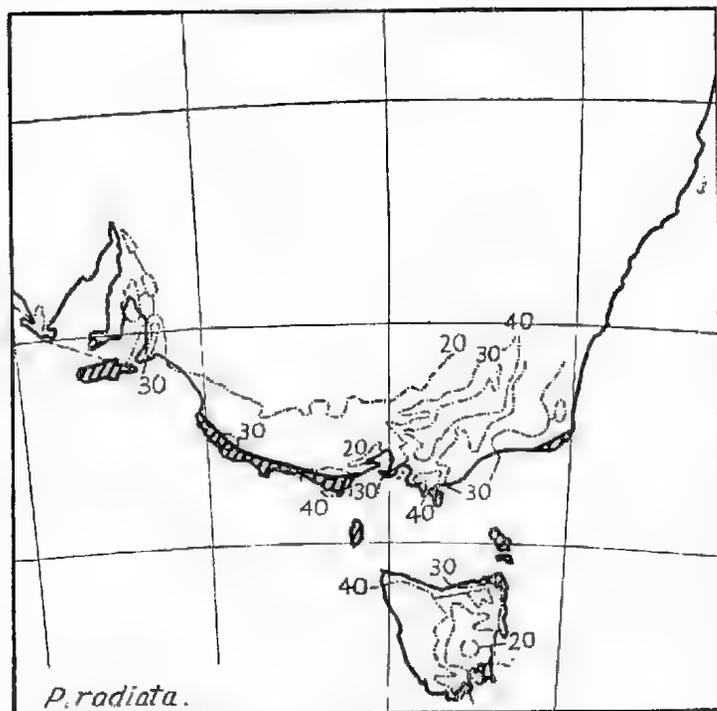


Fig. 4

Map of south-eastern Australia, illustrating localities where temperature conditions are similar with respect to mean, amplitude and phase to those prevailing in the California home of *P. radiata*. The areas are shaded and include Kangaroo Island, the islands of Bass Strait, certain coastal regions of South Australia and Victoria and the north-east corner of Tasmania. The numbered lines are the isohyets with annual rainfall expressed in inches.

It is possible to obtain appropriate combinations of mean annual temperature and amplitude over the whole range, and these combinations have been plotted on the map of Australia and are illustrated in the maps of fig. 3 and 5. The nearest approach to similar conditions occurs near the coast at the extreme western and eastern geographical limits in Australia. Stirling West in South Australia, Terang in Victoria, and Launceston in Tasmania, closely approach in some respects the mean climatic habitat. Some selected values of this kind are given in Table 4.

(5) Calculated from partly interpolated data.

TABLE 4

Temperature and Rainfall Characteristics of Australian Localities showing some Features similar to those of the Zone of native Occurrence of the Canary Island Pine.

Locality	Temperature			Annual rainfall inches	Length of wet season months
	Annual mean ° F.	Amplitude ° F.	Phase, lag behind solar radiation days		
Cape Naturaliste, W. Aust.	61.3	6.7	51	33.4	8.0
Busselton, W. Aust.	60.6	8.5	39	32.0	8.0
Bombala, N.S.W.	52.7	11.0	28	23.8	12.0
Gabo Island, Vict.	59.1	6.9	45	37.3	12.0
Launceston, Tas.	54.9	9.4	31	28.1	12.0
Terang, Vict.	55.5	8.5	36	23.9	12.0
Stirling West, S. Aust.	55.1	9.3	34	46.8	11.4

In most of these cases rainfall may well be excessive and more favourable conditions may possibly be found in somewhat drier zones adjacent to the appropriate temperature-zone.

PINUS PINASTER (Cluster pine)

This pine occurs naturally and is cultivated successfully on the Atlantic coasts of southern France and Portugal. Certain strains are characteristic of Mediterranean France, Spain, Italy and Corsica. The species also occurs in Morocco, in fairly humid environments in the mountains up to a height of 7,000 feet, mainly in the middle Atlas and in certain localities in the Rif. It is rare in the Grand Atlas. It does not generally occur east of Italy or Tunisia, but is said to occur on the coastal islands of Dalmatia. The African occurrences are not regarded as important, but they afford evidence at least of the climatic range of the species. On the whole, the cluster pine therefore belongs essentially to the Western Mediterranean. It is regarded as being much less drought resistant than the Aleppo pine, *Pinus halepensis*, which is much more widely distributed but which does not occur in Portugal.

On the basis of its distribution two races are recognised: *maritima* and *mesoquensis*. The former race belongs to the Atlantic coast, the second to the Mediterranean regions and probably also to Morocco and Algeria. The Moroccan strain is said to be more tolerant of calcareous soils than are the principal races.

The temperature and rainfall characteristics of typical localities are given in Table 5. The wettest month in these regions is October; autumn and not winter is the wettest season.

TABLE 5

Temperature and Rainfall Characteristics of Localities in or near the Zone of native Occurrence of *Pinus pinaster*.

Locality	Temperature			Annual rainfall inches	October rainfall inches	Length of rainy season months
	Annual mean ° F.	Amplitude ° F.	Phase, lag behind solar radiation days			
Atlantic Environment—						
Bordeaux, France	54.1	13.9	31	30.7	3.6	12
Arcachon, France	55.7	13.7	31	34.1	4.5	12
Biarritz, France	56.7	11.5	37	—	—	—
Lisbon, Portugal	59.3	10.3	38	29.7	3.1	9
Oporto, Portugal	57.4	9.9	35	—	—	—
Coimbra, Portugal	58.5	10.5	34	—	—	—
Santiago, Spain	54.9	10.0	37	62.0	6.7	12

Mediterranean Environment—

Var, France	58.3	13.8	35	39.3	6.4	11
Nice, France	59.4	13.8	35	30.9	5.8	10
Toulon, France	58.9	14.2	33	29.1	4.6	10
Marseilles, France	56.8	14.4	32	22.6	4.0	9
Ile de Levant, France	58.6	13.2	34	—	—	—
Montpellier, France	56.1	15.8	30	30.9	4.1	11
Cap Corse, Corsica	59.3	13.1	39	27.0	4.2	—
Cap Pertusato, Corsica	60.6	12.6	42	22.4	2.9	—
Iles Sanguinaires, Corsica	61.7	13.0	45	21.6	3.0	—
Ajaccio, Corsica	61.4	12.3	39	26.4	3.8	9
Bastelica, Corsica	—	—	—	46.6	4.4	11
Corte, Corsica	—	—	—	34.5	3.8	10
Genoa, Italy	59.9	15.0	35	52.0	7.8	12
Sessari, Sardinia	59.9	14.6	37	—	3.4	—

In Corsica, the zone of *P. pinaster* occurs at altitudes of from 1,300 to 3,500 feet, when it gives place to *P. loricio* (*P. nigra*). It is probable that originally *P. pinaster* extended to sea level. Corte is near the average for the Corsican habitat with an annual rainfall of 34.5 inches, a minimum monthly rainfall of 0.5 inches in July and a maximum monthly rainfall of 5.6 inches in November. An estimate of conditions in Morocco, near the north African limit of its occurrence, is possible from data available for Dayet Ashlef. Estimates for the temperature characteristics of the Corsican and Moroccan habitats are given in Table 6. It is difficult to predict the correlation between amplitude and phase and altitude without some local data, but the data for Sessari in Sardinia at an altitude of 730 feet is of some assistance in the case of Corsica.

TABLE 6

Estimates of Temperature Characteristics of Corsican and Moroccan Habitats of *Pinus pinaster*.

	Sea level	Corsica Mean range	Upper limit	Morocco
Mean annual temperature	61° F.	55° F.	51° F.	53° F.
Amplitude - - -	13° F.	15° F.	16° F.	16° F.
Phase - - - -	41 days	35 days	33 days	40 days

The following general limits may be suggested for the temperature characteristics of the zone of *P. pinaster*:

Mean annual temperature	54-61° F.
Amplitude	10-15° F.
Phase	31-39 days

It is possible further to separate the French and Mediterranean zone from the Portuguese zone in order to define the temperature conditions more narrowly. For the Mediterranean zone these may be roughly defined by the following limits and their linear interpolations:

Mean annual temperature	56° F.	61° F.
Amplitude	14° F.	13° F.
Phase	30 days	41 days

For the Portuguese zone the conditions can be more narrowly defined:

Mean annual temperature	59° F.
Amplitude	10° F.
Phase	36 days

These latter conditions, with adequate annual rainfall, are closely reproduced by conditions at Collic, Bridgetown and Donnybrook in Western Australia, rela-

tively near to the coastal plantations of this species of the State Forest service. There is an approach to these conditions in eastern Gippsland and the adjacent coastal regions of New South Wales.

The relevant data for these Australian stations are given in Table 7, where the month of April corresponds to October in the northern hemisphere.

TABLE 7
Climatic Data for some Australian Stations corresponding in
Temperature Conditions to Portuguese Habitats for *P. pinaster*.

Locality	Temperature				Rainfall		
	Mean annual ° F.	Amplitude ° F.	Phase days	Annual inches	April inches	Wettest month inches	Length of season months
Western Australia—							
Collie	59.4	10.9	35	39.4	2.0	7.5	8.0
Donnybrook	60.6	9.8	39	41.1	1.7	7.8	8.2
Bridgetown	58.7	9.7	37	34.2	1.7	5.9	8.1
Victoria and New South Wales—							
Gabo Island	59.1	6.9	45	37.3	3.1	4.3	12.0
Maffra	57.3	9.3	31	23.5	1.4	2.3	12.0
Salé	57.8	9.6	31	23.9	1.7	2.5	12.0
Bega	59.9	10.2	29	33.3	2.2	3.9	12.0
Bodalla	59.3	8.8	33	36.1	2.8	4.0	12.0
Moruya Heads	60.8	8.3	36	34.9	3.1	4.0	12.0

The rainfall distribution in the eastern Australian stations cannot be said to approach at all the conditions in Portugal, notably in the absence of a true drought period in summer. Parallel conditions are therefore restricted to Western Australia.

For the Mediterranean zones there is a wider range of parallel temperature conditions, providing only mean and amplitude are taken into consideration. There is an approach to equivalent phase conditions in northern Victoria and on the western side of the Southern tableland of New South Wales, of which Eurrinjuck and Adelong may be taken as representative. The appropriate combinations of mean and

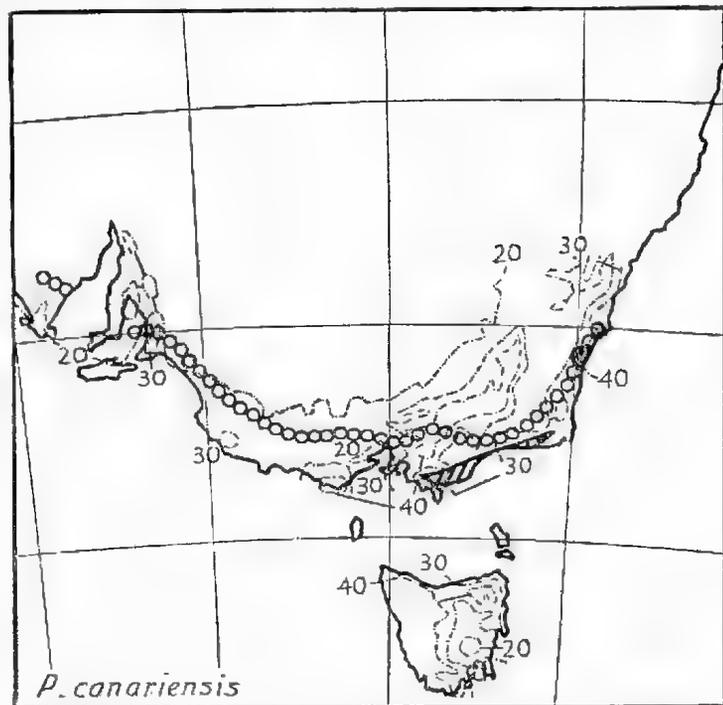


Fig. 5

Map of south eastern Australia, illustrating localities where temperature conditions with respect to mean, amplitude and phase are similar to those prevailing in the habitat of *P. canariensis* in the Canary Islands. The areas are shaded and include areas in eastern Victoria and the south-east of New South Wales. The line of circles indicates parallel conditions with respect to mean and amplitude only. The numbered lines are isohyets with annual rainfall expressed in inches.

amplitude in temperature occur from the north of New England in an arc reaching as far as Rutherglen in Victoria.

The conditions at Adelong and Burrinjuck are given below in Table 8.

TABLE 8

Climatic Data for two Stations in New South Wales corresponding in Temperature Conditions to the Mediterranean Habitat of *P. pinaster*.

Locality	Mean annual	Temperature			Rainfall		
		Amplitude	Phase	Annual	April	Wettest month	Length of season
Adelong	57.9	13.3	30	29.3	1.9	4.0	12.0
Burrinjuck	58.0	13.0	30	33.8	2.1	4.5	12.0

The conditions of evaporation at both these centres is such that near-drought conditions prevail during three summer months. It is probable that appropriate conditions occur near these localities at higher elevations. The information concerning the climatic conditions under discussion are illustrated in fig. 3 and 6.

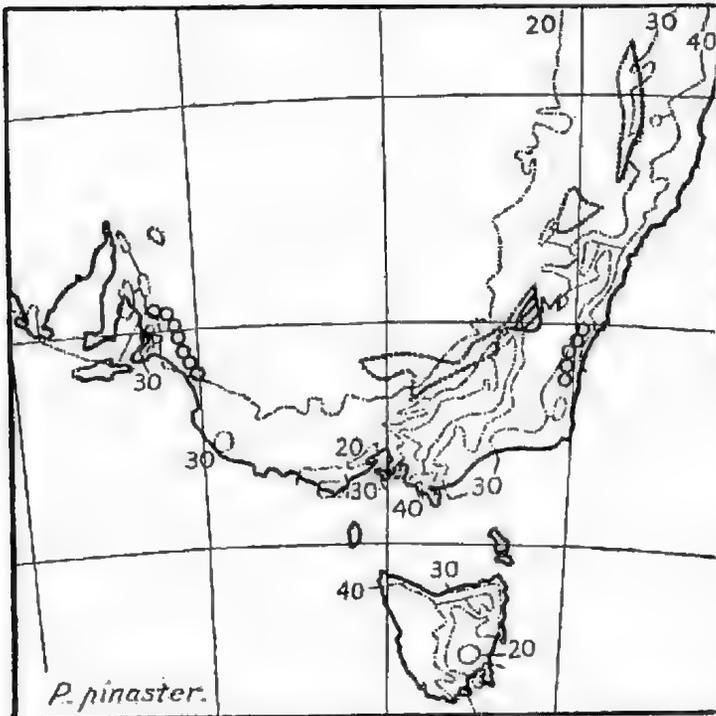


Fig. 6

Map of south-eastern Australia, illustrating localities where temperature conditions with respect to mean, amplitude and phase are similar to those prevailing in the native habitats of *P. pinaster*. These areas are shaded. The area marked M is just north-east of Canberra and reproduces the temperature conditions of the Mediterranean habitats. The area marked P, near Adelaide, reproduces the Portuguese conditions more closely. The lines of circles indicate areas where the Portuguese conditions are paralleled with respect only to mean and amplitude. The areas enclosed in heavily dotted lines indicate areas where the Mediterranean conditions are similarly reproduced. The numbered lines are isohyets of mean annual rainfall expressed in inches.

PINUS NIGRA

(Black pine, Corsican pine, Austrian pine)

The climatic conditions under which the black pine grows in its natural habitats are not so easily defined owing to the paucity of direct meteorological data, associated with the fact that these habitats are at some elevation ranging from approximately 600 feet in southern France and Australia to 6,000 feet in Cyprus and Anatolia. No climatic data have actually been secured relating directly to one of the known habitats of this pine, but rainfall requirements are generally regarded as high, in the neighbourhood of 50 inches per annum.

The main centres of distribution are widely spread but obviously localised. They include southern France, including the Cevennes and Pyrenees; Corsica,

Sicily and Calabria, Austria and Dalmatia, and the region of the Taurus mountains, including Cyprus and localities in Syria. The species also occurs in the Crimea and in the Caucasus region and in the Balkans generally. An isolated occurrence in the Rif of Morocco at 5,000 feet links Africa with the Spanish habitat.

In order to secure an approximation to the temperature conditions of these habitats, correlations were graphically established between altitude, mean temperature, phase and amplitude. Phase tends to be late both at sea level and at very high altitudes, and to be generally correlated with amplitude for geographically grouped localities.

On the basis of these correlations the following estimates of temperature conditions appropriate to *Pinus nigra* have been obtained:

TABLE 9
Temperature Characteristics associated with Habitats of *P. nigra*.

	Mean ° F.	Amplitude ° F.	Phase days
Mean of all estimates	50.4	17.6	31.4
Mean for lowest recorded altitudes	53.0	18.0	31.2
Mean for highest recorded altitudes	48.0	17.4	32.8
Highest temperature estimate (Cyprus)	57.3	20.4	32
Lowest temperature estimate (Austria)	46.4	18.5	26

The high values for amplitude suggest that *Pinus nigra* is associated with a much more continental climate than the pines that have so far been considered.

No Australian locality has a temperature range as high as that of these habitats of *Pinus nigra*. The nearest approach is in the highlands of New South Wales and Victoria. Tasmania is too much within oceanic influences to afford parallel conditions.

Comparison of the above characteristics may be made with the following for Australia:

	Mean ° F.	Amplitude ° F.	Phase days
Mount Buffalo, Vict.	46.4	11.9	34
Omeo, Vict.	53.3	12.6	28
Nimmitabel, N.S.W.	48.5	11.4	28
Crookwell, N.S.W.	52.9	12.4	31
Waratah, Tas.	46.4	6.6	39

PINUS HALEPENSIS (Aleppo pine)

The Aleppo pine is much more widely distributed than the other pines under discussion. *P. pinaster* and *P. halepensis* occur immediately below the zone of *P. nigra*, the former in the western and the latter in the eastern Mediterranean. According to Bean (1925) this is the commonest pine on the south coast of Europe, and is at its finest on the Dalmatian coast. It is more drought resistant than *P. pinaster* or *P. nigra*, and its temperature requirements are continental rather than maritime.

Conditions for two extreme localities may be quoted:

	Mean ° F.	Amplitude ° F.	Phase days	Annual rainfall inches
Ragusa (Adriatic coast)	61.6	15.0	40	59.2
Bou Taleb (Algeria, 4,100 ft. altitude)	53.5	19.0	37	17.1

This latter station has an effective rainfall period of approximately nine months. Temperatures of typical localities for this species are quoted in Table 10.

TABLE 10
Temperature Characteristics for Habitats of *P. halepensis*.

Locality	Mean ° F.	Amplitude ° F.	Phase days
Mean of coolest conditions	53.7	18.9	31
Dalmatian coast	61.2	15.0	39
Palestine coast	68.2	12.3	47
Best range in Cyprus	58.7	20.1	33
Caucasus	56	20	38
Southern France at 1,000 feet	54	17	25
Syrian mountains	59.2	18.9	34

Generally speaking these conditions are more continental than occur in Australia, but the coastal localities can be more closely paralleled. The Dalmatian conditions with respect to mean and amplitude only are reproduced to the north of Cootamundra, New South Wales.

The Palestine coastal conditions are reproduced fairly accurately near Geraldton, Western Australia, as indicated:

	Mean ° F.	Amplitude ° F.	Phase days	Rainfall inches
Geraldton, W. Aust.	67.2	8.2	47	18.7
Chapman, W. Aust.	66.6	11.9	43	18.3

SUMMARY OF TEMPERATURE REQUIREMENTS

It may be convenient at this stage to summarise the mean temperature characteristics of the habitats of the pines under discussion. This is set out in the following table. The summer and winter temperatures are obtained by respectively adding and subtracting the mean and amplitude for each species.

TABLE 11
Summary of Temperature Conditions characteristic of Mean Habitats of Pines of the Mediterranean Environment.

Species	Mean ° F.	Amplitude ° F.	Phase days	Summer ° F.	Winter ° F.
<i>P. radiata</i>	58	6	42	64	52
<i>P. canariensis</i>	56	10	44	66	46
<i>P. pinaster</i> —Atlantic environment	59	10	36	69	49
Mediterranean environment	58	14	36	72	44
<i>P. nigra</i>	50	18	31	68	32
<i>P. halepensis</i>	60	17	36	77	43

The main contrast is between the maritime climate associated with *P. radiata* and the continental climate associated with *P. nigra*. For the first three species listed it is possible to reproduce fairly accurately the appropriate conditions in Australia. For the last two species the amplitudes are not reproduced in Australia.

The temperature homoclines of the first three species are given in the maps of fig. 3, and fig. 4, 5 and 6.

SURVEY OF THE RESULTS OF PINE INTRODUCTIONS

The first introduction of pines was for aesthetic purposes and for shelter breaks, and it was not till the very end of the last century that plantations began to be established to yield softwood for industry.

AESTHETIC PLANTINGS

The first successful introductions were undoubtedly the Mediterranean pines. One which, owing to its economic unimportance has not been dealt with climatically, was the first favourite aesthetically, the stone pine (*Pinus pinca*). Its umbrella crown and its edible seeds contributed to its choice. Next came cluster pine and then Aleppo pine in order of favouritism. These three have survived in city gardens and parklands, homesteads in the country and in windbreaks around the paddocks, from Perth to the Northern Tablelands of New South Wales, wherever the rainfall was sufficient and the soil suitable. Canary pine was a later introduction, and it was not so extensively planted for ornament. The seed was hard to procure, and also the transplanting of the seedlings is troublesome. Black pine under the name of *Laricio* was planted, but only rarely. Growth figures of some of these species planted for ornament and shelter are of interest.

MONTEREY PINE

It was not till the seventies of last century that this pine was introduced from California. Its extraordinarily rapid growth made it a prime favourite, and the Mediterranean species came to be neglected. Grown as a specimen tree, or in avenues, it puts on as much as three-quarters of an inch in diameter and as much as six feet in height in a year. It is very easy to raise in the nursery and can be planted out when only a year old. It was only natural that this pine should have become the prime favourite for planting, both for ornament and shelter. It was planted everywhere in Australia where trees could be grown at all, and it has survived in the belt of winter rainfall where this is more than 20 inches. It has failed in the summer rainfall belt, and its northern coastal limit in New South Wales is around Taree. In the summer rainfall and subtropical warmth it develops a very branched distorted habit of growth and succumbs to the attacks of *Diptodia* following injury by summer hailstorms. Monterey pine is not a long lived tree. Compared with black pine, which grows for 400 years, it is very short-lived, for it only attains about 120 years in its native site in America. The introduction of this tree is too recent to permit of an estimate of its life in the best climatic environment and adaptive situation. It is already certain that its life is a very short one indeed where rain is deficient and soil conditions are not satisfactory. In these circumstances the life of ornamental specimens and avenue trees is between 30 and 40 years. All round the better rainfall areas of southern Australia may be seen grand specimens of Monterey pine of 60 years old. Some of the noblest of them have been felled in recent years owing to the shortage of softwood caused by the war. Specimens four feet in diameter and 120 feet in height are still to be found in the Bowral district of New South Wales, where both rain and soil conditions are very favourable. Such fine trees may be seen in all the southern States, including Western Australia, where the rainfall is more than thirty inches. As the rainfall drops the rate of growth and the longevity are reduced. With altitude compensating in some measure there is an improvement, and very big trees, 60 years old, are to be found on the New South Wales tablelands.

CANARY PINE

Around Adelaide this pine attains 24 inches in diameter and 80 feet in height in 30 to 60 years. In Hobart Botanical Gardens there are two specimens 23 inches in diameter and 71 and 75 feet in height. It is a very common ornamental tree around Melbourne. At Dunlop, in the Australian Capital Territory, there are a few fine specimens 24 inches in diameter at 170 years old. It is a rarer tree in the coastal regions of New South Wales; Clive pine (*P. longifolia*) does better and has replaced it in many park and homesteads.

CLUSTER PINE

Around Adelaide this pine attains a diameter of 30 inches and a height of 80 feet in 50 to 60 years. In the City Park in Hobart there are specimens 40 inches in diameter and up to 89 feet high. Very good specimens are to be seen in the better rainfall areas of Victoria. There were some magnificent specimens at Duntroon in the Australian Capital Territory, one was 36 inches in diameter and 70 feet high. In the coastal region of New South Wales attacks of *Chermes* reduced the vigour of this tree.

BLACK PINE

This pine is rare as an ornamental tree in South Australia. In Victoria there are fine specimens in Ballarat, Mount Macedon and in many of the parts of smaller towns. Some particularly flourishing trees are to be seen in the mountain townships, such as Yackandandah, south of Albury.

It is not common in New South Wales, though it is to be found in many of the stations of the southern highlands. Two good specimens are to be seen at Kupperkunabalong in the Australian Capital Territory. At Watersawang there is a fine row of them, and they are so well acclimatised that crops of seedlings have established themselves in the adjoining paddock. It does not appear to have been introduced in Tasmania in the early days.

ALEPPO PINE

Around Adelaide this pine attains a diameter of 30 inches and a height of 70 feet in 50 to 60 years. It is frequently used as a windbreak. In many inland dry areas, especially where there is lime in the soil, this tree flourishes where cluster pine fails. At Mudgee, New South Wales, it is the best street tree.

Summing up the position so far as the ornamental and arboricultural planting goes, all the species of pines being investigated have succeeded in all parts of southern Australia where rainfall sufficed and soil conditions permitted. It must be remembered that trees planted for ornament, avenues and windbreaks, have a much better chance of survival than trees planted in the close formation necessary to assure a crop of timber-yielding logs. The economic plantation of the forester affords, therefore, a much better test of the suitability of a species to the various factors of environment.

FORESTRY PLANTATIONS

With her apparent wealth of timbers, it was only natural that the artificial creation of forests by planting should have come very late in the history of Australian development. The first State to find the need for growing timber was South Australia, which was deficient even in hardwoods from the beginning of her history. So in 1828 the first plantations of softwoods were established. By that date the vigorous growth of Monterey pine had been recognised, and in consequence it became the chosen foresters' tree very early. The areas planted each year were small, and, in addition to Monterey pine, some of the Mediterranean pines were also planted. In some places the species were mixed and valuable data on comparative growths were obtained. Wirrabara, Bandaleer and Kuitpo, also Penola and Mount McIntyre in the South-East, were all sites of plantations. The rate of annual planting was gradually increased until the twenties of this century, when it reached several thousand acres a year and consisted almost entirely of Monterey pine. By this time, too, the other States had embarked on softwood plantations, so that areas came to be planted in widely separated parts of the continent. While Monterey pine was accepted as the best tree of all, other species, including the four Mediterranean pines, continued to be tested under plantation conditions.

MONTEREY PINE

This species has proved quite successful in the better soils in the karri country of the south-west of Western Australia. Areas of suitable soil were, however, so restricted that it was found best to make cluster pine the main planting species.

In the South-East of South Australia, plantations of this species have attained the best development in the continent. There are now over 80,000 acres of plantation in this region, and the cut of logs amounts to around 5,000,000 cubic feet of timber. This supplies both the saw-logs and thinnings for the production of cellulose; also logs for the making of veneers. Some idea of the rate of growth in this ideal climatic site will be gained by a study of the yield per acre. The maximum rate of growth in cubic feet per acre is 500. The average is around 275. 8,000 cubic feet of logs have been commonly cut per acre from plantations 26 to 30 years old. The success of this species in this region has led to the formation of private companies, and these have established plantations adjoining those of the State Department of Woods and Forests. It may now be confidently accepted that this region will become the most important softwood forest area of Australia, and that this is wholly due to the success of Monterey pine.

While growth was slower, excellent crops have been grown at Bundaleer, Wirrabara, Mount Crawford and Kuitpo. Compared with South Australia, Victoria has not planted so extensively. The best plantations are in the Bright district. The growth here is not so good as in the South-East of South Australia. There are a number of small plantations of great interest, but nowhere is there any large body of pine forest. The Ballarat Water Supply authority established a very successful plantation in its catchment area. Private companies have made plantations, and the one at Portland is the largest. The growth approaches that of the Mount Gambier district.

In New South Wales Monterey pine has not done well in the coastal sites. On the other hand it has succeeded in the mountain region in the Tumut district. Here an excellent rate of growth has been maintained. It is unfortunate that the planting policy established in the twenties was abandoned for 14 years. As a result the total area of plantations of pine is insignificant. While there are many small plantations, nowhere is there a sufficiently large area except in the Tumut district, to test thoroughly the suitability of any of the species.

In the Australian Capital Territory, pine planting was started in 1914 for aesthetic purposes to cover the bare Stromlo mountain near the capital. Economic plantations, chiefly of Monterey pine, have been established since 1926 in the higher rainfall areas in the foothills of the mountain range which forms the western boundary of the Territory. The growth has been satisfactory. It compares with average sites in similar country in the Tumut district of New South Wales. The rate of growth is less than in the South-East of South Australia and would average 200 cubic feet per acre per year. In spite of the dryness of the Stromlo site the aesthetic plantations have done quite well, but although very heavy thinning has been carried out they would seem to be reaching their physical rotation and it is doubtful whether they can be carried beyond 35 years. This area is a good example of the economic value of Monterey pine. Stromlo has supplied the bulk of the flooring for the cottages in Canberra, and, in spite of the fact that the climatic factors are definitely unfavourable, no other species of tree would have given such returns.

Small arboreta, established by the Commonwealth Forestry Bureau to test the suitability of different exotic trees for plantation purposes, gave very interesting results. They were established at altitudes varying from 1,500 to 5,000 feet. Up to 4,500 feet Monterey pine proved the most vigorous of all trees tested. In the plots at 5,000 feet, it failed to become established over three successive

seasons. It was not clear whether it was the effect of long snow cover or of low temperatures.

In Tasmania, only very restricted plantations of this species have been made, and they have not been successful.

CANARY PINE

In South Australia 240 acres have been planted and they are scattered in areas at Wirrabara, Mount Crawford, Kuitpo, Second Valley and Bundaleer. It has done best of all at Kuitpo, where there is a 43-year-old stand. The trees are up to 22 inches in diameter and 90 feet in height. The oldest individual trees are at Wirrabara, and at 65 years are 28 inches in diameter and 104 feet in height.

Western Australia only possesses experimental areas of this species up to 8 acres in extent. These cover a wide area in the south-west in the same localities subsequently mentioned in connection with the Aleppo pine, with the addition of East Kirrup.

The largest trees are at Hamel, and at 45 years are 15½ inches in diameter and 83 feet in height. They have done well at Manjimup; there they are 21 years old and have grown to an average of 10½ inches and a maximum of 14 inches in diameter and heights of from 70 to 80 feet. The species has done well at Nannup and Helena.

In Victoria there are no forest plantations of this species.

New South Wales has used this pine for reclaiming country in process of erosion by wind along the Murray at Moira. It is even healthier looking than the Aleppo pine with which it is associated and is making vigorous growth. "It is exceptional to see a plot that is not a uniform healthy dark green colour," reports the Forester. The mean annual increment in diameter is 0.44 inches, and in height 1.8 feet. The maximum figures are 0.63 inches and 2.1 feet respectively. Unlike Aleppo pine, which stands the frosts of the hollows in this district, Canary pine is susceptible. These differences in frost tolerance are in keeping with the differences in the climatic associations of the two species in their native habitats.

In the Capital Territory only a very small area has been planted with this species. It gives promise at Stromlo of making mill logs, but cannot, of course, compete with Monterey pine in vigour of growth.

CLUSTER PINE

In South Australia areas of plantations running up to 1,500 acres have been established in the South-East. The earliest trials were, however, made at Bundaleer, where there is one acre sixty-one years old. It was also planted at Wirrabara, Mount Crawford, Kuitpo and Second Valley. The development everywhere compares favourably with that of the artificially created forests in the Landes of Gascony. Where it was planted in alternate rows with Monterey pine it has been suppressed by the more rapid grower, except on sites where soil conditions have been unsatisfactory for the latter. It promises to play a larger part in the planting programme of the State as soil surveys reveal areas where it is likely to be the more successful. At Wirrabara it has attained 93 feet in 65 years and a diameter of 30 inches.

In Western Australia this species has been accepted as the best pine for the coastal plains from Perth to Busselton. Considerable areas have been planted, and at first a good deal of trouble was experienced. The growth in some areas was very poor indeed. Research into the cause revealed that it was a question of soil fertility. The use of superphosphate has, it is claimed, corrected the trouble. [Kessell and Stoate (1938), Perry (1939).] Considerable work has also been done on the question of the different races of cluster pine and Perry (1940) reports that the type from Leiria in Portugal was found to be the most vigorous and gave the most symmetrical shape of trunk.

In Victoria the Forestry Commission has established some 2,800 acres of plantation at Anglesea, Frankston and Waare. The oldest is now 21 years, and diameters are up to 14 inches and heights 50 to 65 feet. It is claimed that this tree has been moderately successful only on the best sites in these areas.

In the Australian Capital Territory it has only been the subject of experiment in the altitudinal arboreta. It has not done well, but it is interesting to note that it has not been killed by the very severe frosts that are experienced in this territory. It survives even at 4,500 feet.

In New South Wales it was planted in various localities between Eden and Nowra. Nowhere have large areas been planted, so that it cannot be said to have been seriously tested. The interruption of all softwood planting was a contributing factor to the lack of evidence in this State. In the south coastal plantations it has not proved successful. *Chermes* undoubtedly affected its early growth. No attempt has been made to select the best race for the region.

In Tasmania only small experimental plots have been planted at Strahan on the west coast and at Triabunna and Hastings on the east coast. They are all very young, but reports do not give much encouragement. The Department has now introduced the Portuguese strain, from which better results are expected.

BLACK PINE

In South Australia the total area planted is about 200 acres scattered in small plantations at Wirrabara, Mount Crawford, Kuitpo and Second Valley; and in the South-East at Penola, Myera and Caroline, with largest area at Mount Burr, 97 acres. At Wirrabara it has reached 82 feet and 16 inches diameter in 65 years. Nowhere is it at all comparable with the growth seen in Europe.

In Western Australia planting has been confined to experimental plots in the localities indicated under Aleppo pine, and in addition at Pemberton in the south of the karri country, where its growth is reported as good. In all other localities the species has done badly. The trees are 28 feet high and have a diameter of 5½ inches at 17 years at Pemberton.

In Victoria some 4,300 acres have been planted in the following localities: Aire Valley, Anglesea, Bright, Creswick, Elton Weir, Frankston, Bechelworth, Narbealong, Ovens, Stanley, Tuorong, Waare. It has only succeeded in regions where the rainfall is over 30 inches and where the soil is of good class. The oldest areas are 42 years old, and the height of the trees ranges from 60 to 65 feet, and the diameters from 8 to 14 inches.

In New South Wales this species was tried in all the experimental plantations. Its best growth is at Dago, Nalbo and Goulbi State Forest near the south border. These are all good rainfall and high sites. There is a falling off of growth in the drier regions. A trial was made with seed from the Calabrian forests in Italy, and the young trees planted out at Pilon Hill near Barkow in the mountains. They are only 11 years old, so that it is not possible to say much about their growth. They are healthy and the survival is 99%. The height is 2½ feet and diameters run up to 7 and 8 inches.

In the Australian Capital Territory an area of this species was planted at Pierces Creek in the foothills of the range. The seed all came from Corsica, but very mixed races resulted. The best type has made fair trees, but there are numerous stunted trees with short needles. In the altitudinal experimental plots already referred to, three races are under trial, the Calabrian, the one from the Cevennes known as *P. nigra* var. *salsmannii* and the best Corsican type. All are healthy and vigorous. On the plains of Canberra there are two plots of the Corsican type. They have made useful trees in 30 years, but are not sufficiently vigorous to encourage further planting in this dry area.

ALEPPO PINE

South Australia again leads in area planted, but the total is very small around 230 acres in all, divided between Wirrabara, Bundaleer, Kuitpo and Mount Burr. The best growth was attained at the first two stations. At Kuitpo it is only fair, and at Mount Burr it is poor. The maximum height growth was reached at Wirrabara—101 feet with a diameter of 37 inches.

In Western Australia it has only been planted in experimental plots. They cover a wide area in the south-west, Mundaring, Applecross, Hamel, Manjinnup, Harvey; then back from the coast at Donnybrook, and Nannup and in the karti country at Manjinnup. The best results are recorded at Applecross near Perth. Twelve acres, now 15 years old, show an average height of 41 feet and a diameter of 5½ inches. The trees are vigorous and of good form. A small plot of a third of an acre at Mundaring, now 24 years old, shows a mean height of 52 feet and diameter of 9.2 inches. Some of the break trees run up to 11½ inches in diameter.

In Victoria experiments were made of planting it at Ovens and Beech Forest, but it failed in both sites.

In New South Wales this is one of the species chosen to arrest the wind erosion at Narrandera and at Moira on the Murray. Mr. B. U. Byles reports as follows:

"The plantations at Moira show the best growth of any Aleppo pine I have seen in Australia. They are growing on sand dunes previously timbered with *Callitris glauca*. The trees are healthy and the stem-form remarkably good for the species. From memory I would say that these plantations are equal to, if not better than, anything I saw in the south of France."

Its average rate of growth is 0.37 inches in diameter a year with a maximum of 0.64 inches; the corresponding annual height increments are 1½ feet and 2 feet respectively.

DISCUSSION

THE GROWTH OF MONTEREY PINE IN RELATION TO ENVIRONMENTAL CONDITIONS

A study in a number of localities in southern Australia of the various aspects of the rate of growth of Monterey pine has been carried out by the Commonwealth Forestry Bureau. The records of seasonal elongation of shoots showed that at Mount Burr, in South Australia, growth starts in mid-August, and 71% is put on between then and November; there is restricted growth in the summer, 17%, and between April and June 12% of the annual shoot is added. Growth continues all the year except for three to four weeks in July. In New South Wales, where 18 stations were under observation, in the summer rainfall areas, 80% of the growth was put on in the spring and early summer, 4% to 6% in the summer months and around 15% in autumn. April to June growth occurred in July. In warm summer rainfall stations as much as 60% was put on in summer and 25% in winter. In the dry hills of Carubera, 43% of the 5 feet 6 inches annual shoot developed between September and November, 12% between December and January, 16% between March and April, and 25% in May and June. No growth was recorded in July or August. The increment in area of the trunks of an acre of trees in the same locality showed the following:

Sept. - Nov.	9.1 square feet or 79%
Dec. - Feb.	0.6 " " " 6%
March - April	0.9 " " " 8%
May - June	0.8 " " " 7%

The shoot growth at Manjinnup in Western Australia shows a variation from other stations. Growth started in July, and 27% of the annual shoot was put on between then and the end of September. 16% was put on between October

and March, and the greatest growth took place in the autumn with 57% corresponding with the heaviest rain, 20.9 inches at that time of year.

Dendrographical records show that during periods of drought not only does the diameter increment cease but shrinkages occur. The same phenomenon was observed by Dr. MacDougal in the forests near Monterey and Carmel. The difference is that in its natural habitat the drought and shrinking occurs in the autumn, for, though little rain falls, the misty weather in summer reduces transpiration losses, while in Australia shrinking has only been recorded in the summer months, and there is a significant increment in autumn.

Monthly measurements by Mr. M. R. O. Millett of the average increment in diameter of ten trees at Canberra during the year 1943 have been plotted in relation to temperature and climatic conditions in the diagrams of fig. 7 and 8. Growth is seen to be restricted by low temperatures in mid-winter, and by low rainfall in summer. The climatic index used, the ratio of rainfall to the 0.7th power of evaporation [Prescott (1946)], permits of the assessment of the effectiveness of the monthly rainfall as controlled by the evaporation. A limiting value to this index greater than approximately 0.6 is indicated for the period of effective rainfall. The greater temperature range encountered at Canberra may be compared with that of the Californian home of the species, the mean summer and winter temperatures of which are indicated in fig. 7.

In fig. 9 is illustrated the growth cycle of this pine in relation to mean air temperature, based on observations by Mr. Millett at Yarralumla, A.C.T., during the years 1940-1944, on trees that were kept watered to eliminate the rainfall factor as much as possible. The increments recorded are the four-weekly averages for five trees. To be noted are the much greater growth in spring than in the autumn, and the absence of growth in the seventh and eighth periods in July and August.

The experience in the Australian Capital Territory and on the southern tablelands of New South Wales suggests limits of tolerance of this pine outside the rather restricted range of its native habitat. The limit in the Territory at 4,500 feet is associated probably with a mean annual temperature of 45° F., with an amplitude of 12.5° F., corresponding to a mean temperature of

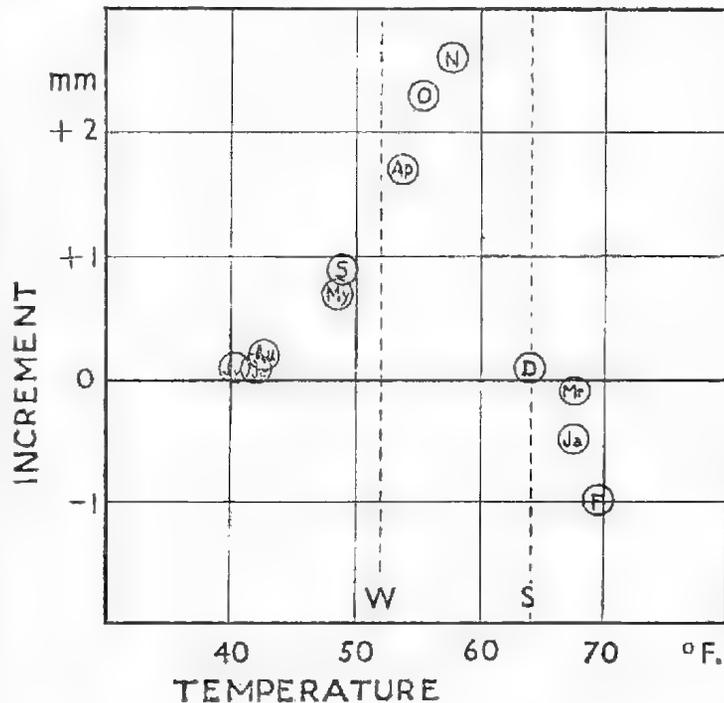


Fig. 7

Mean increment in millimetres per month of ten trees of Monterey pine, 26 years old, in plantations at Canberra, A.C.T., in the year 1943, plotted against the corresponding monthly temperatures. The data are those of Millett.

the coldest month of 32° F. and a mean temperature of the warmest month of 57° F. Assuming that 42° F. is the mean monthly temperature limiting growth and a probable rainfall of more than thirty inches, growth will probably be possible for most of the seven warmer months of the year with occasional checks through summer drought.

Conditions in the Tumut district are associated with a mean annual rainfall of 31 inches and a mean annual temperature of 59° F., with an amplitude of 13.5° F. February is a drought month in terms of average values for rainfall and evaporation, and November, December and January are also likely to be drought months in a proportion of seasons. A mean temperature of 45° F. in the coldest month is some 2 to 3 degrees warmer than Canberra, but still 7 degrees cooler than the native winter climate of this species.

THE CHOICE OF APPROPRIATE SPECIES FOR SOUTHERN AUSTRALIA

The very high yields given by Monterey pine make it the foresters' choice wherever it will grow. Even though the mean annual increment drops to 100 cubic

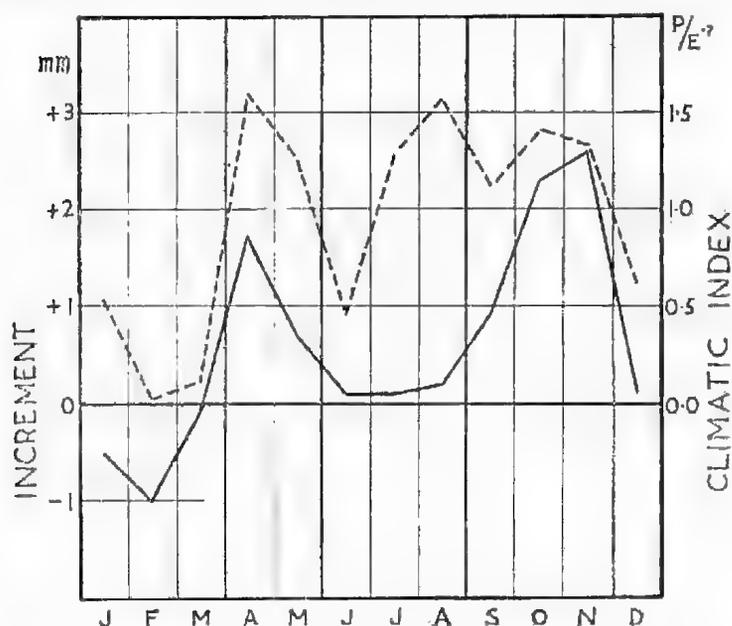


Fig. 8

The increment data of fig. 7 plotted against the monthly climatic index of moisture conditions. The index is the ratio of precipitation to the 0.7th power of the evaporation.

South Wales. Rainfall more than temperature limits its optimum sites, but seasonal distribution of the rain plays an important part. Caution must be exercised in trying to establish it in the regions of well distributed rainfall, while to try and grow it for economic purposes in the summer rainfall areas is to court failure. While 30 inches and over of rain are desirable, such excellent results have been obtained in a winter rainfall of 22 to 25 inches that foresters should continue to experiment with this pine in these comparatively low rainfall regions, low, that is, from a forester's point of view.

(¹) One of the botanical synonyms of this pine is *P. insignis*, and in the early days of its introduction in South Australia it was officially referred to in Annual Reports as the "Remarkable Pine."

feet per acre in some localities, it is doubtful whether other species would yield as high returns in such a short time as this "remarkable pine" (¹) on the same site.

Foresters in all the southern States of Australia must continue to experiment with it well beyond the regions of optimum climatic factors shown on the map of fig. 4. It is a climatically tolerant species and has shown itself very hardy in the heavy frost districts of New South Wales. This opens up a very large area of mountain country in both Victoria and New

Of the Mediterranean pines, cluster pine alone appears to offer a promise of economic return to the forester. It has succeeded well outside its optimum climatic belt in Western Australia shown on the map of fig. 3. It has proved a desirable tree in the soils of South Australia where these were found unsatisfactory for Monterey pine. It will play a more and more important part in the South-East of that State, not only in bringing into production these poorer soils but also in breaking up the very large areas of Monterey pine and so reducing the spread of disease, both entomological and mycological. Further planting of this species is indicated near Adelaide.

New South Wales presents an encouraging field for the establishment of plantations of cluster pine. Experimental planting should be resumed on the south coast, using the best race of Portuguese pine from the forests of Leiria. Further up on the tableland the race known as var. *hamiltonii* might well be used. So much better is the form of the Leiria race, that even where the climatic factors point to the use of the Mediterranean races the Portuguese should be tried first.

Canary and Aleppo pines will fill very valuable roles in arresting wind erosion in many parts of the lower rainfall regions. The economic return in timber from such plantations is of secondary importance, but will provide a useful commodity in a very scantily tree-clad region. In the mountainous districts where water erosion has taken place, these species will be better adapted than any for planting on the very poor eroded steep slopes. The Chapman district of Western Australia suggests itself as a possible area for trials with the Aleppo pine.

Black pine appears to be climatically exotic. While the experiments with it in the mountains of New South Wales are encouraging, there is no doubt that in all cases Monterey pine on the same sites would yield higher returns. It is possible that with western yellow pine (*Pinus ponderosa*), black pine may fill a useful role in breaking up the large areas of Monterey pine in the same way as cluster is doing in South Australia.

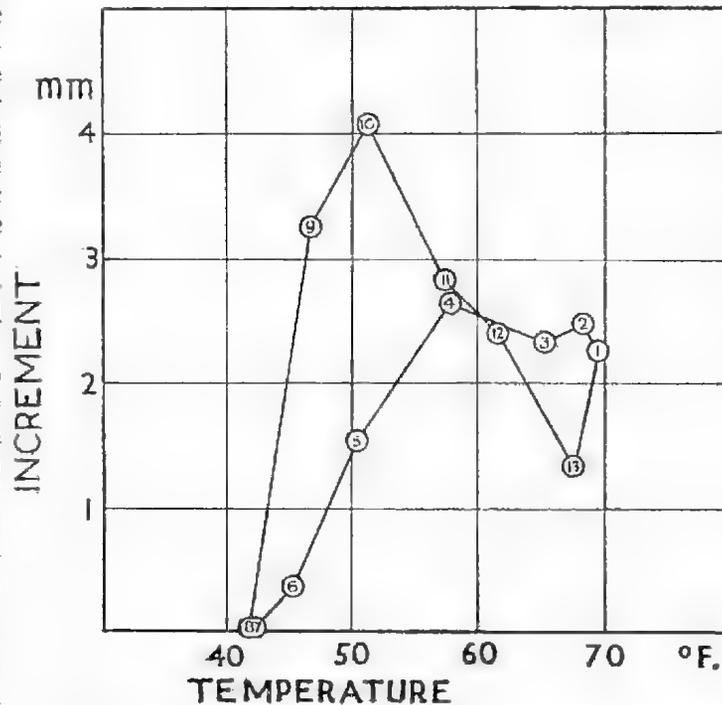


Fig. 9

Illustrating the growth cycle of Monterey pine at Yarralumla, Australian Capital Territory, based on the measurements of M. R. O. Millett. The increments recorded are those of the mean girths of four trees over periods of four weeks, for thirteen successive lunar months of the years 1940-1944. The trees were watered to eliminate the rainfall factor so far as possible.

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SOME HISTORICAL INFLUENCES ON THE DEVELOPMENT OF THE SOUTH AUSTRALIAN VEGETATION COMMUNITIES AND THEIR BEARING ON CONCEPTS AND CLASSIFICATION IN ECOLOGY

BY R. L. CROCKER AND J. G. WOOD

Summary

Recent advances in the understanding of the climatological and pedological pattern of Australia have been paralleled by an improved knowledge of the post-Tertiary historical sequences. New concepts of plant geography and ecology have also been developed. It therefore seems opportune to attempt an analysis of some of the main features of the development of the South Australian flora, and a definition of the factors which have influenced the species-mosaics as aggregated into the present communities.

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By R. L. CROCKER^(*) and J. G. WOOD^(†)

[Read 10 April 1947]

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I. INTRODUCTION

Recent advances in the understanding of the climatological and pedological pattern of Australia have been paralleled by an improved knowledge of the post-Tertiary historical sequences. New concepts of plant geography and ecology have also been developed. It therefore seems opportune to attempt an analysis of some of the main features of the development of the South Australian flora, and a definition of the factors which have influenced the species-mosaics as aggregated into the present communities.

The following discussion has been confined chiefly to South Australia, but the implications and principles can be applied much more generally, and indeed many of them to the Australian flora as a whole. Where necessary, or desirable, no hesitation has been felt in taking examples from outside, or extending the discussion beyond, South Australia.

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II. GEOLOGICAL FACTORS

Modern flowering plants are generally considered to have had their origin in the Cretaceous. Since then the palaeontological record shows a differentiation to more modern types, and by the close of the Pliocene most fossil plants exhibit close generic and even specific relationships to present-day groups (Thomas 1936). It is unnecessary, therefore, to go beyond a consideration of post-Jurassic times in phytogeographical studies of the Australian flora.

The historical influences which have a bearing upon the development of the South Australian vegetation can be considered as being either physiographic or climatic.

1. PHYSIOGRAPHIC INFLUENCES

(1) CRETACEOUS

The early Cretaceous times in Australia were periods of considerable marine inundation, and there was a clear connection of the seas with the ocean to the north, both in the Gulf of Carpentaria region, and to the north-east of Brisbane (Bryan and Whitehouse 1926). It has also been suggested that there was a possible connection with the south, via the Eucla region and the Great Australian Bight. If this were so, east and west Australia would have been completely isolated in the early Cretaceous.

Swamp conditions followed in the late Cretaceous. There are, however, large gaps in the record, and it is probable that swamps did not follow directly the marine sediments (David 1932). They were, in any case, probably much more restricted than the earlier seas. The approximate extent of the Cretaceous seas (after Ward 1926) is shown in fig. 1.



Fig. 1
Approximate extent of Cretaceous seas in Australia.

The latest epoch of major folding in Australia is also believed to have taken place in the Cretaceous. This must have increased habitat diversity and had important effects upon the distribution of the Cretaceous flora. However, neither marine inundation nor the tectonic movements had much direct influence upon the migrations of the flora of southern South Australia. During this period land connection with the east was apparently continuous, and with the west was probably so.

(2) TERTIARY

During the long interval between the late Cretaceous and the Miocene, Australia apparently enjoyed great stability and was reduced to a peneplain. This peneplain is capped by Miocene marine beds in Western Australia and is therefore pre-Miocene, and is probably pre-Oligocene (David 1932).

The Eyrian series is generally considered Eocene or lower Oligocene. The Oligocene proper in South Australia is represented by freshwater alluvial and lacustrine deposits, including lignitic beds, and they have been described by a number of workers (Broughton 1921, Mawson and Chapman 1922, Howchin 1929, Sprigg 1942, and others). Howchin says of the plant remains, "there can be no doubt they represent sub-aerial conditions with low relief of the land and sluggish drainage." The deposits are isolated, and were apparently local.

No major physical barriers to vegetation migrations between south-east and south-west can be envisaged, therefore, in the early Tertiary. In the Miocene, however, considerable areas in southern Australia were submerged, and this must have destroyed the existing vegetation over a large region. The distribution of Miocene-Pliocene seas in southern Australia reached their greatest extent in the ancient Murravian Gulf. They are shown below in fig. 2 (after Ward 1926).



Fig. 2
Extent of late Tertiary seas in Australia.

In addition to destroying the vegetation the seas themselves must have proved a very extensive barrier to migration, and effectively isolated floristically south-east and south-west Australia. Late in the Miocene (David 1932, Sprigg 1942) earth movements began. These continued into the Pliocene, and through the Pleistocene to the Recent. The result was a recession of the sea by the early Pleistocene very nearly to its present position, though parts of the South-East of South Australia were still inundated.

In areas not subjected to inundation the peneplain which formed in the early Tertiary continued to exist and to become further reduced, but volcanic activity in the eastern States, which began in the Tertiary, led to modifications in both soil type and physiography in some regions. The volcanism has continued on a reduced scale right through the Recent, when restricted activity occurred in the South-East of South Australia (Fenner 1921, Crocker 1941).

The late Tertiary earth movements were particularly important in eastern Australia, where portions of old peneplains were uplifted to initiate the present cycle of erosion in the main divides of today (David 1932). South-west Australia was less subject to these movements, and the old peneplain, although uplifted in part, is still preserved there to a remarkable degree.

In South Australia the earth-movements were characterised by block-faulting, which culminated in the elevation of the Mount Lofty-Flinders Range system. Over what are today the Mount Lofty Ranges it is likely that the Miocene marine sediments, which have subsequently been stripped, were very thin, and that before the end of that period or early in the Pliocene, plant colonisation of the elevated regions had begun. Discussing the Eden-Moana fault block, Sprigg (1942) says the faulting was strongly pivotal, and, although continuing to the present day, most adjustment occurred prior to a restricted transgression of the sea in the Pliocene. The old peneplain land surface is still preserved in certain physiographic features of the Mount Lofty Ranges. By contrast, the Flinders lack such conspicuous and general evidence of the older peneplanation, and the greater degree of erosion there suggests that the horst block may have been raised earlier (Mawson 1942). This is almost certain from a consideration of other geological data (Sprigg 1946). The same period of earth movements which built up the Mount Lofty-Flinders system of ranges was also responsible for the initiation of the sunland of St. Vincent and Spencer Gulf (Howchin 1929, Fenner 1930, Sprigg 1946)

(3) QUATERNARY

The blockfaulting initiated in the Tertiary has continued, though on a reduced scale, to the present day. A series of retreats resulted in the emergence of large areas in the South-East of South Australia in the Pleistocene (Woods 1866, Fenner 1930, Ward 1941, Crocker 1941)—perhaps as a readjustment to belated and dwindling volcanic activity.

The Mount Lofty-Flinders system was further modified in the Quaternary, and the Gulfs reached their present extent probably in the late Pleistocene—early Recent. Although the data require reviewing critically, it has been suggested that at about the same time, or somewhat earlier, regional warping and filling on a horizon through Broken Hill-Peterborough and westward from Spencer Gulf had dammed back some of the older rivers, producing a great inland drainage basin (Howchin 1913).

That the Gulfs have acted as a barrier to migration, from east to west and vice-versa, is shown by an analysis of sclerophyll communities on adjacent peninsulas of the region (Wood 1930).

Apart from the Gulfs there appear to have been no physiographic barriers to migration in South Australia during the Pleistocene-Recent.

2. CLIMATIC INFLUENCES

Past climates and their influences upon vegetational dynamics can only be discussed very vaguely in regard to pre-Quaternary times.

The Cretaceous, or at least the early Cretaceous, is considered to have been a period of low temperatures over most of Australia (David 1932). It has been suggested that "the highlands of South Australia, especially perhaps the Gawler Ranges, were white with snowfields."

Tertiary climates are a little clearer. Apparently the early Tertiary was characterised by abundant rainfall and moderate temperatures, for in the Lower Oligocene such mesic elements as *Nothofagus*, *Plindersonia* and *Tristania* were widespread in what are today the more arid parts of South Australia (Chapman 1937). Associated with them were some of the early Eucalypts, including *E. Nientenii* Etring., and *E. Kitsonii* Deane.

The Miocene marine deposits being characterised by coralline limestones indicate warm seas. Indeed, warmer conditions than present are considered to have prevailed right through to the preglacial Pleistocene (Whitehouse 1940). It is not unlikely that, at least during part of the Miocene, rainfall was lower than at present. The Pliocene is generally thought to have been humid, though Whitehouse has suggested that in Queensland there may have been two periods of aridity, alternating with wetter times.

It is apparent that insufficient data have been accumulated so far to permit anything more than very general analysis of pre-Pleistocene climates. On the other hand, post-Tertiary climates can be evaluated better, especially for the late Pleistocene-Recent, but the evidence is still very scanty and the conclusions tentative. The information available has been recently summarised by Browne (1945).

Perhaps the best evidence for a pluvial Pleistocene climate is afforded by the more or less extinct rivers and lakes, and the former existence of large herbivores, in what are now the most arid parts of Australia (Tate 1879, 1884).

It has also been considered that the whole of the Pleistocene was a wet period in Victoria (Hills 1938). These opinions now seem to be generally accepted. David (1932) points out that the reduced temperatures would lower evaporation, and this alone would have the effect of increased rainfall. Whitehouse (1940), on the other hand, believed that, although most of the Pleistocene was pluvial, the very late Pleistocene was characterised by arid conditions in Queensland. The evidence, however, now suggests that desiccation was later than this. It is interesting that the Pleistocene glacial conditions, which were associated with semi-aridity in much of the northern hemisphere, should have been so generally humid in Australia. The reason appears to lie in the minor extension of the Antarctic ice-cap and its stability, coupled with the absence of any major ice-caps in Australia.

Although rainfall was probably plentiful throughout, temperatures varied with Pleistocene glacial and interglacial conditions. These changes must have had a marked effect upon the local flora. Pleistocene glacial conditions in Australia were restricted to small ice fields in eastern Australia and Tasmania. These were too small (see Brooks, 1926) to maintain anticyclones of sufficient intensity to seriously deflect cyclonic depressions. The Antarctic ice-caps are considered to have been more stable than those in the northern hemisphere (Zeuner 1945), and to have had only minor expansions in the Pleistocene. However, what expansions there were probably resulted in a more northerly mean path for Antarctic "lows," which, in the absence of any deflection from the Australian continent, brought pluvial conditions to Australia generally. It would appear quite logical that these continued with only small fluctuations throughout the whole of the Pleistocene, including the interglacial periods. This has some support in the geological evidence.

There can be little doubt, then, that the South Australian Pleistocene flora was subject to varying climatic pressures, and migrations occurred with the changing conditions. Some time after the close of the Pleistocene the rainfall sharply declined and a period of desiccation commenced. Before proceeding to a detailed discussion of the results of this aridity, it is interesting to consider the influence of the major post-Jurassic historical changes on the primary Australian flora.

III. HISTORY OF THE EARLY AUSTRALIAN FLORA

The origin of the Australian flora has been considered by only a small number of writers. Of these Hooker's (1860) "Introductory Essay to the Flora of Tasmania" is regarded as a classic. Since then a restricted literature has developed, especially in relation to the genus *Eucalyptus*, which has been considered as providing the key to the autochthonous element. Works of especial importance are those of Cabbage (1913) and Herbert (1928).

Hooker pointed out that although the Australian flora was characterised by a large number of restricted (that is confined to Australia) species and genera, it exhibited the same primary features as the floras of other continents. He recognised four elements as having played the major roles in its development, namely, Antarctic, New Zealand-Polynesian, Indo-Malayan and Australian elements. These can be reduced to three elements, Indo-Melanesian, Antarctic and Australian.

The Antarctic element is widespread in southern Australia and Tasmania and exhibits close affinities with the floras of New Zealand, southern South America, the sub-Antarctic isles, and to a less extent South Africa. The distribution of this element throughout the southern hemisphere has been held as evidence of former land connection, but the arguments have not been convincing. Attention has been drawn by Gibbs (1921) to the close affinities between the Antarctic element in Tasmania, and the flora of certain mountains in New Guinea. Gibbs considers the Austral-Antarctic element to have migrated originally from the latter region, and produces meteorological evidence for possibilities of wind dispersal of the diaspores. Whatever its origin in Australia the Antarctic element is considered an ancient one elsewhere.

The Indo-Melanesian element is the dominant one in semi-tropical and tropical Australia, and is important in the flora of the arid and semi-arid regions.

Chief interest has been focused on the Australian element which reaches its maximum development in southern Australia, particularly in south-west Australia. Hooker (1860) first pointed out the richness of the flora of south-west Australia in the characteristic Australian orders, approximately six-sevenths of which reach their maximum in that region, the remaining one-seventh reaching maximum development in south-east Australia, with none showing great development in the tropics. Gardner (1922) has indicated the difficulties of defining with exactitude the Australian element, and believes that many genera previously considered belonging to it have too many affinities with the Antarctic or palaeotropical elements, and in fact he questions whether there is a true Australian element. He thinks as it may, certain families and groups which are entirely Australian, or are very poorly represented elsewhere, are worthy of separate consideration, and their remarkable development in south-west Australia must have especial significance.

The centre of origin of the Australian element is unknown. The same general botanical features are shown in the Australian palaeontological record as elsewhere, for example, the first dicotyledonous woods are never known in the Cretaceous of Queensland (Wright 1919) and by the Lower Cretaceous a typical Australian faunula, with such genera as *Eucalyptus* and *Banksia* was existent in South Australia (Chapman 1937), and is preserved also in the lignite of Morwell-

Yallourn, Victoria (David 1932). Hooker was led to suggest from the ordinal and generic peculiarity of the flora in south-west Australia that Western Australia was the centrum of the Australian flora. He points out, however, that from the viewpoint of habitat diversity, one would normally expect East Australia to be richer in peculiar forms. Most of the work concerned with the origin and development of the Australian element has been concerned with floristic elements, and very little attention has been given to the importance of parallel geological factors in its evolution.

In any case, such considerations would have been of little value until conclusions from studies on the basic geology of Australia had reached something like stability. The first plant geographer to consider geological factors very fully was Diels (1906), who postulated the possibility of a pan-Australian flora prior to its being split up by the Cretaceous seas. Wood (1930) also considered that the isolation of the two centres in south-west and south-east Australia, from which migration has subsequently proceeded, was initiated with the epicontinental Cretaceous seas. Subsequently, it was believed, a large measure of isolation has been maintained in west Australia, while considerable admixture with Indo-Melanesian and Antarctic elements has occurred in the east. Hooker had suggested that the flora of South Australia, which is poor in endemics, would be found to be derivative, and intermediate in character between that of the east and west. Wood (*loc. cit.*) was able to confirm this in an analysis of the sclerophyll communities on Kangaroo Island and the adjacent peninsula, and was able to demonstrate that the South Australian gulfs had acted as a barrier to recent migration.

However, since Hooker's day no convincing arguments have been advanced to support his suggestion that Western Australia was the centrum of the Australian element, although it is established as a centre of dispersal. In his analysis of the distribution of the genus *Eucalyptus*, Herbert (1928) has concluded that it is not possible to locate the centre of origin of that genus, but that it is fairly certain that it successfully established itself in regions with a temperate climate and abundant rainfall in the late Cretaceous or early Tertiary. This paper of Herbert is also noteworthy in being the first in which the effect of an earlier aridity was considered systematically.

It is worth reviewing the effect of the geological factors upon the distribution of the primary elements of the Australian flora.

Firstly, the significant floristic and paleobotanical evidence indicates that the typical Australian element probably originated in the late Cretaceous or early Tertiary. There is no evidence of its being widespread until the early Tertiary. By that time, *e.g.* early Oligocene, such genera as *Banksia*, *Hoeka*, *Peuceomania*, *Lomatia* and *Eucalyptus* were well established in South Australia, though much admixed with a New Zealand Antarctic element typified by the myrtle beech, *Nutthofagus*. It is obvious that too much attention has been focussed on the importance of the early Cretaceous seas as isolating primary elements of the Australian flora. In the first place, although it is possible that east and west Australia were then completely isolated, the geological evidence for it is so scant that such a supposition must be considered doubtful. In any case, there is no evidence as yet that the primary elements of the Australian flora had arisen by the early Cretaceous, and indeed all the available evidence suggests a later origin. It is probable that the southern Australian flora was able to migrate from east to west, if not through all the Cretaceous then certainly through the greater part of it, and through all of the latter portion. In South Australia land connection with South-East Australia was apparently continuous throughout.

The over-emphasis upon the importance of the Cretaceous epicontinental seas has been associated with complete neglect, with the exception of a consideration

of the importance of the South Australian gulfs (Wood 1930), of the manner in which isolation has been maintained between east and west in the long interval since the lower Cretaceous.

Because of the incompleteness of the Cretaceous record and the history of the early Tertiary the centre of origin of the Australian element will probably always be unknown. Nor is it reasonable to suggest that there was one centre of origin for the whole element. The richness of the flora of south-west Australia can be understood better in terms of an early widely-distributed flora. That a large and typical Australian element was widespread in the early Tertiary has already been established. If portions of such an element were subsequently isolated in the south-west from general plant geographical principles it is logical to assume that with age and continued isolation a rich endemic flora would have developed. The questions requiring answer are firstly, in what period was such a pan-Australian flora likely to have existed; secondly, when and how did isolation occur; and thirdly, in what manner has isolation been so successfully maintained. It is obvious that all three answers are required to satisfactorily explain the present distributions, and it will be necessary to refer back to the post-Jurassic geological factors summarised previously.

As Gardner (1942) points out, the present distribution of a large number of Australian genera lends definite support to the theory of the previous existence of a pan-Australian element. It was this fact which led Diels to suggest division by Cretaceous epicontinental seas. Reasons have already been given why this suggestion is untenable. It has been shown, however, that typical Australian genera such as *Hakea*, *Banksia*, *Eucalyptus*, etc., were widespread in the lower Tertiary over a great part of south and east Australia. Unfortunately, palaeobotanical evidence does not extend to Western Australia. Nevertheless, the circumstantial evidence is almost overwhelming. It has been mentioned that in the long interval between the retreat of the lower Cretaceous seas and the mid-Tertiary Australia enjoyed great stability, and during this time was reduced to an almost perfect peneplain, with very few, if any, conspicuous ranges. As a consequence, the soil and climatic pattern must have been extraordinarily regular and the zones broad. These circumstances must have been very favourable, if not unique, for the wide distribution of the floral units. It was at some stage or stages of this peneplanation that lateritisation, preserved today as a fossil soil character, was so general. It is most likely, therefore, that the elements widespread in south and east Australia during the Oligocene were also prominent in south-west Australia, more especially as these were times of abundant rainfall. Following lateritisation, and probably well into the early Pleistocene, soil conditions over much of southern Australia preserved a remarkable uniformity and morphological relationship. The evidence then is strongly in favour of a pan-Australian flora from the early Tertiary.

This uniformity would only be preserved if no marked barriers to migration were to develop. Should a subdivision of the flora occur, divergences could subsequently more easily take place. It so happens that the long period of post-Cretaceous stability was broken in the Miocene by the initiation of epeirogenic earth movements, and by the inundation of a considerable portion of southern Australia. Although the climatic zonation was broad, and edaphic conditions exceptionally uniform, there can be little doubt, in view of these seas, that the southern pan-Australian flora was restricted to two major regions in the late Tertiary. The effect of marine inundation as a barrier to migration was heightened by the warmer conditions that prevailed during the late Tertiary, for this climatic effect would have resulted in a migration restricting many groups to the most southerly portions. The Miocene seas had withdrawn almost to that existing at present by the close of the Pliocene.

Whilst it is believed that the foregoing establishes a strong case for isolation of the Australian element in two widely separated portions of the continent, it is still necessary to explain how the isolation has been more or less maintained since the Pliocene. It is necessary to consider in more detail the types of barriers which might have preserved isolation. They are of many kinds. It has been suggested that more or less simultaneously with the development of the Tertiary seas there occurred a southward migration of the flora in southern Australia as a response to changes in climate, and that this increased the effect of the seas in isolating the floras of the two regions. This climatic change was probably responsible for the complete disappearance of some of the more mesic elements in Western Australia, like *Nathoifanus*, and which accompanied the early Australian flora in the early Tertiary of northern South Australia. It is probable that these more mesic elements, or some of them, gained suitable niches in south-east Australia during this southerly migration, because earth-movements (Kosciusko epoch) which were initiated in the Miocene, or even earlier, were increasing habitat diversity.

As mentioned earlier, these earth-movements initiated the break-up of the old peneplains, and had their most profound effect in eastern Australia. In Western Australia their influence was slight, and much of the old peneplain is preserved. In South Australia the climate was greatly modified with the uplift of the Mount Lofty-Flinders Ranges region. Apart from this purely local effect the climatic pattern, as distinct from intensity, in South and Western Australia has been little changed. This being so, the arid region at the head of the Great Australian Bight there, as today, might be a barrier to migration from the south-western province of Western Australia. With higher rainfall conditions, a more northerly and north-easterly expansion of the flora of south-west Australia would be logically expected. Such conditions seem to have occurred over Australia generally in the Pleistocene, so that during that time the Bight area may not have been such a climatic bar to migration. There are, however, barriers to migration other than those of climatic and physiography. The most important are soil barriers. There is good reason to believe that such existed, and an obvious one was the edaphic barrier of the soil type developing on the large deposits of Tertiary limestone inland from the head of the Bight. The isolated flora of the south-west was one selected for lateritic soils and would be largely, if not entirely, unsuited to such different conditions. Further, the gulf region of South Australia must have been a barrier to east-west migrations, as Wood (1930) has shown. The influence of the gulfs, however, has been too recent to have been of very great significance insofar as the maintenance of the historical isolation of the flora of the south-west is concerned. It is important, but outweighed by the other factors already mentioned. With the decline in rainfall associated with the early-mid Recent aridity, there would have been a general contraction of the Australian flora and further isolation. The aridity of the Bight region has undoubtedly been sufficient to preserve isolation since.

It appears that the richness in endemics of the flora of south-west Australia, especially those of the Australian element, is explained reasonably well by the basic historical facts and is evidence for an early pan-Australian flora. The primary division between the floras of south-west and south-east Australia took place probably in the Miocene. Since that time the south-west has been continuously, or almost continuously, floristically isolated from the south-east, with the result that it has preserved great floristic stability. It is unnecessary and undesirable to consider this region as the centre of origin of the Australian element, but it is logical to believe that it has been a centre of dispersal at various times.

Of the other elements it is likely that the Indo-Melanesian is a very old one in the Australia flora, and that invasions through northern Australia have been frequent and sometimes prolonged. It is likely that a major expansion and colonisation occurred during the climatic changes in the Miocene, when a large scale southward migration is postulated as a response to warmer conditions. There must, however, have been many subsequent fluctuations, especially during the colder Pleistocene. That large portion of the Antarctic element which is associated with the mountain plateaux of eastern Australia and Tasmania must be relatively recent, for it is hard to imagine its members finding suitable habitats in the peneplained Australia of the early Tertiary. In all likelihood suitable habitats for this group were not available until the onset of the glacial conditions of the Pleistocene, for although the heights of the higher plateaux may have approached those of today, the Pliocene and pre-glacial Pleistocene are considered warmer than the present. Gibbs' (*loc. cit.*) suggestion that their successful establishment was the result of long distance dispersal must be considered a possibility.

The epi-erogenic uplifts which raised the main divides of eastern Australia in increasing habitat diversity, both edaphically and climatically, also gave an opportunity for successful colonisations by other elements. Similar opportunities would be presented by any climatic fluctuations of the glacial and inter-glacial Pleistocene. Brown (1945) has suggested a major expansion of the rain-forest flora during the Mindel-Riss mid-Pleistocene inter-glacial. This seems possible. Although climatic-induced migrations occurred in the Pleistocene, it is nevertheless to be remembered that the ice-sheets in Australia were so restricted as to be almost negligible, and the climate may have been much more stable than previously thought.

The foregoing comments on the origin and certain features of the Australian flora are an introduction to discussion on the effects of the post-Pleistocene period of aridity. This desiccation has had such an important influence upon the development and distribution of the present vegetation units and communities that it is necessary to consider it in great detail.

IV. THE RECENT ARIDITY

I. THE AGE OF MAXIMUM ARIDITY

The exact age of the development of maximum aridity is uncertain. It was considered by Whitehouse (1940) that the decline in rainfall responsible for the dune systems in south-western Queensland occurred in the very late Pleistocene. This view has recently been accepted by Bryan and Jones (1945) in their stratigraphical outline of the geological history of Queensland. On the other hand Hills (1939), from his important physiographic studies in north-west Victoria, considered that the rainfall decreased in the early Recent, and that the whole of the Pleistocene was relatively wet. In South Australia, palaeontological, geological and palaeoclimatological data have been presented which suggest a very recent age for the effects of maximum aridity. It has been suggested that the arid period occurred "probably much less than 9,000 years ago" (Crocker 1946), and that in the South-East of South Australia the dune-building climax associated with the aridity may have been as recent as 3,000 years ago (Crocker and Curtis 1946).

There can be little doubt that the major dune systems of Australia all belong to the one period of climatic stress (Crocker 1944, *in vivo* Brown (1945) (*loc. cit.*) in attempting a post-Tertiary climatology for Australia has placed the aridity at about 5,000 years ago. Although further evidence is required, it would seem that a recent age can be accepted, and tentatively it might be considered to have been about 4,000-6,000 years ago.

2. TRENDS IN CLIMATE

The most important result of the desiccation was undoubtedly the wholesale destruction of the native flora, which led ultimately to accelerated wind and water erosion. It is obvious that the degree of aridity, or rather the nature and extent of the stresses imposed upon the vegetation were entirely *relative* to the climatic conditions prevailing immediately prior to the decrease in rainfall rather than the level of rainfall itself, for the vegetation communities would be in a state of balance (dynamic) with the edapho-climatic environment. It has been generally agreed that the Pleistocene which preceded the aridity was a wet period (see earlier). In South Australia the large fluvialite and terrestrial deposits which cover so much of the State are considered to be of this age. The trend of aridity in the Simpson Desert region has been discussed by Madigan (1946), who says: "No valid reason presents itself to justify the widely held view that aridity was greater in the past when the sandridges had their bill." He points out that the fact that the sandridges are now fixed is no proof that it would take a long time to replace the flora of the pluvial Pleistocene, and that "the ridges could form in the possibly barren times between the decline of the old vegetation and the establishment of the new."

The relative nature of the aridity is, of course, apparent, but as doubts have been expressed to the view that absolute desiccation has been greater than at present, and because the question is of some importance in the consideration of vegetational dynamics, the evidence will be briefly reviewed. So far as the authors can determine there have been no suggestions that the present-day climate is more arid than that which led to the building up of the large Australian dune systems. The question, then, is whether the present-day climate is more humid than that during the piling up of the sand dunes and dunesheets, or whether more humid conditions have intervened between then and now.

Hill's (1939) considers that in the region of the ancient Murray Gulf there have been relatively wetter and drier periods following the initiation of the post-Pleistocene aridity—"the present and immediate past being relatively wet." His evidence for *intermittent* aridity during the build-up of the dunes was based on the occurrence of horizons of superimposed lime accumulation within the sandridges. This phenomenon might have been due to other causes, as suggested by Crocker (1946), and must now be considered doubtful. The evidence for wetter conditions in this region, however, is important and is of three types. First there are the "capi" hills of the mallee. These are believed due to the solution and re-deposition of dunes of "aged" gypsum with the development of powdery capi at the surface, and would require a higher rainfall than that for the formation of the original dunes. The piling up of gypsum dunes is apparently not operating in the region today. Second, there are the drainage lines through the sandridges below Lake Albury which are considered to have developed before the streams began to cross them, and thus the crest of the general sand drift. In Queensland, Whitehouse (1940) has made a pioneering study of post-Miocene climate, which has provided a stimulus for palaeoclimatological and paleogeological studies elsewhere in Australia. He produces data which indicate that subsequent to the more arid period which followed the Pleistocene pluvial phase, there has been a slight increase in rainfall. The principal evidence lies in (1) degraded chertozem soils, (2) the presence of gypsum and Imbricatus in areas remote from the arid regions in which they are forming in soils today, and (3) the reduction of the effective area of "active type" dunes. In South Australia wetter conditions since the arid period were considered (Crocker 1941, 1946) to be suggested by (1) the wind-piled siliceous sands of the South-East, which are now supporting a "dry sclerophyll" forest, (2) the occurrence of fossil forms of

Nolopala Wanjakala in the lower Murray in the lower Murray which had developed a keel as a result of a sudden increase in temperature and/or salinity (Cotton 1935), and (3) the evidence for warmer seas in very recent times in South Australia, and the suggestions that these may have been coincident with the period of greater aridity (Crocker 1946). Additional evidence is to be had in the occurrence of extensive gypsum deposits, as those in the upper South-East and near Meningie (Jack 1921), and gypsum in buried profiles near Bundaloe (Stephens *et al* 1945) where conditions are too humid for their formation today; and is also provided by the occurrence of fossil calcareous soil horizons under climatic conditions in which lime accumulation would not be expected to occur at present. Such fossil B horizons are to be found in the "travertine" of the Bordertown district. In Western Australia solonetz soils occurring at Rocky Gully, present annual rainfall over 30 inches, indicate greater aridity (Stephens 1946) than at present.

A considerable body of independent data, much of which is of a pedological nature, has been advanced therefore to suggest greater aridity in the past, and most of it appears "valid." On the other hand, some of the evidence as the fact that the dune systems are now vegetated (Hills 1939, Crocker 1941) is of little or no value in itself. Evidence of reduction of the effective area of "active type" dunes in south-western Queensland, as advanced by Whitehouse (1940) and accepted by Browne (1945), is also of doubtful value, for the "dead" low, completely-vegetated dunes which occur as outliers to the Simpson Desert can be matched by similar low vegetated dunes within the desert proper. While no suggestions of the present being more arid than the period of maximum dune building have been advanced, it has been stated that certain buried profiles, as those in the alluvium areas of the Noarlunga-Sellicks district of South Australia, may indicate greater podsolisation than the super-imposed present soil and underlying red soils (Crocker 1946). It is very difficult to assess the age of these profiles, however. They could indicate, though at present it is necessary to proceed cautiously, that there has been a very recent decline following post-arid wetter conditions. Whitehouse (1940) tends to such a conclusion on the abundance of aboriginal artifacts in the far west of Queensland, in regions where there is now no permanent water.

While further evidence is still desirable on some aspects, it would seem that (1) preceding the onset of aridity climatic conditions were much more humid than at present; (2) subsequent to the maximum aridity there was an increase in rainfall, though not of a high order, and indeed very small by comparison with the preceding decrease—otherwise gypsum and lime accumulations of the drier period would have been entirely removed in solution; (3) there may have been a very recent minor decline in rainfall, but considerably more paleopedological research will be needed to further elucidate this. In short, climatic conditions today do not differ greatly from those when dune-building was at its maximum, but rainfall is apparently slightly higher.

The discussion so far has been concerned chiefly with rainfall as an index of climate. Temperature effects are much more difficult to define. It is apparent that the temperatures of the late Pleistocene, which coincided with the last great glaciation, were low, so that in addition to high rainfall preceding the initiation of aridity, we can deduce colder conditions.

The extinction in southern Australia of a suite of surface-dwelling marine species dominated by *Anadara trapesia*, which are now to be found in many localities along the southern coast as sub-fossils, is of particular interest. These species are still living in more northern (warmer) waters, and it is considered their very recent extinction was due to a sudden decline in temperature. It is

also certain that the suite was present in southern waters for a very limited time. The suggestion has been made that the brief stay of these species was coincidental with and consequent upon the high temperatures associated with aridity (Crocker 1946). It has not been suggested at what stage in the development of the desiccation *Anadara* and its associates became established along the southern Australian coast, but it is likely that they persisted beyond the period of maximum dune-building (Crocker and Cotton 1946).

There is strong evidence, therefore, to indicate that higher temperatures than those prevailing at present occurred in South Australia a very short time ago, and these were probably coincident with the lower rainfall of the arid period.



Fig. 3

The recorded distribution of dune systems and dune sheets in Australia.
(Chiefly after Madigan, Hills, Prescott and Crocker.)

3. GENERAL EFFECTS OF ARIDITY

Loss of soil stability in South Australia and surrounding regions on a grand scale resulted from the sudden modification of climate, and it led to the build-up of the extensive systems of aeolian deposits, dunes, dune sheets, etc., of most of our major and lesser ergs (fig. 3). Such widespread wind erosion could only have occurred following the wholesale destruction of the local flora. It is apparent that for this to have happened the aridity must have been not only extremely severe, but its onset must have been particularly sudden. Otherwise the vegetation would have been able to maintain soil stability by simple migration. It was obviously unable to do this.

It is interesting to picture what probably happened. A catastrophic⁽¹⁾ decline in rainfall which initiated the aridity placed such a stress on the pre-arid flora that over the greater part of the State and beyond it was almost completely wiped out. An early replacement of this old flora by a xeromorphic one capable of withstanding the aridity, that is capable of migration and ecesis under the extreme conditions, was not possible. This was chiefly because the most

⁽¹⁾ From the biological viewpoint.

desiccated region today, as for example, the Lake Eyre Basin, were, prior to the onset of aridity, so moist that centres for the rapid dispersal of the diaspores of the required arid element must have been extremely few, and perhaps almost non-existent. As the remnants of the more humid flora disappeared and disintegrated under the extreme desiccation, both wind and water erosion were greatly accelerated. The eroding power of occasional heavy rains, which no doubt still occurred, but with probably greatly reduced frequency, was very high and carried considerable quantities of silt and sand into the drainage basins. This, in the absence of a protective vegetative cover, was transported and winnowed by the winds to initiate dune systems. In other parts the fluvial agencies played a smaller and smaller part, until finally, at the other extreme, dune systems of a purely deflationary origin on which fluvial agencies were unimportant became piled up by wind (Crocker 1946) playing on soils which had completely lost their stability. This loss of soil stability was not general (see fig. 4), nor did it proceed

to the same degree or with the same rapidity everywhere. Certain soils were much more liable to complete loss of stability than others, depending, no doubt, upon a complex of factors. In South Australia soils which were derived from highly calcareous parent material or which contained large quantities of lime in the profile were particularly unstable. As a result the A horizons of the soils developed on the late Pleistocene calcareous dunes, those of our present mallee regions, which had received large quantities of calcium as loess, and those derived from calcareous rocks, as the Tertiary limestones of the Nullarbor Plains, were largely stripped, transported and re-sorted to form ergs. Typical examples are the Nullarbor-Spencer dune system, and those of the South-East and "mallee" regions.

It is possible that strong winds greatly assisted the dune-building, but such a possibility may be dismissed for want of any evidence one way or the other. Although nothing can be said of the intensity of arid winds, the general wind pattern was apparently very similar to that today, because the dune systems throughout Australia, which are entirely or almost entirely of the sandridge or *scif* type, show a consistent orientation with the wind regimes of the present (Madigan 1936, Hills 1939).

One consequence of the fact that soils varied in their erodibility and that possibilities for the maintenance of vegetative cover, despite the adverse climatic trends, varied in different localities (see later), was that the dunes were not all initiated at the same time. For example, although resultant from the same arid period, the time of dune-building initiation and maxima may not have coincided exactly in different localities. The Murray mallee systems may have been slightly in advance or behind those, say, in the lower South-East.

4. CONTRACTION OF THE FLORA, AND SURVIVAL FOCI

Although over the greater part of South Australia and the adjoining hinterland regions the old vegetation was largely destroyed and countless species must



Fig. 4
Portions of South Australia where loss of soil stability was either general or frequent during the mid-Recent aridity.

have been entirely extinguished, remnants of the pre arid flora managed to survive the desiccation in especially favoured situations.

The pre-arid topography was almost identical with that of today, except for the purely superficial sand deposits. It is obvious, therefore, that the rainfall gradients were similarly zoned. This pattern is determined chiefly by latitude and distance from the coast, but is modified by other factors, most important of which are the influences of mountain ranges and hills. It is apparent that when the severe climate stresses associated with the sudden onset of desiccation were imposed, the mesic flora's sole defence was a migration towards wetter conditions.

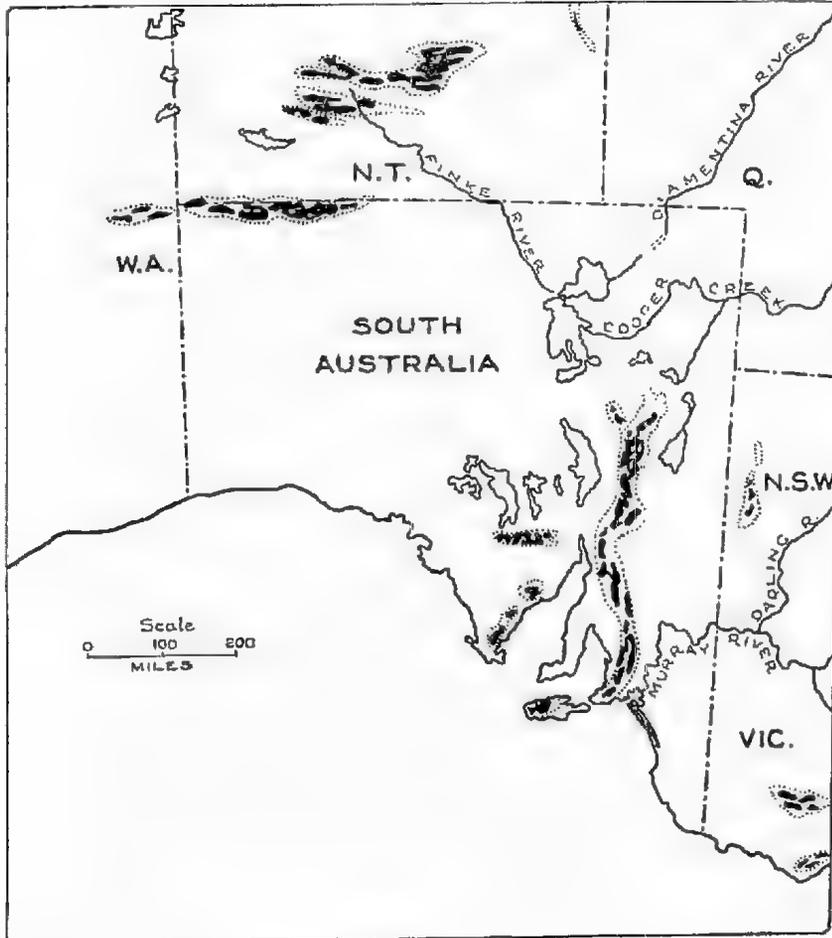


Fig. 5
Principal refuges during the Great Australian Arid Period.

Successful migrations would only be possible where the rainfall gradients were steep—that is where the distances between climatic horizons were small and where the propagule dispersion capacity, the establishment capacity and the ecdysis capacity of the species were rapid enough.

Reference to the present rainfall distribution, and comparison with a topographic map, indicate quite clearly that the possibilities for successful migration were very limited and could occur only adjacent to the major ranges. The ranges were important regions of survival for another reason even where their influence on rainfall was not so great, for within them occurred the greatest diversity of microclimates. In the ranges and hills were the largest number of ecological

niches, the greatest variation in habitats, to be offered the retreating vegetation. They were, therefore, the principal refuges of the relic flora which survived the stress of aridity. Other refuges of less importance were the major drainage lines, any of the lakes which, although reduced in area, did not entirely dry up, and other centres more humid than surrounding areas.

The principal refuges of the arid period in South Australia and adjacent regions are shown on the accompanying map (fig. 5). The most important were, no doubt, those of the Mount Lofty-Flinders Range system. Others of note were Kangaroo Island, the ranges of eastern Eyre Peninsula, the Gawler Ranges, the Murrumbidgee, the Macdonnell-James Range system (Central Aust.), the Gramscians (Vict.) and the Murray drainage system. Although these were the main centres of survival, the vegetative cover within them was very restricted. This is evidenced by the presence of climbing dunes in the Mitchell region of Eyre Peninsula. These dunes are outliers of, but more or less continuous with, those of the Nullarbor-Spencer dune system, and cover portions of the ranges of central County Jervis. Similar evidence is provided by the aeolian sands of portions of the Mount Lofty Range system, as for example, those that are so conspicuous in parts of the Bremer Valley.

V. DEVELOPMENT OF PRESENT COMMUNITIES

The numerous ecological niches which acted as centres of survival were also the focal points from which commenced the migrations leading to the establishment of the present-day communities. No doubt the climatic duress associated with the desiccation resulted in great modifications in the flora. In all likelihood the isolation and continued stress of existing under conditions approaching or at the limits of tolerance for most species, favoured a large number of sub-species and strains relatively unimportant previously, and resulted in endemism of varying degrees. It is interesting to trace the major aspects of this development and to attempt a definition of some of the migratory routes and the principles involved.

I. MIGRATION AND RECOLONISATION

Although the severity of the aridity resulted in such a restriction in area of species and the destruction of the pre-arid vegetation on a grand scale, it is probable that a slow recolonisation was begun by a few drought resistant and perhaps some new genotypes, before any improvement in rainfall took place. Any such migration, however, must have been slow and limited to a few previously unimportant species with poor dispersal capacities, for otherwise the loss of soil stability would not have been so widespread or have proceeded so far. It is obvious that the greatest number of species surviving in the relatively few refuges were far from being under optimum conditions and competition for the available ecological habitats was great. It was not until an improvement in climatic conditions, which probably included an increased rainfall and slightly lower temperatures, resulted in a release of both the pressure of competition and the pressure of an adverse climate that re-colonisation could be very effective.

The speed at which re-colonisation proceeded and the pattern it followed would depend on many factors. In the ultimate analysis it would be governed by the ability of the individual species and its biotypes to produce and disseminate propagules. The speed with which species could exploit the opportunities of an extended climatic habitat range would depend, therefore, on their special mechanisms for dispersal. Although most plant geographers believe that long distance dispersal is of infrequent occurrence owing to the effective barrier of established communities, such a deterrent would not be operative in this case because the area being colonised was virtually a bare one. It is likely, therefore,

that with the relaxation of climatic stress the species with capacity for wide dispersal of germules rapidly became widespread and, especially away from the centres of survival, played the dominant role in the early stages of the seres.

2. MIGRATORY ROUTES

Dissemination of propagules is, of course, only the first stage in the process of re-colonisation. It is necessary for them to germinate and become established in the new sites. Only germules which come to rest in suitable habitats, that is habitats within the range of tolerance of the ecotype, can hope to survive and ecesise. Within the climatic amplitude of the biotypes, successful establishment of species in the invading flora would be governed, therefore, principally by other environmental factors. In the relative absence of competition in the initial stages, there can be little doubt that the distribution of the early elements was determined within their climatic tolerances, chiefly by the edaphic environment. Soil conditions over and above the effect of chance distribution of the initial propagules, were undoubtedly the major ecological agents which modified the checkerboard of the invading vegetation, and indeed, imposed upon it a special pattern.

Although the underlying causes and the modes of dispersal are fundamental to distribution, they would have had little influence in just where the propagules initially came to rest. This was dependent upon the relationship of the parent plant to the agents of dispersion, physiography, etc., that is, chiefly dependent upon meteorological factors, waterways and physiographic conditions. The exact site at which a propagule lodges and germinates is, as has been pointed out by Cain (1944), entirely due to chance in the sense that there is no conscious co-operation between the germule and the complex of dispersal agencies. Following dispersal, germination, and in suitable habitats ecesis, aggregation and re-dispersal of species no doubt occurred, and very soon the factor of competition became operative, imposing a general, though variable, brake upon the rate of migration. Nearer the centres of survival the barrier of competition would obviously be imposed earlier because of the greater density of propagules.

With the release of climatic pressure on the relic flora, re-colonisation, no doubt, commenced from most refuges. It is apparent, therefore, that potential migration could have proceeded in many directions at once. The extent and speed at which these movements took place was governed, apart from those factors residing within the species itself like dispersal capacity, chiefly by the soil mosaic, as mentioned previously. This is indeed a principle of dynamic plant geography (Gleason 1923). It has been stressed by Cain (1944) in saying that successful migration depends upon the occurrence of a "continuity of habitats which are within the ecological amplitude of the migrating species." The "ecological amplitude" of a species has its seat in its genetic constitution, and strictly, therefore, within the species itself, but the occurrence of suitable habitats within this range is chiefly a function of geological and pedological history in which vegetation plays an important, but minor, role. It is almost certain, therefore, that the main migratory routes in the development of the present South Australian flora have been from the survival centres along series of closely related soils.

The extensive dune systems, many of which are linked directly with the survival centres—the Spencer-Vincent system, Murray mallee dunes, Simpson Desert, etc.—would, for example, have been admirable routes for re-colonisation, and were, no doubt, some of the most important migratory tracts. Others were the gibber downs, the mallee-desert loam soil complex, and drainage lines, both minor and major. The mallee-desert loam soil complex covers a multitude of variations, but within it there is a repetition of closely related edaphic habitats

which are not beyond the dispersal range of many species. It was quite clearly one of the major migratory routes. Indeed, in the broad sense, and omitting the drainage lines, the aeolian sand systems, the gibber downs, and the mallee-desert loam soil complex have been the three major edaphic influences in the development and distribution of the present flora. To these may be added the red-brown earths which extend in a practically unbroken sequence from the Adelaide region to the lower parts of the northern Flinders, and the terra rossas and their allies which are associated with aeolianite limestone.

In addition to the importance of series of closely related edaphic habitats within the ecological tolerances of the advancing species, climate has been a determining influence on the direction of the main highways. As the migrations received their greatest impetus with a small increase in rainfall, it is obvious that they proceeded progressively from more humid to drier areas. This is well illustrated by an analysis of the principal elements of the vegetation of the lower South-East of South Australia. Of a total number of 212 Australian species recorded on a general ecological survey of the region (Crocker 1944), 136 were limited to eastern Australia and South Australia, 52 were to be found in both east and west Australia, and 23 were restricted to South Australia. One species (a grass) was limited to South Australia and Western Australia. It is obvious that the major re-colonisation in this region has proceeded from the east, that is from survival centres in western Victoria. The above analysis was made on the vegetation as a whole. A separate analysis of the sclerophyll communities, which occur on soils that were completely unstable and therefore devoid of vegetation during the aridity, would undoubtedly have shown this trend even more strongly, for it is most likely that a few isolated swamps of the inter-range plains of the region did not become completely dry. They probably acted as focal points for re-distribution of some species like *Gahnia trifida*, *Poa australis*, etc.

The principal migratory routes in the re-establishment of vegetation cover and the development of the present communities in South Australia are shown in fig. 6. They have been superimposed upon a somewhat simplified soil map based on that published by Prescott (1944), together with information collected by one of the authors (R. J. C.). The interpretation has been modified to suit the requirements of the present paper and no attempt has been made to indicate the integration of types, such as the occurrence of mallee or gibber soils in inter-dune corridors, etc. More detailed information on soil distribution in South Australia can be obtained from other publications (Prescott 1931, 1944, etc.).

VI. TYPES AND PROBLEMS OF SPECIES DISTRIBUTION

The problems of ecology, and in its broader aspects plant geography, are largely those of explaining the types of species distribution and the differences between plant communities. Because species and their biotypes react differently to changes in environmental conditions, that is, because their potential edapho-climatic environments vary, in the ultimate analysis their distribution is governed by the individual ranges of tolerance. The individual may, therefore, have a potentially wide or narrow distribution, depending upon the occurrence of suitable climatic and edaphic habitats.

It has been difficult to obtain an independent assessment of the effect of soils and climate upon the distribution of species within an association, because climate plays a dominant role in pedogenesis in determining both the geochemical trends and the morphology of the final soil profile. The matter is further complicated by the problem of possible migrations and their direction. A unique opportunity was offered to study the response to changes in climate in the lower South-East of South Australia, where both the direction of migration was known,

and was predominantly unidirectional, and a series of closely allied and largely identical soil types extended, because of an unusual history, across the climatic zones, passing through several of them. The effect of climate was seen to be a gradual modification of both specific composition and structure of the community—a *Eucalyptus Baxteri* sclerophyllous forest. As species approached the limits

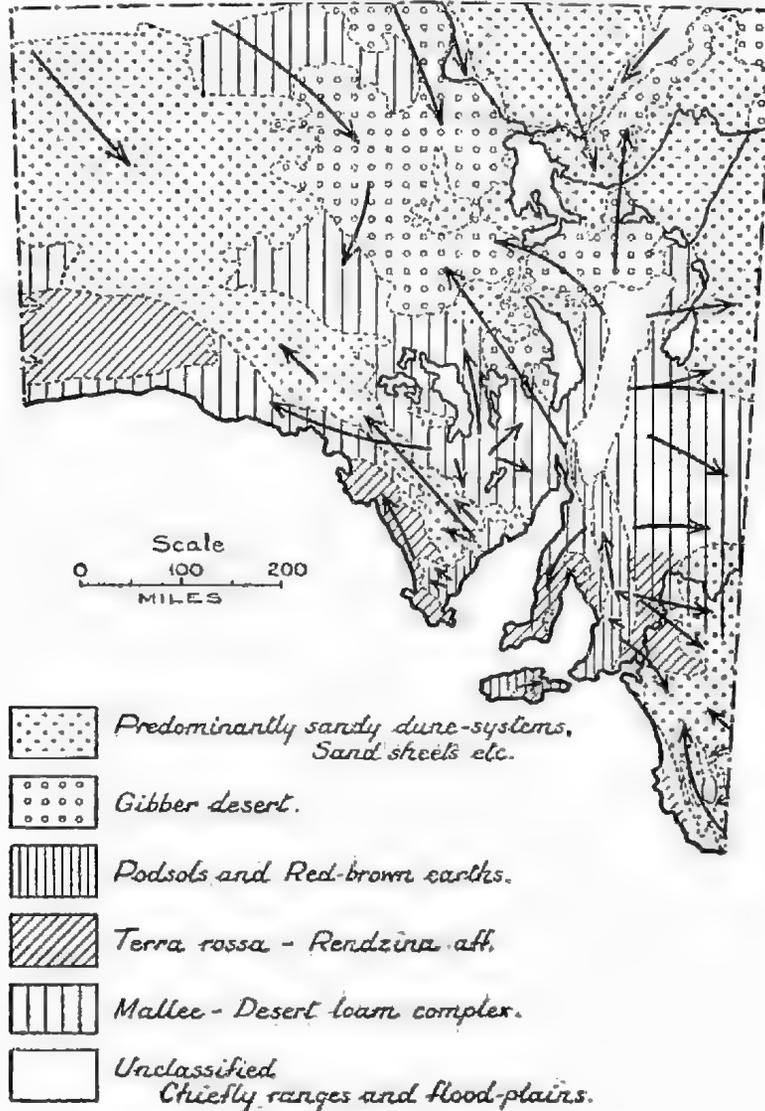


Fig. 6
The principal migratory routes,

of their climatic range on this soil they became dwarfed and depauperate and finally dropped out (Crocker 1944). This "sifting" effect of climate was first noticed by Good (1937) in arid communities. On the other hand, soil changes usually depend on geological history, and vegetational responses to them at the same climatic horizon are sharp and clear-cut and are by no means difficult to follow.

The results of the studies cited in the previous paragraph led one of the authors (R. L. C.) to the conclusion that "edaphic factors . . . are responsible

for the distribution of formations and associations within any climatic horizon." While this generalisation was, in the light of future experience, only a part truth, it could be made quite accurate by the addition of the words, "other things being equal." In practice, except in restricted areas, other things are not equal. First and foremost there are varying migration capacities and the possibility of opposing migrations. For example, it is unquestionable that communities dominated by species dispersing eastwards from the Mount Lofty-Flinders Range refuges met somewhere the barrier of vegetation migrating westwards from eastern centres of dispersal, such as the east coast mountains or the Barrier Ranges, and vice-versa. Migrations in all directions was obviously going on simultaneously and influenced the distribution of communities. It is better, however, to bring the discussion back to the species level. While some species within a community are

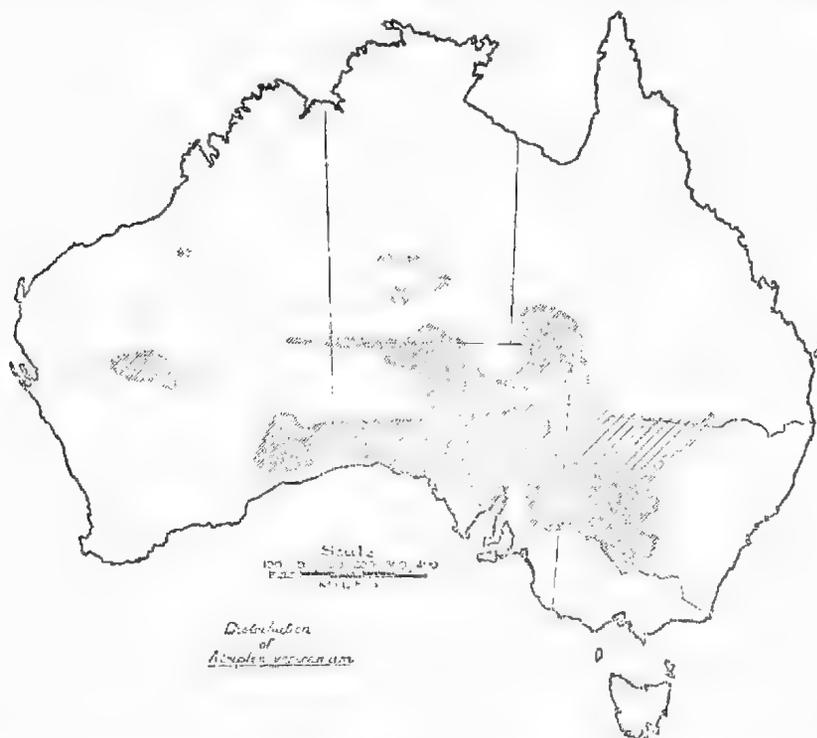


Fig. 7

The recorded distribution of bladder salthush, *Atriplex vesicarium*.

dependent in that their habitat tolerances require the shade or protection, etc., of another of a higher stratum, an understanding of the factors affecting the area of non-dependent (chiefly dominant) species will usually provide the key to an understanding of the former.

Within narrow limits the chance settling of propagules determines the exact distribution as pointed out by Pidgeon and Ashby (1942). In the broader sense, however, there occur many other interesting types of distribution which cannot be attributed entirely to chance. Firstly, there are distributions where over wide areas within the one climatic zone⁽²⁾ the same species keep recurring. Typical examples are the mallees *Eucalyptus oleosa* and *E. gracilis*, and saltbush *Atriplex*

⁽²⁾ Climatic zone is here used in the sense of the zone of tolerance for the individual species.

vesicarium. Secondly there is the type of distribution, and one that is more puzzling, of a species like *Acacia fovea* (waddy), which occurs as two small groups of a few hundred or less trees on the gibber downs, now separated by approximately 200 miles of Simpson Desert sand (Crocker 1946). Another type of discontinuity is that of the sugar gum (*Eucalyptus cladocalyx*), which occurs in three relatively isolated regions in South Australia, namely, restricted parts of Kangaroo Island, Eyre Peninsula and the Southern Flinders Ranges. Cain (1944), in his valuable thesis of plant geography, has applied the term *disjunction* to those distributions where individual species are separated by more than the normal dispersal capacity of the type, and concludes that major disjunctions have almost exclusively resulted from historical causes.

It is obvious that the development of the South Australian flora which has already been traced in outline, has been such that ecological and plant geographical problems in areal distribution of species will only be understood clearly if the historical background is appreciated. At present the restricted knowledge of paleobotany, paleopedology, and paleoclimatology makes anything like a full evaluation impossible. With the start that has already been made, however, it is worth while to raise some of the problems and anomalies and to attempt an explanation of the more striking discontinuities.

1. WIDE (CONTINUOUS) DISTRIBUTIONS

The present recorded distribution of *Atriplex vesicarium* is interesting. It is shown in the accompanying figure 7. Bearing in mind the principle that dispersal proceeded chiefly from wetter to drier habitats, it is likely that *Atriplex vesicarium* had several centres of redistribution. Its isolated occurrence in the Macdonnell Ranges suggests that one migration emanated from there. The northern Flinders and Gawler Ranges were also probably centres of survival and redispersal. Nor is it necessary to believe that there were not others. The two mallees, *Eucalyptus oluosa* and *Eucalyptus gracilis* likewise probably survived the aridity in geographical isolation in several refuges (Eyre Peninsula, Mount Lofty Ranges, etc.), from which they have subsequently spread (see fig. 8). The Victorian and Riverina occurrences are probably migrations from South Australia. Wide and continuous distributions of these types are merely indicative of the occurrence of extensive edapho-climatic habitats within the tolerance ranges of the species, and an ability and opportunity for wide dispersal, for establishment, and ecesis. The two mallees and *Atriplex vesicarium* occur on the desert loam-mallee soil complex. The two soil groups merge more or less gradually into each other in South Australia. While the climatic ranges of the two mallees are less arid than those of *Atriplex vesicarium*, which suggests more humid and probably more southerly centres of survival for them, the distributions do overlap, and towards the limits of their ranges the three species are frequently found together. *Atriplex vesicarium* is a species with fairly wide edaphic tolerances. In addition to growing on mallee soils and certain of the desert loams, it is able to establish and ecetise on some of the gibber desert soils and certain alluvial soils of the Riverina. Because of these wide tolerances it has not been difficult for it to find a series of suitable habitats within its normal dispersal capacity.

2. RESTRICTED DISTRIBUTIONS—RELIC AND ENDEMIC SPECIES

There are two ways of regarding species of very restricted distribution, either as young endemics or as old endemics, that is relics of a previous flora. Willis (1938, 1940), for example, considers that most endemics are young species rather than relics. Ridley (1925) suggests the term *epibiotic* for relic endemics. Much doubt and considerable difference of opinion still exists about the inter-relation

ships of the factors causing speciation, but it has nevertheless been clearly demonstrated that isolation, as in mountain systems and oceanic islands, results in a high degree of endemism.

This is well shown in southern Australia by the high percentage of endemism on Kangaroo Island by comparison with the adjacent peninsulas (Wood, 1930). An analysis of the distribution patterns of the sclerophyll communities in these peninsulas showed that of the 82 species endemic to the region as a whole, 88% were found on Kangaroo Island, and 47% of them were restricted to it. The only other peninsula with endemic species was Eyre Peninsula, where the remaining 12% occurred. It is perhaps even better demonstrated by the comparative endemism in southern Australian eucalypts (Herbert 1928). In the south-west corner of Western Australia (Shark's Bay-Eucla districts) 74.2% of the



Fig. 8

The recorded distribution of the two mallies *Eucalyptus oleosa* and *E. gracilis* in Australia. Their general areas are almost identical.

eucalypts are endemic to the region, which has had a long and undisturbed geological history. Temperate east Australia, geologically a much more disturbed area, and connected by more or less continuous mountain chains with the tropics, exhibits endemism of only 48.7% among the eucalypts. The case for high endemism in geographically isolated areas is, therefore, supported by Australian evidence.

It is of considerable interest in assessing the status of species in our flora to know whether the endemics are young or relic. During the recent extreme aridity the climatic stress imposed a rigid selection upon the Australian plant populations. This, as pointed out earlier, meant the preservation of species in which the biotypical range was considerably modified. The overall result was the extinction of many biotypes (and species) and the preservation of others. The areal extent of the present derivatives can for this reason alone, *i.e.*, climatic selection, have

little relationship to the distribution of the pre-arid parent stock. In addition to the direct climatic filtering to which the old vegetation was subjected, others equally important in determining the present distributions have been superimposed. First there was the effect of desiccation upon the soils themselves. This influence was profound. To varying degrees over most of South Australia soils lost their stability, and, under the accelerated erosion resulting, were stripped of some or all of their A horizons which were re-sorted and piled into dune systems, or spread out as sand sheets. When the re-colonising species began to spread rapidly with the release of climatic pressure, they were confronted then with an entirely new (in the narrow sense) or drastically modified (in the broader sense) soil pattern.

From a consideration of the foregoing, the conclusion seems to be that the present distributions, except where the climatic zones are narrow, cannot do more than give one or two glimpses of the flora of the pre-arid past.

An undoubted relic is *Linistoma Mariae*, and another *Macrosamia Macdonnellii*, which are found in a single valley, the Glen of Palms, in the Macdonnell Ranges, Central Australia. It was suggested by Spencer (1921) that it was a remnant of an older flora and indicative of a wetter climate in the past. There seems no other explanation that could be applied.

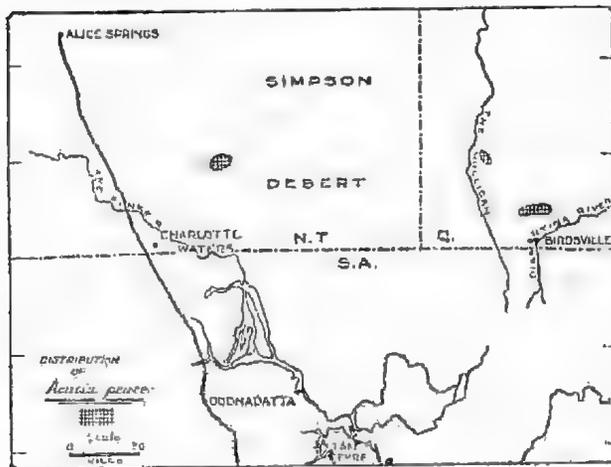


Fig. 9

The distribution of waddy, *Acacia pycnantha*. This is a spectacular tree growing to approximately 50 feet high.

Although dispersal by agents such as birds (Ridley 1930) can occasionally be responsible for wide disjunctions, it is not considered likely to have operated in this case. For one reason there appear to be ample unoccupied habitats within the edapho-climatic amplitude of the species, and if it were capable of dispersal, establishment and recsis over a range of 200 miles, it seems extraordinary that it has not made more progress nearer home, even assuming one or two occurrences have not yet been recorded. The most likely explanation would appear to be that it is a true relic, which was formerly widespread but was restricted to ecological niches in widely separated localities with the onset of aridity. During the desiccation the desert sands piled up between. With subsequent amelioration the species has migrated and spread, but only to a very small extent; perhaps it is still towards the limits of its tolerances.

One of the most interesting cases of discontinuity in South Australia is that of sugar gum, *Eucalyptus cladocalyx*. It occurs in three widely spaced localities (see fig. 10): (1) Southern Eyre Peninsula, (2) Kangaroo Island, and (3) the southern Flinders Ranges. On Eyre Peninsula it grows chiefly on the lateritic

Another species which appears to be relic is *Acacia pycnantha*. Its known distribution has been already described and is shown in fig. 9. It is difficult to imagine that it could be a new species, for the very limited occurrences are separated by an unfavorable edaphic habitat, namely, 200 miles of desert sands. The distance is far beyond the dispersal capacity of the species, unless long distance dispersal had operated.

residuals and podsol, and is particularly depauperate. It has been suggested that it is towards the limits of its edaphic-climatic range (Crocker 1946). On Kangaroo Island it flanks creeks and occurs on soil associated with the older sedimentaries. It is a much more handsome tree than on the adjacent Eyre Peninsula. The lower Flinders distribution is limited to the neighbourhood of Wirrabara, although there are several outliers further north.

In our opinion the three areas of *Eucalyptus cladocalyx* have developed from three centres of survival, and are true relics. Why the species has not spread more is difficult to understand, because its use in homestead plantations indicates that it has a wide edaphic range. For some reason the species has a poor migration (plus establishment) capacity. In this connection it is necessary to remember that ranges of tolerance, that is minimum, optimum and maximum levels of tolerance to any ecologic factor, vary at different stages of development. The possibility that *Eucalyptus cladocalyx* is a new species and that its present distribution pattern is due to long distance dispersal, is very difficult to believe.

Two interesting cases of discontinuity have been observed recently by C. D. Biscoe. One is the rediscovery of an area of red stringybark, *Eucalyptus maculopyrrha*, near Clare, South Australia; the nearest recorded occurrence is in the Grampians in Victoria. The other is the occurrence of grey ironbark, *Eucalyptus hemiphloia*, in the northern Flinders Ranges; the nearest record is its rare occurrence near Marsham Victoria.

Although the general application of long distance dispersal as a means of explaining discontinuities has been largely discredited by the work of Skottsberg (1938, 1939) and others, the possibility of its operating in special cases has been rarely admitted. The main arguments against the theory have rested upon the present distribution of endemics in relation to one of isolation, and because of the difficulty of demonstrating that far travelled germules could enter and compete in the communities already present. In the early stages of the re-colonisation of South Australia this competition factor would be less important, because, as pointed out earlier, the area was virtually a bare one and the chances of successful long-distance dispersal must have been greatly increased. Such conditions would be short-lived, however. Long-distance dispersal is undoubtedly accomplished in the case of light germules like the spores of mosses and lichens (Ridley 1930, Baas Becking 1934). These, in addition to being widespread, frequently develop and grow in such extreme and selective environments that the problem of competition in an already closed community is less frequently operative. A case of distribution of this type in South Australia is that of *Sphagnum*, which is found in two or three small swamps near Mount Burr (Crocker and Eardley 1929). The nearest recorded occurrence of *Sphagnum* is near Melbourne, approximately 250 miles away. The more extreme and specific the environment, the less likely is competition, and the more likely is long distance dispersal to be operative. Classic examples are the distribution of *Reppia maritima* and the "Danahellon" community (Wood and Baas Becking 1937).



Fig. 10
The natural distribution of sugar gum, *Eucalyptus cladocalyx*, in South Australia.

A special type of discontinuity is that of the two acacias, *A. Sowdenii* Maiden and *A. Loderi* Maiden. The former is conspicuous in the Tarcoola-Buckleboon-Port Augusta area at the north of Eyre Peninsula, while the latter is of limited occurrence south of Cockburn along the New South Wales border and extends into that State (see fig. 11). The two species are very closely related. They are almost identical in habit, appearance and other morphological characters. They occur within the same climatic zone, on very similar soil types, and are associated in the communities they dominate with a large number of the same species. They differ taxonomically chiefly in the length of the phyllodia (4-8 cm. and 7-11 cm. respectively), and in the pod of *A. Loderi* being moriliform, while that of *A. Sowdenii* is but slightly constricted. Species of this type which are only slightly different morphologically, but which are geographically very isolated, have been defined as *vicarious* (Setchell 1935). In the author's opinion the above two species have descended from the same parent species, once widespread, and are

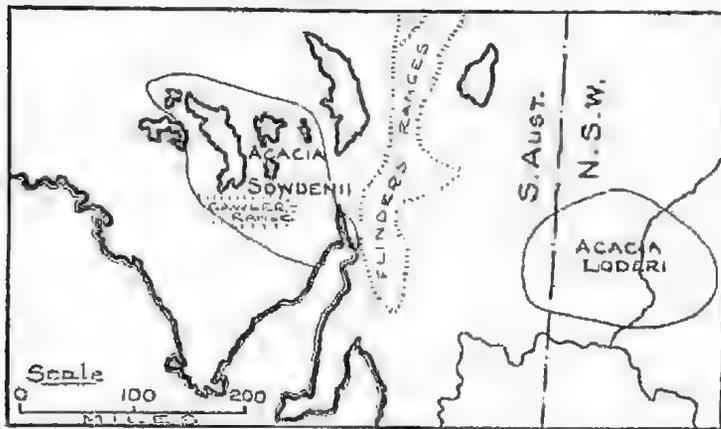


Fig. 11

The disjunction between the vicarious species *Acacia Sowdenii* and *Acacia Loderi*.

merely the product of biotypical isolation within that species. It is likely that the distribution of *Acacia Sowdenii*, for example, has developed either from a survival centre in the northern Flinders, or, as is more likely, from the Gawler Ranges. On the other hand, *Acacia Loderi* was distributed from some other refuges, probably in New South Wales. Under the differing edapho-climatic selec-

tion pressures in the two regions, biotypes which vary in minor characteristics have been preserved and have been given specific rank.

Depending on the point of view, *A. Sowdenii* and *A. Loderi* can be considered either relic (old) or young endemics, for obviously they are both. The relationship between age of species and area as proposed by Willis (1922) would relegate them to the position of young species, on the other hand they are certainly relic in that they are descended from a previously more widespread parent that was restricted in area as a result of unfavourable climatic development. Even better evidence is presented for relic status by the distribution of species like *Livistona Mariae* and *Acacia pencei*. In cases like these the historical sequences indicate a reasonably good basis for consideration as relics.

It is essential, however, to retain the dynamic concept of vegetation and to realize that the historical changes, which cause contraction in area, may preserve in some of the old populations strain characteristics that will allow rapid expansion of area for the new edapho-climatic conditions when the restrictive pressures are removed. In other words, relic species can be widespread, as well as confined in area (epibiotics). In the broad sense, therefore, species like *Atriplex vesicarium* and *Eucalyptus oleosa* may be, and probably are, true pre-arid relics. Young endemics might also have become widespread in South Australia, provided their ecological amplitudes were wide enough to permit dispersal, establishment and

ecesis either on a high level of competition, or if they had developed prior to, or upon the release of climatic pressure, at a lower level of competition.

The *Acacia Sorolezii* and *A. Loderi* discontinuity has been considered an example of biotype isolation of a more widespread parent species or population. In view of the new historical data it would seem that some of the closely related pairs of species (Wood and Baas Beeking 1937), in the Eucalypt sclerophyll forests of the Blue Mountains region of New South Wales and in the Mount Lofty Ranges, South Australia, might be considered to have had a similar origin. It is not unlikely that in the pluvial pre-Arid, that is, in the late Pleistocene and/or the early Recent, or at an even earlier time, a series of suitable edapho-climatic habitats existed to bridge the intervening area. Isolation followed with the aridity (or earlier), and has resulted in differential biotype selection. Many of the pairs, therefore, are probably related historically to a common parent, and are an example of divergence rather than convergence.

3. NEW SPECIES AND TAXONOMIC PROBLEMS

Timofeef-Ressovsky (1942) has applied the term *micro-evolution* to variation for which scientific evidence of mode of operation can be obtained. Speciation and geographical differentiation belong to this class. As a result of much genetic work considerable agreement has been reached on the factors involved in micro-evolution, and it is agreed that mutation is the main mechanism for providing new evolutionary material. Cytogenetic work has also shown that full speciation is generally due to the accumulation of small character differences, and not to single mutations as claimed by Willis (1940). What little is known of mutation rates suggests that they are of a very low order and that they arise at random (Sewell Wright 1940). Evolution, or successful differentiation resulting in speciation is the result of factors other than mutation shaping the evolutionary material, and of these selection and isolation are most important (Timofeef-Ressovsky 1940, Darlington 1940, etc.). The role of the different factors in evolution no doubt varies under different circumstances as pointed out by Diver (1940), nor is there any theoretical reason for believing this is not so (Sewell Wright 1940).

In the foregoing sections reasons have been given for assuming a large pre-arid relic element in our flora. Certain discontinuous distributions have been discussed from this angle, because a relic origin appears to be the most logical and straightforward explanation of their present areas. It is obvious, however, that considerable evolutionary differentiation has probably occurred since the onset of aridity, some of which would have resulted in full speciation. Further, the isolation resulting from the contraction of the flora must have favoured speciation.

Isolation is considered a directive factor in evolution by Timofeef-Ressovsky. The chief importance of geographical isolation lies in the restriction of free interbreeding, which results from partial isolation of a population. Because of this, isolated portions of the original population with differing evolutionary potentials might give rise to mutations which come under different selective pressures, and finally result in considerable divergence within the different centres of isolation. The absorption of differentiations resulting in this way is probably prevented by the restrictions to interbreeding. It is possible that in this manner, or something closely akin, reproductive isolation and hence full speciation can be ultimately achieved. On the other hand, reproductive isolation may be more frequently the result of hybridisation and intercrossing following the reunion of adaptive complexes developed under geographical or ecological isolation (Dobzhansky 1941). In either case geographical isolation has played an important role. So far as the Australian flora is concerned, the contraction in area associated with the arid

period must have been an important directive factor promoting biotypical differentiation. Further, on the release of climatic pressure, the rapid expansion of area of those biotypes able to exploit the new edapho-climatic habitats must have given some excellent opportunities for reunion—that is for hybridisation, back-crossing, and various other types of intercrossing.

It might be expected then, in view of the history of the Australian flora, and the present state of knowledge of factors effecting speciation, that considerable differentiation has occurred since the isolation of the flora in numerous centres of survival during the Recent desiccation. Many of these divergences have probably resulted in full speciation. One limiting factor is undoubtedly the relatively short time involved. Even assuming that the arid period was centred much longer ago than is at present believed (4,000-6,000 years), it was probably not more than 10,000 years ago. Considering the generally low order of those mutation rates⁽³⁾ which have been measured by geneticists, and the fact that the great majority of these in any case have no adaptive value, the amount of full speciation over this period must have been limited. It would of course depend, amongst other things, upon the degree of both potential and developed differentiation in a particular group prior to contraction, and this would have varied widely within the differing species complexes.

Geographical and ecological isolation are very closely related and grade into each other. The importance of ecological isolation in differentiation, however, does not seem to have been sufficiently stressed. With vegetation, areal limitations within the climatic tolerances of a species are most frequently determined by edaphic factors, either directly or indirectly. It is obvious that greater selection pressures are operative at these boundaries, which are usually much sharper than climatic boundaries, and any mutations of edaphic adaptive value have an opportunity of avoiding absorption in panmixy by migration to different soil types. In this way they may escape disintegration, even though they possess no sterility barrier. Cain (1944) has summarised the case for this type of differentiation extraordinarily well, and concludes "that speciation is usually a population-periphery phenomenon which gains expression through migration that allows isolation and selection." When the total peripheral areas of widespread species are considered the enormous opportunities for achievement of ecological isolation are realized.

There are, therefore, several reasons for believing that a fairly rapid evolutionary development of some species groups would have occurred subsequent to contraction during aridity.

Some of the chief difficulties of the Australian ecologist or plant geographer, are concerned with biological diversity within species, and the fact that this varies enormously. The range of biotypical variation permitted in a species is largely subject to certain taxonomic conventions and the systematist's personal interpretation of them. The example of *Acacia Sowdenii* and *Acacia Loderi* is a case in point. Here relatively minor differences have led to acknowledgment of two separate species. In the author's opinion⁽⁴⁾ it is extremely doubtful whether the differences between these two are beyond the biotypical range of a normal species. The fact that the real distributions are isolated from each other is quite understandable on historical grounds.

⁽³⁾ The examples are too few at present to be considered an entirely reliable index of likely rates in nature.

⁽⁴⁾ Even if specific rank were justified in this case other examples are readily at hand.

Difficulties of this kind are common for the ecologists and are due, amongst other things, to the fact that a static system of nomenclature (the Linnaean) is being applied to something dynamic. For a number of practical reasons, well summarised by Huxley (1940), this is unavoidable. On the other hand, as Turrill (1940) points out, taxonomists emphasise, unintentionally, certain diagnostic characters without knowing their real significance. Obviously, many problems for the taxonomist can only be solved by a consideration of the development of the group. Continued reference has been made in preceding sections to the low level of competition in the early stages of re-colonisation. This low level of competition has been of considerable importance in influencing expansion of area and the distribution of certain species. It has been pointed out by Worthington (1940) that in studying cases of differentiation in nature the evolution of the environment must be considered in addition to that of the organisms, and that the existence of numerous unoccupied niches and the absence of predators are very important in determining the amount of differentiation possible. He was considering the evolution of fresh water fish, but his comments apply no less to plant species, and in essence merely amount to lack of competition increasing the rate of potential differentiation.

With the rapid expansion of the flora following the release of climatic pressure, normal rates of differentiation must have been greatly exceeded for those biotypes which were suited to exploit the new edapho-climatic conditions. A large percentage of the first viable seeds of migrants would themselves become successful migrants, and more generations would be passed through in a limited time. As mentioned earlier, the brake of competition would soon be applied, but this would not be fully operative, at least for some species, until something approaching the usual equilibria of plant communities was achieved. Here then is another reason to anticipate relatively rapid differentiation within some groups of the Australian flora.

With relatively short-term geographical isolation of the type suggested during the Great Australian Arid Period, it would be most likely that differentiation only rarely proceeded as far as full speciation, at least in the sense of the attainment of inter-specific sterility. Expansion of the flora from the centres of survival would almost certainly have led in some cases to consolidation of gene variations in the attainment of full speciation. Usually, however, such a level of differentiation would not be reached, and the result would merely have been considerable hybridization. Indeed in either case we could expect the production of a large number of heterozygous hybridised and inter-crossed forms and very variable "species complexes." Much of the differentiation developed during isolation has undoubtedly subsequently been preserved by some form of ecological isolation. Cain has pointed out that hybridization and the production of hybrid swarms is particularly likely to occur with a change in ecological conditions, as with man's activities in removing a barrier and permitting free intermixing. That this barrier is frequently that of biological competition is certain, but it may be any barrier to cross-fertilisation. In the case of insect pollinated plants it might, for example, be due to invasion by insects which cover a wider range. In the hybridisation between two species of *Solidago* studied by Goodwin (1937) it was due to opportunities for migration presented with the drainage of the swamp. Although most studies on hybridisation have been made in relatively small areas, it is obvious that possibilities for its development with the release of climatic pressure following contraction, and isolation of the greater part of the Australian flora were exceptional. Further, these were greatly stimulated by the relaxation of another normal ecologic barrier in the low level of competition.

Reasons have been given to indicate that expansion during recolonisation gave a potentially variable species, whether new or relic, a great opportunity of developing that variability under different selective pressures, and where different opportunities for inter-crossing occurred. This probably also encouraged an extraordinary biotypical variation and the production of widespread hybrid forms. If the historical sequences and their consequences which have been postulated are correct, it would be expected that: (1) there would be a large relic element in our flora (examples have been given to substantiate this); (2) considerable differentiation is likely to have occurred in some groups during isolation, most of which, however, did not develop reproductive isolation; and (3) because of (2), and the subsequent release of climatic (and biologic) pressure, extraordinary opportunities for hybridisation and intercrossing occurred during migration. If, as has been considered, the aridity was centred as recently as 4,000-6,000 years ago (or even though it were considerably older than this), the expansion of the flora is sufficiently recent to have preserved much of this supposed complexity in some groups. It might be further expected, therefore, that it would be exceedingly difficult to say where some species should begin and/or end. That this is so is apparent to any taxonomist or ecologist who has been faced with the necessity of classifying related Australian species. It might be anticipated as a corollary that many "species," frequently taxonomically good species, would not have developed genetic isolation during geographic isolation and would be largely preserved in different areas today by ecologic barriers. These species would show free capacity for hybridisation if brought together. Very little has been attempted in the study of hybridisation between related species in Australia. It has been suspected for a long time that the genus *Eucalyptus* had a great capacity for the production of polymorphism in this way. Some most interesting and valuable recent work of Brett (1946) has demonstrated that this is so, and to a degree never previously imagined. His work also indicates quite clearly that many species of *Eucalyptus* are preserved as entities solely on account of the ecological isolation they enjoy. The complexity of forms in many species groups in the Australian flora must be considered strong support for a very recent expansion of area.

Perhaps the best example of biotypical complexes recorded in Australia is afforded by the *Eucalyptus olivosa-E. incrassata* group of mallee. Herbert (1928) reports that of 53 eucalypt species recorded for the goldfields region of Western Australia (34 endemic), almost half the forms⁽²⁾ are allied to the above two groups. *E. dumosa* and *E. incrassata* form a somewhat similar complex in South Australia. Another example of a complex within one group of closely related species is shown by the endemics on Kangaroo Island. Of the 82 endemics belonging to 4 genera, listed by Wood (1930), no less than twelve are species and varieties of the genus *Pultenaea*. That is, although the endemics of the region belong to 47 different genera, 15% of them are in one genus, and most of these are closely related. It is apparent that historical ecological stresses have permitted potential variability in the genus *Pultenaea* on Kangaroo Island to develop fairly freely. As a result *Pultenaea* is a virile genus.

Species complexes of this type are only likely to be thoroughly understood as a result of cytogenetic studies, followed by experimental analysis of hybridisation of the type carried out by Goodwin on *Solidago*, and being done by Brett for *Eucalyptus* in Tasmania.

(2) Many of these are obviously not deserving of specific rank.

4. SOME REVISION AND FURTHER CONSIDERATIONS

In the preceding sections a survey has been attempted of the major geological, paleoclimatological and paleopedological factors which have influenced the development of the vegetation of South Australia. Although geological conditions since the Cretaceous have been fundamental in their modification of the floral mosaic in various ways, a period of severe aridity in the middle Recent which followed a pluvial epoch, and was apparently rapid in its onset, has been the greatest modifying influence insofar as the distribution of the present units is concerned. It resulted in both wholesale destruction of many species and a contraction of area of almost all those surviving.

The contraction in area caused various degrees of isolation in the centres of survival, and with subsequent climatic variations there has been ample opportunity for reunion; these were factors which made for diversification. Other influences also probably encouraged speciation where the potentialities existed. There are, however, obviously large relic elements in the present flora—perhaps the largest portion, and many of the restricted species are old and not new endemics.

It is likely that destruction of the pre-arid flora frequently meant extinction in one refuge area and preservation in another nearby. The absence of a species in one region, therefore, clearly does not indicate that it never extended so far. Frequently it was merely unable to obtain a suitable survival niche in one locality, but able to do so in another. Cases in point are the absence of the stringybarks, *Eucalyptus obliqua* and *E. Baxteri*, or the cup gums *E. cosmophylla* on Eyre Peninsula. They are present both on Kangaroo Island and in the Mount Lofty-Fleurieu Peninsula regions. One would expect the southern portion of Eyre Peninsula to be a poorer centre of survival than the other regions, because it is poorer in habitat diversity, and there is no valid reason for assuming that these species were not once present there.

Although it is always difficult, and at present frequently impossible, to reach a satisfactory understanding of the reason for a particular species distribution, we can be relatively certain of one important fact. That is that the *plant communities themselves are young*—the combinations are new. One would expect as a result that they would show some signs of instability. There are, however, no great instabilities apparent, and this must be due to the enormous stabilising influence of possession, together with the high colonising potential when the level of competition is low. The first occupant of a vacant niche thereafter holds a great advantage. One case in which the relationship between two associations appears to be in a state of flux is that of the *Eucalyptus diversifolia* association and the *Melaleuca pubescens-Casuarina stricta* association, where the two occur on shallow terra rossa soils developed on aeolianite limestone. Indications are that the balance between these two associations, the former a sclerophyll scrub and the other an open savannah woodland, is a very delicate one, and that the sclerophyll is invading the woodland in some places. At Section 6, Hundred Uley, Eyre Peninsula, the area occupied by the sclerophyll scrub today is very much

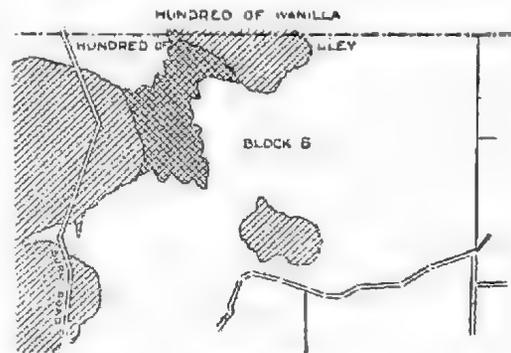


Fig. 12

Eucalyptus diversifolia association (hatched), Section 6, Hundred Uley, Eyre Peninsula. The double-hatched portion is an extension since the original survey.

greater than that delimited by the surveyors in their land survey of 1877. A different type of instability, which is potential rather than real, is shown by species which are growing at the extreme limits of their tolerances. Most of these must be poor competitors and could readily be replaced by species more suited to the environment were they available. Examples of this nature include *Eucalyptus cladocalyx* on Eyre Peninsula, which is existing over much of its area in a depauperate state on soils and under climatic conditions which are supporting the more highly integrated *E. Baxteri* association on Kangaroo Island. Another case is the extreme dwarfing of *E. Baxteri* at the limits of its edapho-climatic range in the Upper South-East, and then there are a large number of species which occur in an excessively dwarfed state in many of our communities; for example *Banksia marginata*, which occurs normally as a tree or tall shrub, can be reduced to less than six inches in height and still ecceise.

Because of the complex of factors which can modify the relationships between soil and vegetation it is not surprising that other things are not equal, and the generalisation that within the same climatic horizon the distribution of vegetation is determined by soil conditions frequently does not hold. There are difficulties in defining soil-vegetation relationships precisely. Firstly, there are the taxonomic problems mentioned earlier, and secondly there are, from the soil viewpoint, the severe limitations imposed by analytical techniques, especially those which attempt to evaluate soil fertility. These difficulties will always be apparent because soil fertility, for instance, is without exact definition unless referred to a particular biotype or series of biotypes, while the subtleties of genotypical variation which have ecological significance will always escape the taxonomist to a greater or lesser degree. Added to these problems are the difficulties of assessing the climatic and purely biological factors of the environment. Indeed, plant ecology, or for that matter ecology generally, is faced with some very real problems. The acceptance of the fact that speciation represents no absolute stage in evolution, (see Muller 1940), but is gradually arrived at, and that in the taxonomists' species all types of intergrades occur, means that identification and understanding of the genotypical variation with which the geographer or ecologist is dealing is a necessary prerequisite. Further, he has to assess the complex environment and inter-relate these two, that is organism and environment. Although in a general way the factors concerned are known fairly well, further progress so far as plant ecology goes must depend largely upon progress in other fields, such as pedology and climatology.

Despite the limitations imposed by difficulties like the above, and the discontinuities that have been stressed, it is nevertheless possible to arrive at very useful classifications and understandings of the vegetation. South Australia has been a good centre for working out many of these relationships because the overall simplicity of the soil mosaic, the regularity of the climatic zonation, and the limited refuges, both in extent and number, from which the present communities have developed, has impressed upon the vegetation patterns a simplicity that is wanting in the eastern States.

VII. ECOLOGICAL CONCEPTS AND THE DEVELOPMENT OF THE SOUTH AUSTRALIAN VEGETATION

The dynamic view of vegetation has resulted in the concept of a *succession* of plant communities towards a *climax* association determined entirely by climate. Of the earlier propounders of the succession concept perhaps Cowles (1901) was the first. It was Clements (1916), however, who brought it prominently to the fore and elaborated it in his publications until plant ecology became burdened

with a very special terminology, chiefly developed about deductive theories. The succession of associations leading to the final climax is known as a *seres*. It was suggested that in the present-day communities the climax was readily recognisable—it was the most widespread assemblage within a climatic zone and that all other communities could be classified as seral stages, either as relic communities or as communities leading directly to the climax.

A pioneering attempt by Wood (1937) to classify the communities of South Australia and show their inter-relationships on a successional basis, although doing much to bring order out of chaos, was soon found wanting. It resulted in a reconsideration (Wood 1939) of some of the fundamentals underlying ecological nomenclature.

The failure to apply successfully the successional concept to a classification of South Australian communities has largely been due to the historical development of the vegetation. We have suggested that the present associations have resulted from the re-colonisation of vast bare areas by dispersal from centres of survival. The associations are very young and their distribution has been determined within a climatic zone chiefly by edaphic conditions. The distribution patterns have been greatly influenced, however, by other factors such as individual dispersal capacities, chance dispersals, opposing migrations, location of survival centres, biotypical differentiation, barriers, etc. It is not surprising that the final species-aggregates (associations, etc.) are not made up of units with identical tolerances, nor would this ever be expected. Although, therefore, the species which played a dominant part in the developmental seres associated with re-colonisation are probably all still living, it is obvious that present-day aggregates are different and cannot be considered seral stages in the accepted Clements sense—unless, indeed, they all be considered edaphic subclimaxes. One might as well consider them all edapho-climatic climaxes, but must appreciate their dynamic state.

It is a logical consequence of speciation and evolution, and of historical changes, that the dynamic nature of vegetation will always be maintained. The degree of stability will be greatly governed by the historical sequences, and these will vary from country to country. It is perhaps understandable that the concept of succession towards a climax and the concept of climate-induced migrations of whole communities, rather than individuals, has been pushed so far in America, where the paleontological record indicates a very long history, and where climatic fluctuations, though extensive, have been gradual. Gleason (1923), for example, has been able to produce a considerable quantity of data to show that the principal vegetational elements in the Middle West were differentiated in the Tertiary and "have continuously maintained their present relative position." Such continuity of relationship could never be envisaged for elements of the Australian vegetation. In the Tertiary, when Australia was reduced to an almost perfect peneplain, climatic climaxes would perhaps have been recognisable in the theoretical sense.

The ecological concepts and units of classification proposed by Clements (1916), and followed by Tansley, were based upon the philosophical concept of organism. Since this classification had been found unworkable for South Australian vegetation, Wood (1939) proposed a rational basis which should underlie any system of classification of plant communities, and tentatively suggested units of convenience. It is proposed here to amplify and extend the considerations given in the previous paper, and, in the light of further field experience, to define units suitable for classifying vegetation.

Ecology, in large measure, consists in defining the limits of species which grow naturally together, and in understanding the factors responsible for their maintenance as a community. Ecology, after all, is a branch of physiology. In

the laboratory we study the reactions of species when all environmental factors save one or two are constant; in ecology in the field we study these reactions when the whole constellation of environmental factors varies and where we have the added complication of competition between species.

The basic fact underlying all ecological work is the matter of experience that any particular species will develop and be maintained only within certain environmental limits—these limits include soil conditions of nutrients, water, etc., and climatic conditions. These limits we may term the “potential environment” of the particular species.

Any particular environment selects from any population of species exposed to it those species whose potential environment coincides in part with the actual environment—in other words, we are led to a simple Darwinian explanation.

Competition between species and changes in the genetic constitution may cause changes in frequency, and an initial assemblage of species may alter the chemical environment, so opening the way for further change in the species-aggregate.

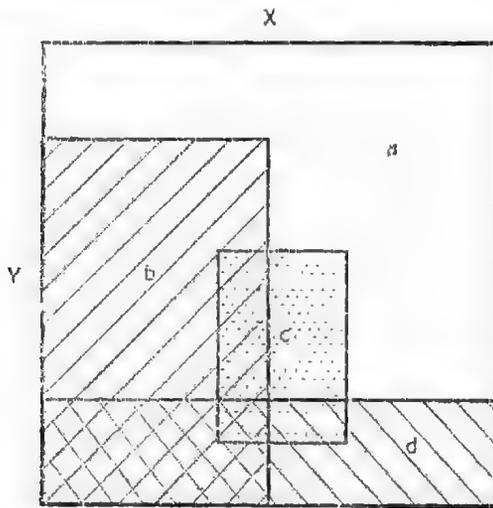


Fig. 13

world dominated by *Dunaliella viridis*. The potential environments of members of this community for three chlorides at different concentrations have been delimited by Baas Becking.

Wood (1937) has drawn attention to convergence in species-composition of oligotrophic bogs (pH 4.0-4.5), at Drenthe (Holland) and Mount Compass (South Australia), where closely allied species of the same genera occur in the same communities. Eardley (1943) studied a South Australian fen (neutral to alkaline prats) and showed the remarkable similarity in species-composition with East Anglian fens and some North American swamps. Wood (1939) illustrated how some of the chief associations in South Australia were related to annual rainfall, phosphate content and pH of the soil.

It is a matter of experience that some species have a wide potential environment, whilst others have an extremely limited one, and this is particularly true of many species of the genus *Eucalyptus*. With these underlying ideas in mind, vegetation units (*i.e.*, species-aggregates which live naturally together) can be considered.

Suppose we consider a hypothetical case of a community of four species, *a*, *b*, *c*, *d*, whose potential environments with respect to two independent factors, say, *x* and *y*, are as follows, the species *a* extending over the whole area (fig. 13).

If the unit community is defined as one of definite and uniform composition, as was done by the Third International Botanical Congress, then it is clear that there are several different units occurring within the habitat. These units are the "associations" of Swedish ecologists. They lead to a completely unwieldy classification, e.g., Ostvald (1923) has described 164 separate associations in a stretch of moorland 40 square miles in area.

On the other hand, Tansley (1939) considers the tree dominant only as defining the association, and on this classification the whole area dominated by a would be the unit. Tansley's classification of the British oak-beechwoods, together with some habitat factors is as follows:—

Association (climax) : oak-beechwood.

Consociations (one dominant only).

oak	}	<i>Quercetum roboris</i> - -	damp clays and loams: neutral to alkaline
		<i>Quercetum sessiliflorae</i> - -	(a) savannah woodlands-podsols - (b) with heath-peaty podsols
beech	}	<i>Fagetum calcicolum</i> - -	rendzina pH 7.5-8.0
		<i>Fagetum rubosum</i> - -	brown earth 4.5-7.7
		<i>Fagetum ericetosum</i> - -	podsol 3.5-4.5

consociates (seral stages) are:

birchwood	—————>	oakwood
ashwood	—————>	beechwood

This unit of Tansley (the association) is too broad a unit of classification for practical purposes. Indeed, the example above seems to violate the very idea of an "association" of plants, for the groupings of associated plants are totally unlike in the different communities—some consociations have no species in common with each other! It also violates Tansley's definition "constant habitat," for, although climatic factors remain relatively constant in the above association, other equally important factors, *vis.*, soil types, nutrients, pH and water relationships are widely different. The system really breaks down owing to the wide potential environment of the dominant species—much wider than that of any of the species associated with it.

Suppose we take a specific case, and apply Tansley's classification to the communities in South Australia dominated by *Eucalyptus Baxteri*, the brown stringybark. The following well-defined communities are readily distinguished:

<i>E. Baxteri-E. Huberiana</i> - -	wet podsols
<i>E. Baxteri-E. obliqua</i> - -	normal podsols
<i>E. Baxteri</i> - -	dry and shallow podsols
<i>E. Baxteri-E. diversifolia</i> - -	siliceous sands and residual podsols over ironstone
<i>E. Baxteri-E. cosmophylla</i> - -	lateritic soils (residual podsols)

The rainfall over the whole group of communities varies from 40 to 14 inches per annum. The floristic make-up and species-frequency of each of the above communities is quite distinctive; some of the communities have few species in common except *E. Baxteri*. The first community is a savannah woodland, the second and third dry sclerophyll forests, the fourth a mallee scrub, and the fifth a treeless macchia. There is no evidence whatever of any successional trends between them.

Furthermore, in the South-East of South Australia, ranges of residual podsoils occur parallel to the coast and at right angles to the rainfall isohyets, from 30 inches in the south to 14 inches in the north. Progressing northwards, one finds a gradual dropping out of some species and their replacement by others. *E. Baxteri* continues as a dominant throughout; in the wetter areas as a forest tree, then as a stunted small tree, then as a shrub less than 3 feet high. Finally it disappears, but most of the plants associated with it in the stunted phase continue on as heath or mallee-heath, obviously related to the former community.

It is clear that *E. Baxteri* is a species with a wide potential environment, much wider than that of most of the other plants associated with it. To delimit a community based on the distribution of *E. Baxteri* alone is to ignore the associated species and simply to define the area occupied by the eucalypt species.

Relatively few species are distributed purely at random, and associations, under whatever system, are determined subjectively. In defining an association we take a middle course between the British-American and the Scandinavian-Swiss schools. We define an association as *a constant association (i.e., growing together) of dominant species recurring in similar habitats*. The term *dominant species* refers not only to the tree species, but also to the dominant shrub and/or herb species which give the characteristic look or facies to the community. It is similar in practice to the "consociation" of Tansley, but without the implications inherent in his definition. This is the grouping of greatest use in vegetation studies in Australia, though not necessarily the most fundamental unit. In practice we have found associations to be closely correlated with soil types; or if on different soil types, then some compensating factor can normally be found, e.g., water relations, nutrients, etc.

The association is made up of smaller units and may be grouped into larger ones.

The smaller units are the *type* and the *society*. *Type* we define as *a local change in the dominants of the upper stratum of an association which is accompanied by little or no change in the other dominants*. A *Society* is *a local change in the dominants of the lower stratum*.

The concept of type has been used for a long time in forest practice. Apparently it was first used by Graves (1899), who stated "the same type of forest will tend to be produced on the same classes of situation and soil in a specified region. There will be variations within the type, but the characteristic features will remain constant, that is the predominant species, density, habit of trees, character of undergrowth, etc. If a portion of the forest is destroyed by fire, wind or otherwise, the type may for the time being be changed, but if left undisturbed will revert to the original form, provided the condition of the soil is not changed."

This definition, in essence, is still retained in the Glossary of technical terms of the Society of American Foresters (1944), where it is added: "The term suggests repetitions of the same characters under similar conditions."

Pryor (1939) first used the term in ecological literature in Australia, using "quantitative floristic uniformity of the dominants" as the criterion. Pidgeon (1942) defined forest type as "a forest stand which has, wherever it occurs, the same floristic composition of dominants, and which develops in essentially similar habitats." In both definitions the term "dominants" refers to the dominant tree species.

Both the above workers have used this unit with advantage, for it is a reality in the field. The authors of the present paper disagree with their definition of forest type since it neglects the associated species, and in this way departs somewhat even from the original concept. However, the difference is one of definition rather than of fact, for Pryor (*loc. cit.*) states: "In an area with very few

dominant species, e.g., jarrah region of Western Australia, the lowest order community (*i.e.*, type) must be determined by some criterion additional to the floristic composition of dominants, e.g., the floristic composition of the lower strata of the community." and again, "the vegetation type corresponds approximately with the Association of Braun-Blanquet and the Faciation of Clements." The essence of Braun-Blanquet's association is "uniform floristic composition"—not of dominants only. We prefer, therefore, the definition of type as described above. In practice, there is no conflict between different Australian workers in actual delimitation of types in the field. The concept of type has been used in studying the forests of the mountainous areas of New South Wales and South Australia (Pryor 1939; Pidgeon 1942; Roomma 1946). In these areas the need for such a unit arises from the extreme sensitivity of many *Eucalyptus* species to changes in the micro-habitat; changes which in other parts of the world cause alterations in the shrub or herb layers only. It is clear that some eucalypt species have a more restricted potential environment than have the shrub species with which they are associated.

The type is a more fundamental unit than the association as defined above, and it will be clear that an association as defined by us is a collection of types. In a forest association, the floristics of the associated species of the undergrowth remain the same, though there may be local changes in the tree species.

In uniting associations into larger groups any characteristic of the association may serve as a basis for classification. These classifications abstract some characteristics of the association. It is clear that several alternative classifications can be made; they are not necessarily mutually exclusive but are complementary, and any may shed some light on vegetation problems.

The French-Swiss school groups associations into larger units on the basis of a common flora, although this sometimes leads to grouping together of associations which are not nearly allied. Using structure and life form as criteria, associations may be grouped into such units as sclerophyll forest, savannah woodland, savannah, etc., in any particular area. These are the *Formations* of Tansley and are groupings of great convenience, although their use does not always lead to grouping of nearly related associations, e.g., the mallee-heath and heath of the upper South-East (Jessup 1946), nearly related in floristics and habitat would be separated on this basis.

In South Australia we have used one feature of the habitat, *vis.*, *allied soils*, associated with related floristic composition of species as a basis for classification. Within definite climatic limits, associations on nearly related soil types and with related floristic composition are grouped together as an *Edaphic Complex*. A striking example of an Edaphic Complex is the associations found on podsolized soils in the Mount Lofty Ranges within the climatic zone limited by the 25-50" annual isoyet. Detailed work in progress (Specht 1946) shows that on these soils well-defined associations occur with the following eucalypts as dominants; *E. obliqua*, *E. Baxteri*, *E. cosmophylla*, *E. fasciculosa*, *E. leucocylon*. The podsoles include normal, immature and residual podsoles, podsoles on deep sands and "grey-brown" podsoles; they vary in their nutrient and water relations. Floristic lists for each of these communities show that with few exceptions the same species occur in each of them; their frequencies, however, differ greatly in the different associations, but are constant for any one community associated with a particular eucalypt. Shrub species dominant in one association may be only occasional or rare in another. It is possible that here we see the selective effect of environment at work on a relatively young species-population. Selection has proceeded to such an extent that the separate associations can readily be distinguished, but the associations themselves have unity in floristic composition and in habitat in the Edaphic Complex.

The greater portions of South Australia possess a heritage from the past, in that many soils retain certain morphological features which are "fossil," *i.e.*, not formed in equilibrium with present climate, but relics of former, more or less irreversible, soil processes. The result of Recent aridity has been a stripping and resorting of the upper horizons of many of the old soils, and the building up and exposure of "new" soil material, which is now re-subjected to pedogenic processes. The result is a very diverse pedogenic history for many soils.

In this complicated variety of habitats the Edaphic Complex is of value. For example, in the upper South-East, on neutral to alkaline sands, Jessup (1946) has shown that a mallee scrub—the *E. diversifolia*-*E. rugulosa* association—occurs on crests of hills; on shallow sands of the same type, and on well-drained adjacent sand plain or heath, the *Casuarina pusilla*-*Xanthorrhoea australis* association occurs. The hill slopes is an ecotone or transition region with dominants from both associations present and with *E. leptophylla* more prominent—this is the well-known mallee-heath. In the two associations the associated species are quite distinct. On undulating plains in this area the vegetation at first sight is extremely complex, varying with every rise, and its edaphic relationships only became clear when the well-defined sandhill-plain region was studied. Such areas can often best be mapped as a Complex and sorting out of associations left to detailed study.

Similarly, on the laterite and associated soils on Kangaroo Island, the following associations can be distinguished:

<i>E. Baxteri</i> - <i>E. cosmophylla</i>	-	-	on laterite soils
<i>E. remota</i>	-	-	on heavy or massive laterite
<i>E. diversifolia</i> - <i>E. cosmophylla</i>	-	-	on laterite soils with some siliceous sands
<i>E. Baxteri</i> - <i>E. diversifolia</i>	-	-	on siliceous sands (A horizon of the laterite)

The mallee-broombrush complex in the South-East, Kangaroo Island and Eyre Peninsula (Crocker 1946, Jessup 1946, Wood 1937) is a good example of a complex of associations closely allied, but showing some marked floristic differences owing to endemism on Kangaroo Island and Eyre Peninsula, and to differing selection pressures in centres of survival in the three regions during the aridity.

The vegetation on the immature soils derived from the Hawkesbury Sandstone in New South Wales, and described by Pidgeon (1942), is an Edaphic Complex.

In the associations described above there is no evidence of succession or of invasion, but only of transition. Indeed, selectivity of environment—especially of climatic factors—is particularly marked in several areas of South Australia where a relatively uniform soil extends over a wide range of present-day climatic conditions. Examples are the ranges in the South-East, the residual podsoils on Kangaroo Island and the mallee soils. Here we may follow the slow dropping out and replacement of species by others as rainfall decreases, till at the two extremes are found communities with few or no species in common.

Communities which in Tansley's system are regarded as seral, *i.e.*, those which show allogenic succession, may also be grouped as an edaphic complex. The communities on steep hillsides and skeletal soils, as well as on mature soils on tops of ridges, and on gentler slopes in the Mount Lofty Ranges, may be cited as an example. In each case the habitats are different and selective, so are the floristics, although they are allied. The hillside communities are stable, and a uniform terminal community is only theoretically possible by a levelling down of all physiographic units to the uniform soil type. These examples might be termed edaphic successions; but in any case it is desirable to separate them from biologically induced successions.

The examples given of the past history of South Australian soils and vegetation and the impossibility of reconstituting the past, illustrate the dangers of dogmatizing about successions of this kind. All our experience indicates that succession should not be used in any scheme of classification of communities.

This does not imply that biotic succession does not occur. It is obvious on sand dunes, and in swamps generally where the plants themselves cause changes in the habitat to produce a special soil carrying, at equilibrium, a terminal community. Within associations as defined by us biotic successional changes occur following fire, felling, grazing, etc., but there is no evidence of seral changes, only a selectivity of the habitat. This is well illustrated in the lower South-East, where the following communities in the same climatic zone are clear-cut both in floristics and habitat and with no evidence of seral stages between or leading to them.

<i>E. Baxteri</i>	- -	Sclerophyll forest	- -	on residual podsols
<i>Xanthorrhoea-Hakea</i>	Heath	- -	- -	wet acid podsols
<i>E. camaldulensis</i>	-	Savannah woodland	-	meadow podsols
<i>E. ovata</i>	- -	Savannah woodland	- -	intermediate meadow podsol-rendzina
<i>Gahnia-Cladium</i>	-	Savannah	- -	rendzina
<i>Maleleuca pubescens</i>	-	Savannah woodland	-	terra rossa

Much of the lack of succession is doubtless due to the low degree of integration of the open and light-demanding communities of *Eucalyptus* as well as to the historical factors discussed previously. Invasion is more obvious in highly integrated communities and certainly occurs in Australia where rain forest impinges on Eucalypt forest, but the lack of succession in our forests generally prohibits its use as a characteristic in any scheme of classification.

VIII. DISCUSSION AND CONCLUSIONS

Of the elements which make up the Australian flora the Australian element is the most prominent in the southern regions. As has been indicated its centre of origin is obscure, but in all likelihood there were many centres. Its present distribution strongly suggests a southern origin, but it is more likely that the primary elements developed when Australia generally had a temperate and more uniform climate. Perbet (1928) has suggested that the genus *Eucalyptus* successfully established itself under a temperate climate with abundant rainfall. It is perhaps significant that along the invasion routes of the Indo-Melanesian element there has been practically no two-way traffic. This lack of reciprocity was early noted by Hooker (1860), and it does suggest invasions following withdrawal of the Australian element to the south. In any case, the evidence is very strongly in favour of something in the nature of a pan-Australian flora in the early Tertiary—at least over the southern half of Australia. Such a possibility is made more likely by the edaphic and climatic uniformity which existed, for at this time the continent was reduced to an almost perfect peneplain. This uniformity was broken by marine transgressions, volcanic activity and earth-movements which reached their maximum in the late Tertiary, though each, and especially the latter, carried on into the Quaternary to some extent. Habitat diversity was further increased in the Pleistocene by the generally high rainfall causing active erosion of the newly-formed divides, and the spreading of large alluvial deposits. In the late Pleistocene other factors such as the deposition of large quantities of calcareous loess over Southern Australia led to a modification

of the edaphic conditions, while in the Quaternary generally, large oscillations in the flora occurred as a response to changing climatic conditions.

Of these climatic changes, the most significant from the viewpoint of the distribution of the present vegetation communities has been a post-Pleistocene period of aridity, which followed pluvial conditions.

The desiccation was so severe and sudden that it resulted in a considerable portion of the pre-arid flora being entirely wiped out. The surviving remnants were isolated in numerous refuges, most important of which were those regions where habitat diversity, especially climatic diversity, was greatest. The present-day plant communities are the result of re-colonisation of vast, virtually bare, areas, especially in the arid regions. This expansion achieved its greatest stimulus with a slight release of the climatic pressure. The Australian flora today contains a very large pre-arid relic element. Despite the favourable conditions for biotypical differentiation with reunion following isolation and the possibilities of later invasions (greatly favoured by the low level of competition), it is likely that this relic portion is still the larger. In a broad way the flora of the arid regions is a blending of the Indo-Melanesian element from the north and north-east with the Australian element from the south-west, south and south-east, which has occurred subsequent to the Great Australian Arid Period. It can be looked on, therefore, as a large ecotonal region. This blending of the two elements is well illustrated by the floristic analyses of Murray (1931) and Gardner (1942).

There is evidence for a post-Pleistocene xerothermic period in many places in the world (see Huntington and Visber 1922), but nowhere does it appear to have been so severe, or to have had such far-reaching consequences as in Australia, unless perhaps in the southern Mediterranean region. In view of the close relationship between the occurrence of maximum aridity, warmer seas and higher seas (10-20 feet) in Australia, and the evidence for a post-glacial worldwide (eustatic) rise in sea level of this order, it is not unlikely that aridity was much more general at this time than has been imagined. Hansen (1934), from studies on the Bear River delta, British Columbia, has concluded that present temperatures have not persisted for more than 4,000-5,000 years, the mid-post glacial being warmer. Although Australia largely lies in the latitudes where the high pressures tend to favour aridity, it is likely that the widespread effects of the desiccation were due to a combination of factors. Of these the general lack of relief (near-peneplanation) of the greater part of the continent, large areas of laterised soils which in many areas probably preserved up to this time much of their easily-stripped A horizons, the occurrence over much of Australia of great quantities of alluvium and detrital material, and of certain lime-rich soils in southern Australia which were liable to easy loss of stability, together with the presence of a very mesic flora, are most important and are sufficient to explain the results.

One fact which is apparent from the analysis of the development of the South Australian plant communities is that the associations themselves are very young. Their distribution has been determined within a climatic zone chiefly by edaphic conditions, in that these have been responsible for the sequence of related habitats, which have made up the migratory routes and have largely determined the speed and direction of migration.

As already mentioned the distribution patterns have been greatly influenced, however, by other factors such as individual dispersal capacities, chance dispersals, opposing migrations, location of survival centres, varying degrees of biotypical differentiation (including speciation), barriers, etc. It is not surprising that the final species-aggregates (associations, etc.) are not made up of units with identical tolerances. Nor is it surprising that an attempt to inter-relate these communities

(Wood 1937) as seral stages in the accepted sense of Clements (Clements 1916) should have been unsuccessful. The degree of stability of vegetation will be governed by the historical sequences, and these will vary greatly from country to country and within a country.

In some respects the response of the flora to aridity in Australia was very similar to some of the flora fluctuations of the Pleistocene ice-ages in the northern hemisphere. These, like our aridity, wiped out the vegetation over large areas, but left centres of survival. Glaciation, however, was a much more gradual phenomenon, permitting a considerable amount of adaptive differentiation to proceed. More important still was the fact that most species had a sufficiently wide amplitude and a fast enough migration capacity to keep ahead of the ice in its advance, and to follow it fairly closely in retreat. In this way wholesale destruction was avoided and the pattern of re-colonisation has been, in fact, entirely different. Chances for unlimited hybridisation and/or consolidation of biotypical differentiation did not occur to the same degree. The time factor, too, has been so very different. The historical sequences and their consequences seem sufficient to explain the specific stability of the north European and American floras by comparison with the great specific complexity of the Australian flora.

The ordinal and specific peculiarity of the flora of south-west Australia and the high percentage of endemics (70-80%) is considered to be adequately explained by a consideration of the paleobotanical evidence in relation to geological and climatic history. A pan-Australian flora probably existed in the early Tertiary. A southerly climatic-induced contraction in the Miocene coincided with the inundation of large portions of southern Australia, and effectively isolated floristically south-east and south-west Australia. The sea had retreated almost to its present position by the end of the Pliocene. Despite certain expansions of the flora since that time, a large measure of, if not complete, isolation of the flora of the south-west has subsequently been maintained. The barriers to migration have been chiefly edaphic and climatic, though the foundering of the gulfs of South Australia was also significant.

The richness in endemics of the flora of south-west Australia is the most interesting feature geographically in the flora of the continent.

It was mentioned in discussing this matter earlier that the flora isolated in the south-west by the late Tertiary seas was a peneplain flora, and that before or since then it must have become "adapted" to lateritic soils because they were at some stage of the Tertiary a widespread feature of the peneplains. Western Australia largely avoided the late Tertiary-Quaternary uplifts which resulted in the eastern divides and the Mount Lofty-Flinders system, and has been both prior and subsequent to this, one of the most stable parts of the Commonwealth. The lateritic soils are preserved there to a better degree than anywhere else in Australia. This emphasises the importance of edaphic barriers in maintaining isolation after the removal of other physical barriers on the retreat of the Tertiary seas. In addition to the edaphic barriers mentioned earlier is that caused by the development, with accession of calcareous loess during the late Pleistocene, of a large area of pedocalcic soils lying right across the migratory routes. This alone would prove a severe and extensive obstacle to late migrations. That the Australian element in the south-west of Western Australia is one selected by lateritic soil can hardly be doubted. According to Gardner (*loc. cit.*) those parts of the south-west richest in the purely Australian element are the sand heaths. "The floristic wealth of these heaths is probably unparalleled anywhere else on earth," he says. It is significant that these are in the region of Australia where parts of the old lateritic profiles are preserved, but more significant, these sand heaths are some of the few regions where the old A horizons of the laterite.

truncated more or less, and perhaps suffering some local rearrangement, are still preserved.⁽⁶⁾ The sand, which is underlain by laterite, is portion of this old A horizon. The floristic stability of the flora of the south west is paralleled, therefore, by a great measure of edaphic stability. Because of the narrow climatic zonation, climatic stability, or at least the provision of a wide range of climatic habitats within a short distance, has been maintained also for a long time.

From the survey that has been made in this paper of geological history, and its consequences on the Australian, and especially the South Australian flora, it is apparent that these geological factors have played an important part in the development of many groups of plants.

The foregoing considerations, both on the Australian flora and the development of the vegetation of South Australia, are based on only a very imperfect understanding of Tertiary and Quaternary geological and climatic history, in addition to a very restricted paleobotanical literature. Their tentative nature must, therefore, be stressed. However, although many modifications to the conclusions are to be expected, the present agreement amongst geologists on many of the basic facts in the Australian post-Mesozoic record, extended ecological and pedological knowledge, and the establishment of many new principles in plant geography are sufficient justification for an attempt of this type. Further improved interpretations will depend largely on advances in Australian geology, pedology, paleobotany (including paleoecology), cytogenetics and phylogeny.

This analysis of the time factor in ecology with its insistence on the selective effect of edaphic factors and migrating plant populations has strengthened the view put forward by one of us (J. G. W. 1939) and amplified here, *vis.*, that the basis underlying ecology is a physiological one, and that in the case of species growing naturally together the potential environment of the individual species overlaps the actual environment. In no case is there evidence of succession or progression to a climatic climax.

In the system of classification of communities proposed, the unit (the association) is based upon constant association of dominant species in which the term dominant refers not only to tree species, but to characteristic species of other layers. The concept of edaphic complex, first proposed as a unit of convenience, is shown by practical experience to be especially valuable in view of the complex soil mosaic consequent on the previous history of the area considered.

IX. SUMMARY

1. An analysis is made of some of the factors affecting the development of the Australian flora in the light of an improved knowledge of the geological, pedological and ecological pattern of Australia, and in relation to the more recent paleobotanical literature.

2. Evidence for a mid-Recent period of aridity in Australia is brought together and summarised. The significance of this desiccation on the distribution pattern of species and communities in South Australia is discussed in some detail. The presence of a large pre-arid relic element in the flora is postulated, and reasons given to explain the presence of a large number of "species complexes."

3. A number of Australian plant geographical problems are considered. These include the origin of the Australian element, and the high degree of endemism in the south-west of Western Australia.

4. Ecological concepts are discussed in the light of the time factor involved. The bases underlying systems of classification are discussed and ecological units are defined.

⁽⁶⁾ C. G. Stephens, Bull. 206, C.S.I.R. (Aust.), in press

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KEY TO THE SOUTH AUSTRALIAN SPECIES OF EUCALYPTUS L'HERIT.

BY NANCY T. BURBIDGE, M.SC.

Summary

The publication, in 1934, of Blakely's "Key to the Eucalypts" marked a definite advance in our knowledge of the genus, since the book made a very useful companion to Maiden's rather bulky "Critical Revision of the Genus Eucalyptus." It was a pity that Blakely's work, which was the result of years of patient and intensive labour, appeared under such misnomer, since identification of specimens with the aid of his "key" is difficult even when one has acquired a certain familiarity with the genus. This is particularly so when dealing with some of the members of such a complex as that around *E. odorata* or *E. oleosa*. Owing to the number of new species described by Blakely and the modification of some of the older ones, the key in Black's Flora of South Australia is no longer adequate and a new one is needed.

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By NANCY T. BURBIDGE, M.Sc.
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[Read 10 April 1947]

The publication, in 1934, of Blakely's "Key to the Eucalypts" marked a definite advance in our knowledge of the genus, since the book made a very useful companion to Maiden's rather bulky "Critical Revision of the Genus Eucalyptus." It was a pity that Blakely's work, which was the result of years of patient and intensive labour, appeared under such misnomer, since identification of specimens with the aid of his "key" is difficult even when one has acquired a certain familiarity with the genus. This is particularly so when dealing with some of the members of such a complex as that around *E. odorata* or *E. oleosa*. Owing to the number of new species described by Blakely and the modification of some of the older ones, the key in Black's Flora of South Australia is no longer adequate and a new one is needed.

Since Blakely's death no botanist has taken over his eucalyptological work, which is to be regretted when the economic and botanical importance of the genus is considered. The whole genus is badly in need of integrated research by taxonomists, ecologists and geneticists, and hence this paper merely tries to clarify the present confusion so that a key to the South Australian species can be constructed.

The genus *Eucalyptus* includes an unusually high percentage of variable and unstable species which, for want of a more definite term, can be called polymorphic. Hybridisation is known to occur in the field, and evidence concerning its extent in Tasmania is being accumulated by Brett (5). Under natural conditions, and with such slow growing and long-lived species, it must be a long period before the results of any cross can be stabilised. It is possible that complete stability is never attained, and the plants representing various stages may be found close together in one locality or scattered throughout a region according to their adaptability to different habitat conditions. Possibly this explains the existence of some of the species complexes. But, whatever the cause of polymorphism may be, it is the resulting variants which must be dealt with in a key.

When there is a series of related forms, the status given to any particular variant depends partly upon the amount of material available for comparison. If specimens A., C., and E. are found they may all apparently deserve specific rank. Add D. and they may be reduced to varieties. Add B. and F. and it becomes very difficult to separate them at all under any reliable character. On the other hand, the larger and more polymorphic a species becomes, the harder it is to delineate it sharply from other related species. Hence a balance must be struck, and since the meaning of the word "species" is, under these circumstances, more than usually uncertain, one is forced to take a somewhat utilitarian view and seek the most workable arrangement for practical purposes.

This work is not intended as a complete revision of the local species which would require some years of study both in the herbarium and in the field, as well as a fuller knowledge of Eucalypts occurring in other parts of Australia. The writer is in full agreement with Ferdinand von Mueller when he states, "to assign to each species its proper place involves the study of all allied congeners, and these are often . . . dispersed at wide distances in Australia" (9). At present there are large gaps in localities whence specimens have been obtained. Until the areas around the Great Australian Bight and to the north of the Nullarbor Plain have been studied, relationships with Western Australian species cannot

be solved. Central Australia is still, botanically speaking, terra incognita and much remains to be learnt concerning the southern species which extend north and the tropical forms which occur over the border of South Australia. In the east, affinities with species in New South Wales and Victoria are better understood, but knowledge is far from complete.

DISCUSSION OF CHARACTERS USED IN THE KEY

In his preface Blakely states that the original intention of Maiden was to design a key based on the nature of the cotyledonary and juvenile foliage. Owing to incomplete data this proved impossible and Blakely used the anther type in his primary division of the genus. The shape and number of juvenile leaves is likely to be of real importance when relationships are being traced, but in a key such a character would be difficult to employ since the necessary material is not always available to the collector. In basing his key on the anthers Blakely followed Bentham (1), but, unfortunately, great familiarity with his herbarium material and a certain lack of field experience led to subdivision into a large number of groups based on slight differences in shape. The result is confusing both to the novice and to the experienced botanist. The original plan as designed by Bentham was reasonably sound, though until adequate anther material of all species is available the value of this character cannot be fully estimated. Blakely's subsections are so difficult to recognise that anthers have been omitted from this key, except where several features of the organ can be contrasted with corresponding characters in other species.

Bentham's secondary divisions were largely based on the character of the fruit, and in the preparation of this paper more and more reliance came to be placed on this feature, particularly on the nature of the disc and the type of the valves. Correlation between anther type and fruit character was imperfect, though it exists to some extent. This issue is probably confused because of the number of lines of development which are represented among the species.

The top of the fruit is formed of four zones. The outer rim represents the abscission line left by the fallen operculum and is known as the *calycine ring*, the next is the *staminal ring*, then the so called *disc* whose ontogeny has not yet been described. It is not certain that this term has been consistently employed by botanists. Inside the disc is the top of the ovary which ruptures into the *valves*. The variations produced in these zones in different species are considerable. The calycine ring is rarely important, though it is wide and conspicuous in the flowers and fruits of *E. pyriformis* and its affinities. This fact has been employed in the key. In some cases the staminal ring is a narrow elevated ring in the flower, but it usually becomes inconspicuous in the fruit. In others, e.g., *E. leucoxylon*, the ring is comparatively wide, but thin and projecting over the disc. In this species the ring either falls away during maturation of the fruit or it remains partially attached on one side of the fruit. In *E. intertexta*, and also in *E. calcicultrix*, which lies between *E. leucoxylon* and *E. odorata* there may also be a distinct staminal ring in the maturing fruit, but usually it is not deciduous and it may break up into a number of small pieces attached around the rim of the fruit.

In fresh flowers and young fruits the disc is more or less continuous with the top of the ovary. As the fruit matures or, in collected specimens, dries the distinction between the two parts becomes increasingly marked until, with the opening of the valves, they appear quite unrelated. The disc itself may be broad as in *E. Baxteri*, a narrow ridge as in *E. incrassata*, a ring as in *E. oleosa* or *E. leptophylla*, or it may be little more than a lining to the top of the tube when the capsule is sunken as in *E. fasciculosa* or *E. odorata*. When broad the disc may be domed, i.e., convex as in *E. comalduensis* and *E. viminalis*; flat as in *E. vitrea* or concave, i.e., oblique as in *E. obliqua* and *E. leucoxylon*.

The valves may be short and triangular as in *E. camaldulensis* in which case they represent the top of the ovary, or they may have sharp points formed by the rupturing of the persistent base of the style as in *E. incrassata* and *E. dumosa*, or the sharp points may be long and coherent at the apex due to the persistence of the entire style as in *E. oleosa*. In the latter case the valves are brittle and may break off short, confusing the inexperienced student.

Just which type can be regarded as the most primitive is a question demanding a wider and more extensive study and correlation with the affinities demonstrated by such characters as juvenile foliage and anther shape. Owing to South Australia's central position, geographically, the local Eucalypts include species representing a number of different lines of development. Consequently much speculation here concerning phylogeny within the genus would be out of place.

In specimens bearing immature fruit the valves open during drying and release the seed. Such capsules may appear fully developed and will give a false impression of the size normal for the species. In plants growing in arid habitats a lack of soil moisture or a sudden hot spell at the crucial time may induce a similar dehiscence of immature fruit. Another probable cause of subnormal size and shape in fruit, apart from insect or mechanical damage, is when no seeds mature. This is suspected when *E. Morrisii*, which is supposed to have a high convex disc, bears fruits with flat ones (pl. i, fig. 4 b-c).

The word "striate" has caused some confusion in the literature. Blakely used it rather freely whenever the bud or fruit was slightly marked by longitudinal lines. Others have allowed the term to cover fruits which Blakely would have called ribbed. In this paper the word is used when longitudinal ridges or lines are apparent owing to the shrinkage of non-sclerised tissues, e.g., *E. incrassata* var. *costata*, while "ribbed" has been used when the ridges are deep enough to have been evident when the specimen was fresh, e.g., *E. pyriformis* and *E. incrassata* var. *angulosa*. In a few cases it is difficult to draw a line between the two conditions, but in general the above use of the terms can be quite consistent.

With reference to distribution, it may be stated here that Blakely's lists of localities were compiled from the material in the Sydney Herbarium. They are, therefore, incomplete in some cases, e.g., *E. elaeophora*, and incorrect in others, e.g., *E. goniocalyx*. The latter reference was based on a specimen which is, in the writer's opinion, *E. elaeophora*.

Short descriptions of the species have been included to make the use of the key easier. Field details such as bark, wood colouration and juvenile foliage have been omitted. The writer cannot claim a wide knowledge of the first two, and all have been covered in Blakely's descriptions.

KEY TO THE SPECIES

(N.B.—This key is based on appearance of specimens when dry. Ribbing or wrinkling of buds and fruits is always less evident in fresh material.)

- | | | |
|---|------|-------------------------|
| A. Staminal ring lobed. Buds tetragonous. Leaves opposite | .. | 1. <i>endesminoides</i> |
| AA. Staminal ring not lobed | | |
| B. Operculum thick, leaving a broad rim outside the staminal ring. | | |
| Disc with an erect ridge around the partially sunken valves. | | |
| C. Buds pedicellate, calyx tube ribbed. | | |
| D. Fruit more than 4 cm. in diameter | .... | 2. <i>pyriformis</i> |
| DD. Fruit less than 4 cm. in diameter | .. | 3. <i>pachyphylla</i> |
| CC. Buds sessile, calyx smooth. | | |
| D. Buds glaucous | .... | 4. <i>ozymitra</i> |
| DD. Buds not glaucous | .. | 5. <i>Oldfieldii</i> |
| BB. Operculum not thick. | | |
| C. Disc broad and convex or flat around the short broad valves. | | |
| D. Valves either markedly exsert and contributing to the length of the fruit or in the orifice. | | |

- E. Peduncles and pedicels slender. Operculum rostrate or conical 6. *camaldulensis* & var. *obtus*
- EE. Peduncles and also pedicels when present not slender, usually short and stout.
- F. Mallees or small stunted trees.
- G. Species occurring in arid interior.
- H. Operculum conical to rostrate. Fruit almost or quite sessile.
- I. Operculum acuminate to beaked. Bud glaucous .. 4. *axymitra*
- II. Operculum obtuse. Buds not glaucous ... 7. *Morrisii*
- HH. Operculum hemispherical. Fruit pedicellate ... 8. *Ewartiana*
- GG. Coastal or subcoastal species.
- H. Operculum hemispherical or hemispherical-conical. Buds and fruits pedicellate ... 9. *remota*
- HH. Operculum conical to rostrate. Buds and fruits very shortly pedicellate or sessile ... 10. *diversifolia*
- FF. Trees occurring in higher rainfall areas.
- C. Fruit about 10 x 10 mm., markedly sessile (except var.), usually in globose clusters. Operculum hemispherical or short and very obtuse ... 11. *Baxteri* & var. *pedicellata*
- GG. Fruit smaller than above. Operculum conical.
- II. Juvenile leaves ovate-orbicular, glaucous. Buds and fruits more or less glaucous ... 12. *rubida*
- HH. Juvenile foliage broad or narrow lanceolate, pale green. Buds and fruits not glaucous.
- I. Umbels with three flowers ... 13. *viminalis*
- II. Umbels with three or more flowers occurring on same branch.
- J. Umbels on leafless branches or racemes ... 13a. *viminalis* var. *racemosa*
- JJ. Umbels all axillary ... 13b. *viminalis* var. *Huberiana*
- DD. Valves enclosed and more or less concealed by the disc.
- E. Operculum conical, about as long as the tube. Venation semi-longitudinal. Bark rough ... 14. *vitrea*
- EE. Operculum shorter than tube, hemispherical. Venation longitudinal. Bark smooth ... 15. *pauciflora*
- CC. Disc narrow and forming a ring or rim on the top of the fruit or, if broad, concave and extending obliquely into the capsule or forming a lining inside the top of the fruit.
- D. Disc forming a ridge or concave and oblique.
- E. Operculum hemispherical-apiculate. Disc strongly oblique ... 16. *obliqu* & var. *megacarpa*
- EE. Operculum conical or rostrate (except *E. ruscina*).
- G. Staminal ring obscure or if evident on fruit then not broad and extending over the disc.
- H. Flowers in axillary umbels.
- I. Stamens all fertile. Outer ones not markedly longer than inner. Buds without conspicuous oil glands.
- J. Anthers versatile, opening widely to base with cells parallel and side by side, with a conspicuous gland on back.
- K. Trees in high rainfall country.
- L. Buds not angular at base. Fruit turbinate ... 17. *ovata* & var. *grandiflora*
- LL. Buds angular at base. Fruit cylindrical .. 18. *elacophora*
- KK. Mallees.
- L. Buds and fruits sessile on very short but not flattened peduncles, bicostate or unribbed. Top of ovary not ridged between valves when immature. Valves in orifice .. 19. *cosmophylla*

- LL. Buds and fruits pedicellate, or if sessile and bicostate then with flattened peduncles. Top of ovary usually ridged between valves in immature fruits.
- M. Valves deeply enclosed. Umbels deflexed
- MM. Valves in or near orifice. Umbels erect.
- N. Valves broad and triangular with short points. Fruit 10 x 10 mm. or larger.
- O. Fruit smooth. Peduncle terete ...
- OO. Fruit striate. Peduncle terete or narrow but flattened ...
- OOO. Fruit coarsely ribbed. Peduncle broad, flattened ...
- NN. Valves narrow and more or less subulate. Fruit smaller than above.
- O. Buds and fruits short and fat, the latter broader than long and so sessile as to be almost imbedded in the end of the flattened peduncle ...
- OO. Buds and fruits not as above.
- P. Fruits sessile, striate, on thick peduncles ...
- PP. Fruits pedicellate, sometimes only shortly so.
- Q. Calyx tube 2-4-ribbed and passing into a flat pedicel. Peduncle flattened. Operculum hemispherical-conical, obtuse ...
- QQ. Calyx tube not 2-4-ribbed.
- R. Peduncles and pedicels not slender. Operculum shorter than tube.
- S. Buds smooth or very minutely striate. Peduncle terete ...
- SS. Buds with radiately ribbed or striate opercula. Peduncle angular or flattened ...
- RR. Peduncles and pedicels slender.
- S. Operculum as long as the cupular calyx tube, obtuse ...
- SS. Operculum shorter than tube, hemispherical and flat-topped ...
- JJ. Anthers more or less adnate to the top of the filaments; dehiscing by pores, slits or by broad cells opening back to back. Valves narrow and subulate.
- K. Filaments sharply reflexed in bud and with a bend when flowering.
- L. Buds and flowers pedicellate ...
- LL. Buds and flowers sessile ...
- KK. Filaments crumpled in bud, with or without some reflexed, not bent when flowering.
- L. Buds and fruits sessile. Leaves erect ...
- LL. Buds and fruits pedicellate. Leaves spreading.
- M. Fruit globose to sub-tricelate. Operculum not wider than tube at junction.
20. *pimpiniana*
21. *incrassata*
- 21a. *incrassata* var. *costata*
- 21b. *incrassata* var. *angulosa*
22. *conglobata*
23. *anceps*
24. *rugosa*
25. *dumosa*
26. *pileata*
27. *brachycalyx* & var. *chindoo*
28. *concinna*
29. *leptophylla*
30. *uncinata*
31. *encorifolia*

- N. Leaves opposite, sessile or almost so. Plant usually very glaucous. Operculum rostrate 32. *Gillii* & var. *petiolaris*
- NN. Leaves alternate, petiolate.
- O. Operculum with the same surface texture as the tube.
- P. Operculum conical.
- Q. Leaves shining and glossy ... 33. *oleosa*
- QQ. Leaves, buds and fruits glaucous 33a. *oleosa* var. *Peeneri*
- PP. Operculum rostrate. Leaves dull and more or less glaucous 33b. *oleosa* var. *glauca*
- OO. Operculum very obtuse or flat-topped, the surface wrinkled and usually a different colour from that of the smooth tube 33c. *oleosa* var. *angustifolia*
- MM. Fruit urceolate. Operculum smooth, wider than tube at junction 34. *Flocktoniae*
- II. Outer stamens sterile and longer than inner. Buds with translucent oil glands.
- J. Buds and fruits quadrangular 35. *calycogona* & var. *Staffordii*
- JJ. Buds and fruits not quadrangular 36. *gracilis* & var. *erecta*
- HH. Umbels paniculate, sometimes simple axillary umbels also present.
- I. Buds 7 x 5 mm., valves of fruit narrow, enclosed in orifice 37. *intertexta* & var. *fruticosa*
- II. Buds 4 x 3 mm., valves broad and exsert ... 38. *coolabah*
- GG. Staminal ring broad (up to 2 mm.) and conspicuous after flowering, more or less deciduous.
- H. Three flowers per umbel.
- I. Fruit smooth.
- J. Fruit 7-15 mm. long 39. *leucoxylon*
- JJ. Fruit more than 15 mm. long 39a. *leucoxylon* var. *macrocarpa*
- II. Fruit subangular, 4-6-ribbed 39b. *leucoxylon* var. *angulata*
- HH. Umbels with three or more flowers. Fruit 6-7 mm. long 39c. *leucoxylon* var. *pauperitum*
- DD. Disc very inconspicuous and lining the rim of the calyx tube.
- E. Flowers in axillary umbels which may become clustered or terminal due to lack or loss of leaves.
- F. Leaves more than 0.8 cm. wide.
- G. Buds crumpled or wrinkled like a withered apple. Leaves lanceolate to broad lanceolate, the marginal nerve distant and the leaves often tri-nerved at the base. 40. *calcicultrix*
- GG. Buds more or less angular with angular pedicels, not wrinkled like a withered apple.
- H. Fruits more than 4.5 x 4.5 mm.
- I. Buds sessile or on very short thick pedicels. Leaves lanceolate or broad-lanceolate, rather thick. Mallee 41. *Lansdowneana*
- II. Buds pedicellate, often markedly so. Leaves narrow lanceolate or, in tree forms, broad ... 42. *odorata*
- HH. Fruits 4.5 x 4.5 mm. Buds very shortly pedicellate, slightly glaucous. Leaves narrow lanceolate .. 42a. *odorata* var. *angustifolia*

FF	Leaves narrow linear, less than 0.8 cm. wide	43, <i>viridis</i>
EE	Flowers in paniculate umbels.	
F	Leaves alternate.	
G	Fruit smooth or with one or two striations, not costate.	
H	Operculum as wide as the top of tube.	
I	Buds and fruits pedicellate. Trees.	
J	Operculum conical.	
K	Fruit larger than 5.7 x 4.5 mm.	
L	Leaves, buds and fruits glaucous	44a, <i>hemiphloia</i> var. <i>albens</i>
LL	Leaves, buds and fruits not glaucous ...	44, <i>hemiphloia</i>
KK	Fruit 5.7 x 4.5 mm. (sometimes almost sessile)	44b, <i>hemiphloia</i> var. <i>microcarpa</i>
IJ	Operculum hemispherical	45, <i>largiflorens</i>
II	Buds and fruits sessile or very shortly pedicellate (see also <i>hemiphloia</i> var. <i>microcarpa</i> above).	
J	Operculum conical. Fruit subangular, up to 10 x 9 mm. Leaves lanceolate	41, <i>Lansdowneana</i>
JJ	Operculum hemispherical. Fruit 3.5 x 3.5 mm. Leaves broadly lanceolate	46, <i>Bahriana</i>
HH	Operculum conical, narrower than top of tube ...	47, <i>fasciculosa</i>
GG	Fruit truncate, costate. Operculum hemispherical-apiculate	48, <i>cladocalyx</i>
FF	Leaves opposite	49, <i>gumophylla</i>

NOTES ON THE SPECIES

1. *EUCALYPTUS EUDESMIOIDES* F. Muell. in *Fragm.*, ii, 35 (1860).

Dwarf mallee or small tree. *Mature leaves* opposite, shortly petiolate, lanceolate, subglaucous, 4.6 x 1.2.5 cm. *Umbels* axillary, three-flowered, peduncles teretè. *Buds* clavate, tetragonous, obtuse, shortly pedicellate, 6 x 4 mm. *Operculum* hemispherical shorter than tube. *Stamens* in four clusters alternating with small calyx teeth. *Fruit* pedicellate, campanulate to urceolate, smooth or slightly angled, 14 x 10 mm. (after Blakely).

This species, recorded for the Birksgate and Blyth Ranges in the extreme north-west of the State, has no close affinity with any other South Australian form.

2. *EUCALYPTUS PYRIFORMIS* Turcz. in *Bull. Soc. Nat. Mosc.*, 22, pt. ii, 22 (1849).

Mallee with straggling habit. *Mature leaves* alternate, petiolate, broadly lanceolate, 6.15 x 2.4 cm., surface dull. *Umbels* axillary, 3-flowered, peduncles deflexed, thick and short. *Buds* ovoid or pyriform, shortly pedicellate, 5.6 x 3.4 cm. *Operculum* conical with a rostrate apex, very thick but narrowing to about 4 mm. thickness at the point of attachment to the calyx tube, striate, twice as long as tube. *Tube* wide and shallow with 7.9 coarse ribs and a few smaller ones. *Stamens* red or yellowish. *Fruit* broadly turbinate, more than half the height being due to the high disc. Staminal ring present as a line separating the calycine ring and disc, the latter erect and with a distinct ridge around the broad, thick, deltoid, partially sunken valves. *Fruit* 4 x 7 cm. (pl. i, fig. 2).

This species, with *E. pachyphylla* and *E. Oldfieldii*, is distinguished by the thickness of the operculum and by the ridged disc which forms a small crater-like valley around the valves. These characters are less distinct in *E. Oldfieldii*, which forms a link with *E. oxymitra*, *E. Ewartiana* and *E. Morrisii*.

It is known to occur along the transcontinental railway from Tarcoola westward.

3. *EUCALYPTUS PACHYPHYLLA* F. Muell. in Jour. Linn. Soc., 3, 98 (1859).

Mallee. *Mature leaves* alternate, petiolate, ovate or broad to narrow lanceolate, 6-10 x 2-5 cm. *Umbels* 2-3-flowered, axillary, peduncles terete, spreading not deflexed, 6-10 mm. long. *Buds* shortly pedicellate, ovoid-rostrate, 25 x 20 mm. *Operculum* conical-rostrate, striate to ribbed, about 2-3 mm. thick at point of attachment, 1-1½ times as long as broad. *Tube* wide and shallow with 3-5 sharp but narrow ribs and with smaller ones between. *Fruits* as in *E. pyriformis* but smaller, 15-20 x 20-30 mm., ribs more rounded in older fruits (pl. i, fig. 3).

Description of the bud was taken from Maiden (Crit. Rev., pl. 75, fig. 5-6). This species was collected by Professor J. B. Cleland at the junction of Boundary and Fraser Creeks on the border of South Australia and Northern Territory.

4. *EUCALYPTUS OXYMITRA* Blakely in Trans. Roy. Soc. S. Aust., 60, 155 (1936).

Glaucous mallee. *Mature leaves* alternate, petiolate, broadly lanceolate, thick, 5-7 x 2-4 cm. *Umbels* axillary, 3-7-flowered, peduncles short. *Buds* shortly pedicellate, ovoid or globular with a hooked-rostrate apex 10-12 x 7-8 mm., glaucous. *Operculum* hemispherical-rostrate or conical-rostrate, 2-3 times as long as wide shallow tube. *Fruit* pedicellate, glaucous, subglobose, 11 x 11 mm. disc broad, semiconical, smaller than calycine portion (after Blakely) (pl. i, fig. 1).

Fruiting specimens used by Blakely have not been seen by the writer. The affinities of this species and also the identity of S. A. White's Everard Range specimens (see below) depends on whether the disc in this species is ridged around the valves or not. Its occurrence in this State is still in doubt.

5. *EUCALYPTUS OLDFIELDII* F. Muell. in Fragm., ii, 37 (1860).

Mallee. *Mature leaves* alternate, petiolate, narrow to broad lanceolate, 7-13 x 1.5-3 cm. *Umbels* axillary, 3-flowered, peduncles thick, sometimes very short. *Buds* globular to ovoid-rostrate, almost or quite sessile, 20 x 10-15 mm. *Operculum* conical or rostrate, thick, longer than tube. *Tube* smooth, wide and shallow. *Fruit* hemispherical to turbinate, 11 x 15 mm.; disc portion nearly as large as base, ridge and hollow around valves less evident than in *E. pyriformis* and *E. pachyphylla* (mostly after Blakely).

There is some doubt as to whether this species actually occurs in South Australia. Black (Fl. S. Aust., 418) mentions a specimen from Missionary Plains, MacDonnell Range under *E. Oldfieldii* which has since been described by Blakely as *E. oxymitra* (see above). The specimen consists of buds and leaves without fruits. Of S. A. White's material mentioned by Black (*l.c.*), both have leaves and fruits but no buds. In his MacDonnell Range specimen the disc is ridged though rather smaller than is illustrated for *E. Drummondii* by Maiden (Crit. Rev., pl. 74, fig. 4b), while in the Everard Range material the fruits have a convex disc, reminiscent of that in *E. Ewartiana*. Pending collection south of the border the recording of *E. Oldfieldii* for this State must remain doubtful.

6. *EUCALYPTUS CAMALDULENSIS* Dehii in Cat. Pl. Hort. Camald. ed. 2, 20 (1832). *E. rostrata* Schlecht. in Linnaea, 20, 655 (1847).

Medium to large-sized tree. *Mature leaves* alternate, petiolate, lanceolate, 5-11 x 2-4 cm. *Umbels* axillary, 5-10-flowered, peduncles and pedicels slender and terete. *Buds* ovoid or diamond-shaped, acute, pedicellate 6-10 x 3-5 mm. *Operculum* conical and acute or rostrate, longer than the wide shallow tube.

Fruit hemispherical or broadly cupular with the erect valves at least as long as the wide base, 6-8 x 5-6 mm., the valves broadly triangular and more or less incurved.

This widespread species occurs throughout the State. It is associated with watercourses and creeks.

7. *EUCALYPTUS MORRISII* R. T. Baker in Proc. Linn. Soc. N.S.W., 25, 312 (1900).

Mallee or small tree. *Mature leaves* alternate, petiolate, linear-lanceolate to lanceolate, 6-12 x 12 cm. *Umbels* axillary 3-6-flowered, peduncles semiterete or terete, 5-10 mm. long. *Buds* ovoid, semisessile on short thick pedicels which may be slightly angular as they pass into the calyx tube, 7-10 x 4-6 mm., with copious dark oil glands. *Operculum* conical, very obtuse, $1\frac{1}{2}$ -2 times as long as tube. *Tube* obconical, about as long as broad, smooth or with one or two small ridges. *Fruit* truncate-turbinate or ovoid according to the convexity of the wide disc, valves short and broadly triangular, exsert at the top of the disc (pl. i, fig. 4).

With regard to the variation in the development of the disc, Maiden (Crit. Rev., pl. 135, fig. 6) figures the disc as continuous with the valves. This is always more marked in fresh material than in dried. Maiden's fig. 6 was apparently taken from R. T. Baker's original plate, but neither author states whether the specimen used was fresh or dry. In material collected by the writer an excellent match with Maiden's fig. 6a and 6b has been obtained. In most of the South Australian specimens the buds and fruits are smaller than the dimensions given for New South Wales material.

In this State the species is found in the Flinders Ranges, from Quorn northwards.

8. *EUCALYPTUS EWARTIANA* Maiden in Jour. Roy. Soc. N.S.W., 53, 111 (1919).

Mallee. *Mature leaves* alternate, petiolate, lanceolate, 5-9 x 1.5-2.5 cm., surface dull. *Umbels* axillary, 3-7-flowered, peduncles terete, up to 2 cm. long. *Buds* pedicellate, clavate or globular, 8-10 x 6-8 mm. *Operculum* very obtuse, being hemispherical or basally truncated-spherical, thick, $1-1\frac{1}{2}$ times as long as tube, smooth. *Tube* wide and shallow, half as long as wide. *Fruit* pedicellate, globose or clavate due to the very convex disc which provides nearly half the length, valves deltoid and very exsert, 8-10 x 8-12 mm. (pl. i, fig. 8).

Despite the fact that Maiden (Crit. Rev., 44, 120) stated that the authors placed this species among the Macrantherae, Blakely included it with the Platyantherae. Blakely records this species for South Australia, but gives a Central Australian locality—Missionary Plains, MacDonnell Range. Black (3) states that the valves have long points (up to 4 mm. long), which break off early. These have not been seen by the writer.

9. *EUCALYPTUS REMOTA* Blakely in Key to Euc., 197 (1934).

Mallee. *Mature leaves* alternate, petiolate, lanceolate, to broadly lanceolate, slightly falcate resulting in better development of the base on one side than on the other, coriaceous, 6-12 x 1.5-3 cm. *Umbels* axillary, 3-8-flowered, peduncles semiterete, 5-11 mm. long. *Buds* pedicellate, clavate, 4-6 x 4-5 mm. excluding the subangular pedicels. *Operculum* hemispherical or hemispherical-apiculate, about as long as the tube. *Tube* obconical, passing into the pedicel to form a long narrow funnel, surface wrinkled in dried material. *Fruit* pedicellate, pyriform, slightly wrinkled when dried, flat-topped, 6-9 x 5-8 mm., disc slightly convex and rounded to very slightly concave but usually flat, about 1 mm. broad; valves short, in orifice or almost covered by disc (pl. ii, fig. 1).

Blakely placed this species near *E. Consideriana* and *E. Sieberiana*, which both belong to eastern New South Wales, Victoria and Tasmania. However, to the writer the relationship with *E. diversifolia*, which occurs in the same localities as *E. remota*, is far more marked, especially in the fruits. The buds and slightly asymmetrical leaves suggest a link with *E. obliqua*. *E. remota* is known as a useful indicator plant for a soil type on Kangaroo Island, which is, so far, the only area in which the species has been found.

10. *EUCALYPTUS DIVERSIFOLIA* Bonpland, in Pl. Jard. Mahm., 35, t. 13 (1813).
E. santalifolia F. Muell. in Trans. Vict. Inst., 1, 35 (1855).

Large Mallee. *Mature leaves* alternate, petiolate, linear-lanceolate to broadly lanceolate. *Umbels* axillary, 3-6-flowered, peduncles semiterete 4-7 mm. long. *Buds* shortly pedicellate or sessile, shape of two cones attached base to base, smooth or very slightly wrinkled when dry, 7-10 x 4-6 mm. *Operculum* conical or conical-rostrate, about the same size and shape as the combined tube and pedicel, 4-6 mm. long. *Tube* obconical, 3-4 mm. long. *Fruit* sessile or very shortly pedicellate, hemispherical to campanulate or obconical, 8-12 x 10-15 mm., disc 1.5-2 mm. broad, slightly convex and rounded or flat; valves broad and triangular in orifice and slightly more exsert than in *E. remota*, so that the short points protrude above the disc (pl. ii, fig. 3).

When buds are lacking it is not easy to distinguish between *E. diversifolia* and *E. remota*, but the fruits of the former are larger, have a wider disc and are always more shortly pedicellate than those of the latter.

This species occurs as a coastal or subcoastal mallee from the west coast of Eyre Peninsula to the Victorian border, including Kangaroo Island.

11. *EUCALYPTUS BAXTERI* (Denth.) Maiden and Blakely in Crit. Rev., 70, 451 (1928). *E. santalifolia* var. (?) *Baxteri* Benth. in Fl. Austral., 3, 207 (1866).

Small to medium-sized tree. *Mature leaves* alternate, petiolate, ovate to broadly lanceolate, asymmetrical at base. *Umbels* axillary, 5-9-flowered, peduncles stout 4-6 mm. long. *Buds* obovoid on short thick pedicels, 4-5 x 3-4 mm. *Operculum* hemispherical, slightly shorter than the obconical or hemispherical tube. *Fruit* sessile, subglobose due to the convex disc which is 2-3 mm. wide, 9-12 x 10-13 mm., arranged in tightly packed globose clusters on the short stout peduncles, valves incurved, in orifice or slightly exsert (pl. iii, fig. 1).

- 11a. *E. BAXTERI* var. *PEDICELLATA* Maiden and Blakely in Crit. Rev., 70, 457 (1928).

Differs from the above in that the fruits are shortly pedicellate. The opercula are verrucose.

The species occurs in the Mount Lofty Range and southwards to the South-East and the Victorian border, also Kangaroo Island. The variety is known to occur in the South-East and may be found in other parts of the above districts.

12. *EUCALYPTUS RUBIDA* Deane and Maiden in Proc. Linn. Soc. N.S.W., 21, 156 (1899).

Medium to large-sized tree. *Mature leaves* alternate, petiolate, lanceolate. *Umbels* axillary or lateral on leafless portions of the branchlets, 3-flowered, peduncles semiterete or slightly flattened. *Buds* shortly pedicellate or almost sessile, ovoid or cylindrical, 5-7 x 3-5 mm. *Operculum* conical, obtuse. *Tube* cylindrical, slightly longer than or equal to the operculum. *Fruit* sessile or shortly pedicellate, obovoid or turbinate, 5-6 x 6-7 mm.; disc concave, valves deltoid and exsert.

The South Australian material seen was less glaucous than as described by Blakely. It appears to lie between *E. elaeophora* and *E. viminalis* among our species. It occurs in the Mount Lofty Range.

13. *EUCALYPTUS VIMINALIS* Labill in Nov. Holl., ii, 12, t. 151 (1806).

Large tree. *Mature leaves* alternate, petiolate, linear-lanceolate to lanceolate, 10-20 x 1-2-3 cm. *Umbels* axillary, normally 3-flowered, peduncles subangular, 3-6 mm. long. *Buds* obovoid with pointed apex and short usually thick pedicels, 6-10 x 3-5 mm. *Operculum* conical to conical-rostrate, equal to or slightly longer than the obconical tube, at its broadest somewhat wider than tube. *Fruit* sessile or very shortly pedicellate, turbinate to subglobose or pyriform, 6-8 x 6-9 mm. (including valves); disc convex, contributing to the length of the fruit, about 1 mm. wide, valves exsert and erect, short and broad.

Occurs in the Mount Lofty Range and southwards to Mount Gambier and the Victorian border.

13a. *EUCALYPTUS VIMINALIS* var. *RACEMOSA* (F. Muell.) Blakely in Key to Euc., 162 (1934).

In this variety the umbels are arranged on short leafless branches. Blakely states that the umbels are 3-flowered, but South Australian specimens agreeing excellently in other respects with the figure (Crit. Rev., pl. 118, fig. 9) have multiflowered umbels. There is no reference in the text of the Critical Revision to this variety, and Blakely's note appears to be the only description. The variety occurs in the South-East of the State.

13b. *EUCALYPTUS VIMINALIS* var. *HUBERIANA* (Naudin) N. T. Burbidge *stat. nov.*; *E. HUBERIANA* Naudin in Second Mem., 42 (1891).

E. Huberiana was separated from *E. viminalis* by Blakely, though Maiden (Crit. Rev., 28, 173) considered it merely a synonym and remarked that it was always possible to find multiflowered umbels on trees with mostly 3-flowered ones. *E. Huberiana* differs in timber value, rougher bark, form of growth and in the multiflowered umbels. Recent specimens, collected near Adelaide, showed some branchlets with 3-flowered umbels and some with four or more flowers. This supports Maiden's observation and there seems to be no character which can be used for differentiation at the specific level and the form is herein given varietal rank (pl. iii, fig. 2). Naudin's species was based on a single tree growing under cultivation at Nice. This is a practice which is open to criticism. Many Eucalypts produce an atypical growth under horticultural conditions, and also there is no evidence concerning the origin or purity of the seed used.

Distribution is the same as in *E. viminalis*, also on Kangaroo Island

14. *EUCALYPTUS VITREA* R. T. Baker in Proc. Linn. Soc. N.S.W., 25, 303 (1900).

Medium to large-sized tree. *Mature leaves* alternate, petiolate, narrow to broad lanceolate, the venation very oblique and approaching semilongitudinal, the main nerve some distance from the edge and frequently there are minor nerves outside, 10-15 x 1.5-2 cm. *Umbels* axillary, singly or in pairs or in short axillary panicles, 7-12-flowered, peduncles terete or semiterete, 7-10 mm. long. *Buds* on relatively stout pedicels which pass into the tube without marked change, clavate, 5-6 x 4-5 mm. *Operculum* hemispherical-apiculate or conical-acute, as long as tube. *Tube* obconical or cylindrical. *Fruit* pyriform, shortly pedicellate, 5-6 x 6-7 mm.; disc 1-2 mm. broad, convex or almost flat, covering the short enclosed valves.

In the south of the State. Specimens from Waitpinga, Kalangadoo, Mount Gambier and other South-East localities have been seen.

15. *EUCALYPTUS PAUCIFLORA* Sieber in Spreng, Syst. Cur. Post, iv, 195 (1827).

Small to large tree. *Mature leaves* alternate, petiolate, lanceolate, venation longitudinal or almost so, 8-14 x 1.5-3 cm. *Umbels* axillary, 5-12-flowered, usually about 9, peduncles thick, terete or compressed 7-15 mm. long. *Buds* clavate, pedicellate 5-7 x 4-5 mm. *Operculum* hemispherical, obtuse, shorter than tube. *Fruit* shortly pedicellate, globose to pyriform 7-10 x 5-8 mm.; disc flat but rather prominent, extending over the enclosed valves (after Blakely).

This is a rare species in South Australia. No specimens were available during the preparation of the above description. It is reported to occur in the Mount Gambier district.

16. *EUCALYPTUS OBLIQUA* L'Herit. in Sert. Ang., 18, 20 (1788).

Large tree. *Mature leaves* alternate, petiolate, lanceolate, asymmetrical at base and slightly falcate. *Umbels* axillary or sometimes arranged in short racemes or panicles, peduncles terete or semiterete, 7-20 mm. long. *Buds* on long, relatively thick pedicels which pass without sharp increase in size into the calyx tube, 10-12 x 4-5 mm. with pedicel. *Operculum* hemispherical-apiculate, slightly wider than tube at junction, shorter than obconical tube. *Fruit* pyriform or ovoid, 7-9 x 7-9 mm.; disc oblique, i.e., concave, covering the short enclosed valves. In some South Australian specimens the disc is almost flat.

It occurs from the Mount Lofty Range near Adelaide to the South-East, and is also found on Kangaroo Island.

16a. *EUCALYPTUS OBLIQUA* var. *MEGACARPA* Blakely in Key to Euc., 194 (1934).

This can be distinguished from the above by its coarser buds and larger fruits, 10-12 x 10-12 mm., which are more definitely constricted at the orifice than in the typical form (pl. ii, fig. 2).

The type material of the variety, which came from Millicent, has been seen at Sydney and in the collection of Mr. J. M. Black. In other specimens, from Eight Mile Creek, in the Waite Institute Herbarium, the buds are often clavate and swollen, a malformation apparently due to some gall-forming insect.

17. *EUCALYPTUS OVATA* Labill. in Nov., Holl., pl. ii, 153 (1806).

Large tree. *Mature leaves* alternate, petiolate, lanceolate to ovate-lanceolate or ovate, 7-14 x 2-4 cm. *Umbels* axillary or on leafless portion of the branchlets, 4-8-flowered, peduncles terete or semiterete, 5-10 mm. long. *Buds* pedicellate, smooth, obconical-rostrate or clavate or like two cones attached base to base, 7-10 x 4-6 mm. *Operculum* conical, shortly acute or rostrate, shorter than or almost equal to the tube, sometimes with a sharp ridge marking the junction with the obconical tube. *Fruit* broadly obconical, 5-8 x 5-7 mm., the calycine and staminal rings forming a flat band or dark line around the outside of the rim; disc rounded, half to one mm. broad, valves short and broad in orifice (pl. iii, fig. 3).

Occurs in the Mount Lofty Range and south to Mount Gambier and to Victor Harbour. Also on Kangaroo Island.

17a. *EUCALYPTUS OVATA* var. *GRANDIFLORA* Maiden in Crit. Rev., 27, 146 (1916).

Buds (15 x 9 mm.) and fruits (10 x 13 mm.) larger than above, the former with rostrate operculum and the above mentioned ridge, the latter broadly obconical and slightly constricted below the rim.

Kalangadoo and Mount Gambier.

18. *EUCALYPTUS ELAEOPHORA* F. Muell in Fragm., iv, 52 (1864).

Medium to large-sized tree. *Mature leaves* alternate, petiolate, lanceolate to broadly lanceolate, 10-22 x 1.5-3 cm. *Umbels* axillary, sometimes in pairs, 3-7-flowered, peduncles flattened and angular, 5-12 mm. long. *Buds* sessile or sub-

sessile on thick angular base almost indistinguishable from the tube, cylindrical, more or less bicostate or angular, 8-10 x 4-6 mm. *Operculum* conical, shorter than tube. *Fruit* sessile or very shortly pedicellate, cylindrical or obconical with a thick more or less angular base, otherwise smooth, 6-9 x 6-8 mm.; disc less than 1 mm. broad, forming a narrow rim around the short broad valves which are exsert or in the orifice (pl. iii, fig. 4).

Blakely apparently had no South Australian material at Sydney except the poor specimen which was included under *E. goniocalyx*, so reference to this State was omitted on p. 146, but it was included in the list of species occurring in South Australia on p. 289.

Southern Flinders Range, Mount Lofty Range and southern parts of the State, including Kangaroo Island.

19. *EUCALYPTUS COSMOPHYLLA* E. Muell. in Trans. Vict. Inst., 1, 32 (1855).

Varying from a small mallee-like shrub to a medium-sized tree. *Mature leaves* alternate, petiolate, usually thick and coarse, lanceolate to broadly lanceolate, 10-15 x 1-4 cm. *Umbels* axillary, 1-3-flowered, peduncles very short and sometimes lacking. *Buds* obovoid, bicostate on very short flattened pedicels, 14-18 x 9-12 mm. *Operculum* conical, conical-apiculate or rostrate, shorter than or equal to tube and sometimes wider. Filaments cream or pinkish coloured. *Fruit* hemispherical, turbinate or shortly cylindrical, more or less bicostate, 10-17 x 12-18 mm., the calycine and staminal rings forming a sloping outer edge to the rim, with the steeply oblique disc lining the inside around the 4-6 short, broad but acute valves which are just below the orifice (pl. iii, fig. 5).

Blakely states that the umbels are 3-6-flowered but none with more than three flowers have been seen by the writer. Mueller's original description was "tri-floris." Neither of Mueller's variations, included by Blakely (p. 103) are sufficiently distinct to warrant separation. The figures in Critical Revision (pl. 91, fig. 4-5) show only slight deviation from the normal, and recent collecting does not indicate any real differentiation.

Occurs in the Mount Lofty Range and south to Encounter Bay and Kangaroo Island.

20. *EUCALYPTUS PIMENTINIANA* Maiden in Crit. Rev. 16, 211 (1912).

Mallee. *Mature leaves* alternate, petiolate, lanceolate to broadly lanceolate, 6-9 x 2-4 cm. *Umbels* axillary, 3-8-flowered, peduncles terete or semiterete, deflexed. *Buds* obconical or cylindrical, rostrate, pedicellate, striate, 20-30 x 10-14 mm. *Operculum* hemispherical-rostrate or conical rostrate, smooth or faintly striate. *Fruit* pedicellate, cylindrical and gradually narrowing into the pedicel, striate, disc as described below for *E. incrassata*, valves with short points, deeply enclosed (pl. iii, fig. 6).

Occurs on the eastern border of the Nullarbor Plain at Ooldea and Barton.

21. *EUCALYPTUS INCRASSATA* Labill. in Nov., Holl., pl. ii, 12, t. 150 (1806), *sensu stricto*.

Mallee. *Mature leaves* alternate, petiolate, narrow to broadly lanceolate, 6-12 x 1.5-3 cm. *Umbels* axillary, 3-7-flowered, peduncles slender, terete or semiterete and slightly angular, up to 3 cm. long. *Buds* cylindrical-obovoid to urceolate-rostrate, shortly pedicellate in the former case to long pedicellate (up to 6 mm.) in the latter, 10-18 x 5-7 mm. *Operculum*-conical to very rostrate with a more or less hooked apex, commonly somewhat wider than the calyx tube and shorter, smooth or with obscure fine wrinkles or with prominent lines but not distinctly ribbed. *Tube* obconical or constricted in the middle and very urceolate, smooth to striate with fine lines or obscure ribs. *Fruit* pedicellate or sessile, urceolate or barrel-shaped being constricted at each end, smooth or slightly wrinkled when

mature, 10-12 x 9-10 mm.; the tube wider than the disc, so that the calycine ring forms a narrow but distinct platform around the erect rather sharp disc whose outer face is formed by the old staminal ring and whose inner is oblique to almost erect; valves with subulate points due to the persistence of the base of the style, when open either in orifice or, more usually, below and enclosed (pl. ii, fig. 8-9). When immature the top of the ovary is ridged between the unopened valves. This last character is found in the remaining varieties below, and also in the members of the *dumosa* complex.

Occurs on Yorke Peninsula, in the Flinders Range, the Murray Mallee and south to the Upper South-East.

It has proved impossible to make a satisfactory demarcation between this species and *E. angulosa* Schauer., a wide range of intermediates having been collected. The specimens have therefore been grouped as follows. It is probable that these represent mere points in a series, and collectors are warned that intermediates may be found.

21a. *EUCALYPTUS INCRASSATA* var. *COSTATA* N. T. Burbidge *stat. nov.*;
E. costata Rehr. et. Muell. in *Miq. Ned. Kruidk. Archief.*, 4, 136
(1856).

A coarser form than the above. *Mature leaves* fairly thick and coriaceous. *Umbels* on slender flattened peduncles (up to 3 cm. long), which broaden below the flowers. *Buds* similar to the above, but more definitely ribbed or striate. *Operculum* as above. *Fruit* on short, more or less angular pedicels, barrel-shaped or cylindrical, marked by striations or sharp narrow ribs, 10-18 x 9-12 mm.; disc as above, valves enclosed (pl. ii, fig. 10).

This is the *E. angulosa* of various writers on South Australian ecology (10) (19). J. M. Black combines it with the following, as did Maiden. The striation or ribbing of both the bud and the fruit is far less pronounced in fresh material. The ribs are revealed on drying, due to shrinkage of the less sclerised portions. Maiden (pl. 14, fig. 2) shows a fruit rather more coarsely ribbed than the majority of specimens, but it can still be contrasted with that in his fig. 5, which is the form described below.

Occurs on Eyre and Yorke Peninsulas and Kangaroo Island; also in the Murray Mallee and the Upper South-East.

21b. *EUCALYPTUS INCRASSATA* var. *ANGULOSA* Beith. in *Fl. Aust.*, iii, 231 (1866),
pro parte; *E. angulosa* Schauer. in *Walp. Repert.*, ii, 925 (1843) *sensu*
stricto.

A very coarse form with thick lanceolate leaves. *Umbels* 2-5 flowered, peduncles thick, flattened, 10-20 mm. long. *Buds* obovate or cylindrical with short pedicels, 20-25 x 10-15 mm. *Operculum* conical or shortly rostrate, striate or ribbed, shorter but not wider than tube. *Tube* obconical or cylindrical, coarsely and deeply ribbed by projecting hard ridges which continue into the slightly flattened and ribbed pedicel. *Fruit* almost cupular to cylindrical, coarsely ribbed by the abovementioned ridges, 15-20 x 14-18 mm.; disc and valves as in other forms above (pl. ii, fig. 11).

This coarse form agrees with Maiden's illustration (pl. 14, fig. 1, 3, and 5), *i.e.*, with Western and South Australian material. In this State it is mainly found on Eyre Peninsula.

THE DUMOSA COMPLEX

This group of forms has always been a difficult one. The type of *E. dumosa* was collected by Allan Cunningham in New South Wales. Specimens in the Sydney Herbarium, collected at Wyalong, which is accepted as approximately the type locality, proved to have cylindrical buds which were smooth or almost so,

and to have a conical operculum shorter than the calyx tube. This form is rare in South Australia but occurs along the eastern border and near the Murray River. In this State most of the material classed as *E. dumosa* has buds with ribbed conical opercula. This agrees with the Western Australian species, *E. pilcata*. There are intermediates in the eastern part of the State, but on the whole the two are reasonably distinct. There is also *E. brachycalyx* with an obtuse, conical operculum which is striate rather than ribbed. On Kangaroo Island there are a number of forms. The most distinctive is *E. conglobata*, in which the buds are so sessile as to be flattened at the base and the calyx tube is wider than long. There is also *E. rugosa*, where the bud has a flattened pedicel and the tube is 2-4-ribbed.

Unfortunately, the whole group is complicated by the description of *E. anceps*. Maiden described this as a variety of *E. conglobata*, but placed it intermediate between *E. conglobata* and *E. dumosa*. It differs from the former in that the buds and fruits, though sessile, are not basally flattened and the fruits are barrel-shaped and from *E. dumosa* in a relatively shorter calyx tube and in the lack of pedicels. Compared with true *E. dumosa* this diagnosis would hold, but in practice *E. anceps* lies between *E. pilcata*, *E. rugosa* and *E. conglobata*, and as such it includes a heterogeneous collection of variations. Presence or absence of pedicels is not a good diagnostic character, and sessile buds and fruits of *E. rugosa* are difficult to place; the same applies to *E. pilcata*, and apart from individualistic variations such as these there are probably a number of hybrids and ecotypes.

Another species related to the group but more easily recognised is *E. concinna*. An effort to reduce some of the forms to varieties proved unsatisfactory and they were retained as species to avoid adding to the existing confusion.

22. *EUCALYPTUS CONGLOBATA* (R. Br.) Maiden in Crit. Rev., 6, 273 (1922).

Mallee. *Mature leaves* alternate, petiolate, thick, narrow to broad lanceolate, 5-14 x 1.5-2.5 cm. *Umbels* axillary, 3-8-flowered, peduncles short, thick, more or less angular, broadened at the top to form a receptacle. *Buds* squat, broadly ovoid, flattened at the base and closely sessile, 8-10 x 6-8 mm. *Operculum* shortly and broadly conical, obtuse or acute, smooth or slightly striate, as long as or slightly longer than tube. *Tube* shortly cylindrical, bicostate, about twice as wide as long. *Fruit* cylindrical or hemispherical, 2-3-ribbed, 5-6 x 8-10 mm.; disc narrow, valves with subulate points which project above the rim (pl. iii, fig. 7).

Eyre Peninsula and Kangaroo Island,

23. *EUCALYPTUS ANCEPS* (R. Br.) Blakely in Key to Euc., 118 (1934).

Mallee. *Juvenile leaves* opposite, sessile, slightly lobed at base as to be almost stem clasping, ovate to broadly lanceolate. *Mature leaves* alternate, petiolate, lanceolate, rather thick and rigid, 5-12 x 1.2-5 cm. *Umbels* axillary, 3-6-flowered, peduncles relatively thick, flattened or subangular, 6-12 mm. long. *Buds* sessile or almost so, cylindrical or ovoid, narrowed at both ends, 8-10 x 4-6 mm. *Operculum* conical, obtuse, acute or shortly rostrate, radiately striate, about the same length as the tube or slightly shorter. *Fruit* sessile on thickened peduncles, cylindrical to barrel shaped, striate, 7-10 x 6-8 mm.; disc narrow, valves in orifice, short but subulate (pl. iii, fig. 8).

Eyre Peninsula, Yorke Peninsula, Murray Mallee, Upper South-East and Kangaroo Island.

24. *EUCALYPTUS RUGOSA* (R. Br.) Blakely in Key to Euc., 120 (1934).

Mallee. *Mature leaves* narrow to broadly lanceolate, 5-10 x 1-2 cm. *Umbels* axillary, 3-8-flowered, peduncles stout, flattened, broadened below flowers, becoming coarser during maturation of fruits. *Buds* pyriform on short, stout, flattened,

3-4-angled pedicels, 6-7 (9-12 with pedicels) x 5-6 mm. *Operculum* hemispherical, flat-topped or very obtuse, smooth or slightly striate, a little narrower than the ribbed tube or almost equal, also shorter. *Fruit* pyriform or turbinate, ribbed with 2-4 main ribs two of which are broadened below into the flat pedicel, and sometimes with a few striations (pl. iii, fig. 10).

Eyre Peninsula, Kangaroo Island, Encounter Bay and the Upper South-East.

25. *EUCALYPTUS DUMOSA* A. Cunn. fide Schauer in Walp. Rep. Bot. Syst., 2, 925 (1843).

Mallee. *Mature leaves* alternate, petiolate, lanceolate, 6-10 x 1-2 cm. *Umbels* axillary, 4-8-flowered, peduncles comparatively stout and semiterete. *Buds* smooth, cylindrical, shortly pedicellate. 7-12 x 3-5 mm. *Operculum* hemispherical to shortly conical, minutely striate or almost smooth, much shorter than the cylindrical tube. *Fruit* cylindrical to campanulate, somewhat wrinkled or striate, shortly pedicellate, 6-10 x 5-7 mm.; disc narrow, valves with protruding subulate points (pl. iii, fig. 9).

A New South Wales species which extends to the eastern border of this State and down into the Murray Mallee.

26. *EUCALYPTUS PILEATA* Blakely in Key to Euc., 120 (1934).

Mallee. *Mature leaves* alternate, petiolate, narrow to broad lanceolate, 5.5-10 x 1-3 cm. *Umbels* axillary, 3-6-flowered, peduncles terete or semiterete, 6-15 mm. long. *Buds* pedicellate, obovoid or cylindrical, 8-14 x 4-5 mm. *Operculum* hemispherical to acutely conical, radiately striate or ribbed, sometimes wider than tube, shorter than or equal to the cylindrical or obconical or cupular tube, which is smooth or striate. *Fruit* pedicellate, cylindrical or obconical, striate or almost smooth, 7-10 x 6-8 mm.; disc narrow, valves sunken with protruding subulate points (pl. iii, fig. 11).

Eyre Peninsula, Yorke Peninsula, Murray Mallee, Encounter Bay, and Kangaroo Island.

Form a. Obovoid pedicellate buds with almost smooth operculum. No fruits available. This form seems distinct enough to warrant mention, but without fruits and further information it does not seem strong enough to make a variety. It occurs on Eyre Peninsula.

27. *EUCALYPTUS BRACHYCALYX* Blakely in Key to Euc., 119 (1934).

Mallee. *Mature leaves* alternate, petiolate, linear to narrow lanceolate, shining, 5-10 x 0.7-1.5 cm. *Umbels* axillary, 3-9-flowered, peduncles slender, slightly flattened. *Buds* ovoid-ellipsoidal, on slender pedicels, 7-9 x 4-5 mm. *Operculum* conical, obtuse, about the same size and shape as the cupular, striate tube, usually with irregular wrinkles rather than striate, commonly slightly different in colour from the tube. *Fruit* hemispherical to campanulate or turbinate, smooth or faintly striate, 6-7 x 5-6 mm.; disc narrow, less than 0.5 mm. wide; valves subulate and exsert except where the brittle points have been broken off (c.f. Blakely). (pl. iii, fig. 12).

This species could be mistaken for *E. oleosa* var. *angustifolia*, but it can be differentiated by the large obovate versatile anthers with a conspicuous gland and, in fruit, by the turbinate open capsule (not globular as in *E. oleosa*) and by the spreading rather than erect valves.

Eyre Peninsula, Flinders Range and to the east thereof along the border of the shrub steppe and mallee scrub.

27a. *EUCALYPTUS BRACHYCALYX* var. *CHINDOO* Blakely l.c.

Buds somewhat smaller than those above, 5-6 x 3-4 mm. *Operculum* striate and very obtuse, slightly longer than substrate cupular tube, also slightly narrower than tube giving a marked "egg-in-egg-cup" appearance. *Fruit* as above.

It is doubtful whether this variety is a true one. The species itself is quite distinct and may be recognised by the slender peduncles and pedicels to the umbels, the cupular calyx tube about the same size and shape as the operculum and by the narrow shining leaves. It was unfortunate that Blakely contradicted his own description of the operculum.

Distribution as above.

28. *EUCALYPTUS CONCINNA* Maiden and Blakely in Crit. Rev., 71, 49 (1929);
E. ochrophylla Maiden and Blakely in Crit. Rev., 71, 50 (1929).

Mallee. *Mature leaves* alternate, petiolate, lanceolate, broad or narrow, thick and glossy. *Umbels* axillary, 3-7-flowered. Peduncles terete or semiterete, 6-12 mm. long. *Buds* clavate, pyriform or cylindrical, 8-10 x 6-8 mm. on pedicels like the peduncles and 4-12 mm. long. *Operculum* hemispherical, very obtuse or flat-topped, about half as long as broad, more or less striate, sometimes slightly broader than tube. Stamens red (type from Victoria Desert) or pale (Cleland's specimens quoted under original description of *E. ochrophylla*). *Fruit* pyriform, almost turbinate or cylindrical, smooth or faintly striate, 6-10 x 6-10 mm.; disc about 1 mm. wide, rounded above with the dark line of the calycine ring outside, capsule slightly sunken but the subulate valves protruding and spreading or rarely coherent at top as in *E. olivosa* (pl. iii, fig. 13).

Cleland's specimens of *E. ochrophylla* show a definite variation towards *E. concinna*, and the buds cannot be separated in any particular character. The type of *E. concinna* has very long pedicels (matched among *E. ochrophylla* material) and the buds are golden-brown, whereas in *E. ochrophylla* they are greenish. The yellowish colour of the leaves in the latter species is not a reliable character.

Occurs along the transcontinental railway at Ooldea and Immana.

29. *EUCALYPTUS LEPTOPHYLLA* F. Muell. in Miq. Ned. Kruidk. Archief., 4, 123 (1856).

Mallee. *Mature leaves* alternate, petiolate, linear or narrow lanceolate, with numerous oil glands, 5-10 x 0.6-1.5 cm. *Umbels* axillary, 3-8-flowered, peduncles 5-8 mm. long, terete or semiterete. *Buds* like two more or less equal cones attached base to base, on a slightly angular pedicel as thick as the peduncle, 5-7 x 3-4 mm. *Operculum* conical, acute or obtuse, about as long as tube or shorter. *Stamens* sharply reflexed in bud and with a sharp bend in the filament when flowering. *Fruit* pedicellate, hemispherical to cupular, 4.5 x 4.5 mm.; disc forming a flat or rounded ring at the top of the fruit; valves narrow, subulate and protruding through the orifice (broken off in old fruits) (pl. iv, fig. 12).

Along the transcontinental railway at Ooldea and Tarcoola, also Eyre and Yorke Peninsulas, Flinders Range, Murray Mallee and Kangaroo Island.

30. *EUCALYPTUS UNCINATA* Turcz. Bull. Soc. Nat. Mosc., 22, 23 (1849).

Very close to the preceding species but buds and fruits somewhat coarser. The chief difference is in the bud, which is sessile or on a short thick pedicel indistinguishable from the tube. *Operculum* conical, obtuse and shorter than the obconical or cylindrical tube 6-8 x 3-4 mm. *Fruit* sessile or almost so, pyriform or barrel-shaped, 5-6 x 4-5 mm. (pl. iv, fig. 13).

These two species were united under the latter name by Bentham in the Flora Australiensis, but were separated by Maiden. It would be difficult to separate them without buds, though the slender pedicels and yellow-red branchlets in *E. leptophylla* are characteristic.

Eyre Peninsula seems to mark the eastern limit of this Western Australian species.

31. *EUCALYPTUS CNEORIFOLIA* DC., Prodr., 3, 220 (1828).

Mallee. *Mature leaves* alternate, petiolate, narrow linear to linear lanceolate, 5-11 x 0.4-1 cm. *Umbels* axillary, 6-15-flowered, peduncles short. *Buds* cylindrical, shortly pedicellate or sessile, 7-12 x 3-5 mm. *Operculum* smooth, cylindrical to conical, obtuse, about the same length and shape as the tube. *Fruit* shortly pedicellate or sessile in densely packed semiglobular clusters, hemispherical, 5-6 x 7-8 mm.; disc flat, about 1 mm. broad, around the partially exsert, subulate but short valves.

Kangaroo Island and Encounter Bay.

32. *EUCALYPTUS GILLII* Maiden in Crit. Rev., 15, 177 (1912).

Glaucous mallee. *Mature leaves* opposite or almost so, glaucous, sessile or shortly pedicellate, ovate, oblong or shortly lanceolate, 4-6 x 1-2.5 cm. *Umbels* axillary, glaucous, 4-9-flowered, peduncles semiterete, slender. *Buds* glaucous, ovoid or cylindrical-rostrate, pedicellate, 8-15 x 4-7 mm. *Operculum* conical, acuminate or rostrate, longer than the cylindrical tube. *Fruit* ovoid or globular, pedicellate, 5-8 x 5-8 mm.; disc very small, valves exsert. long and subulate but usually broken off short.

Northern Flinders Ranges.

32a. *EUCALYPTUS GILLII* var. *PETIOLARIS* Maiden in Jour. Roy. Soc. N.S.W., 53, 59 (1919).

Differs from the above only in that the leaves are definitely petiolate (up to 1 cm.) and broadly lanceolate. It is doubtful whether this form is worth retaining as a variety.

The type came from Wirrahara, but other specimens from the northern Flinders Range have been seen.

33. *EUCALYPTUS OLEOSA* F. Muell. in Miq. Ned. Kruidk. Archief., 4, 128 (1856), *sensu stricto*.

Mallee or small tree. *Mature leaves* alternate, petiolate, narrow lanceolate, usually glossy, 5-10 x 1-2 cm. *Umbels* axillary, 5-14-flowered, peduncles semiterete. *Buds* pedicellate, ovoid or cylindrical. *Operculum* conical, longer than cupular or semiglobular tube. *Fruit* pedicellate, globular or clavate 5-9 x 5-9 mm.; disc narrow, valves thin, long and subulate, very exsert. coherent at the apex but breaking easily and hence often lacking from specimens (pl. iv, fig. 4).

A photograph and some fragments of the type material have been obtained through the courtesy of Dr. F. P. Jonker of the herbarium of the State University at Utrecht, Holland. It is mixed *E. uncinata* Turcz. (buds and flowers) and *E. oleosa* F. Muell (immature fruits). The latter, which is regarded as the true type, was, according to the Melbourne Herbarium authorities, collected from the Murray Mallee. When inquiries concerning the type were first made it was hoped that the specimen would show the shape of the operculum, since this feature is variable and has been the basis of differentiation in several varieties. Unfortunately, this is still unsettled. It is believed, however, that the specific name was associated with a form having a conical operculum, since Mueller's species, *E. sociilis*, published in the same paper, has a rostrate one.

(One of the most important and widespread mallee species, as can be seen by reference to Wood's vegetation map (10).

33a. *EUCALYPTUS OLEOSA* var. *PEENERI* Blakely in Key to Euc., 270 (1934).

Leaves, branchlets, buds and fruits more or less ashy-grey. *Leaves* oblong to oblong lanceolate. *Operculum* obtusely conical, twice as long as cupular tube.

This may not be a good variety. Blakely founded it on material from Ooldea, and specimens probably belonging to it have been received from Eyre Peninsula and Kangaroo Island.

- 33b. *EUCALYPTUS OLEOSA* var. *GLAUCA* Maiden in Jour. W. Aust. Nat. Hist. Soc., 3, 171 (1911); *E. socialis* F. Muell. in Miq. Ned. Kruidk. Archief., 4, 132 (1856); *E. transcontinentalis* Maiden in Jour. Roy. Soc. N.S.W., 53, 58 (1919).

Leaves lanceolate to broad lanceolate, usually dull or subglaucous. *Buds* cylindrical- or urceolate-rostrate. *Operculum* rostrate and longer than cylindrical or urceolate tube. *Fruit* narrowed into orifice and sometimes with a tendency to be urceolate (pl. iv, fig. 1).

The nomenclature of this form was confused by Maiden. In Crit. Rev., 15, 167, he redescribed var. *glauca* and listed *E. socialis* F. Muell. as a synonym. Later he quotes his description of *E. transcontinentalis* (Crit. Rev., 34, 268) with *E. oleosa* var. *glauca* as a synonym, but there is no mention of *E. socialis*. South Australian material matched with Maiden's specimens in Sydney is identical with the type of *E. socialis* from Mueller's material in the Melbourne herbarium. It does not seem to be distinct enough for specific rank and forms a link between *E. oleosa* and *E. Flucktoniae*. It would appear that Blakely's description of *E. socialis* was superfluous.

This form occurs from the Nullarbor Plains eastwards across Eyre and Yorke Peninsulas, along the Flinders Range to the north and also east to the Murray Mallee, the Victorian border and Kangaroo Island.

- 33c. *EUCALYPTUS OLEOSA* var. *ANGUSTIFOLIA* Maiden in Crit. Rev., 39, 278 (1919).

Leaves narrow to broad lanceolate, usually glossy. *Buds* pedicellate, cylindrical or ovate. *Operculum* crumpled or wrinkled on the surface, conical or cylindrical, very obtuse or flat-topped, different in colour from the tube. *Fruit* globular (pl. iv, fig. 2).

When Maiden described this variety he gave *E. socialis* F. Muell. as a synonym and figured (Crit. Rev., pl. 65, fig. 17 a-b) a Murray River specimen collected by Mueller. This specimen is referred to as "the type," and then as "a reputed type specimen from Mueller," but it is not clear whether he means it as a type of *E. socialis* or of his var. *angustifolia*. There is, however, no mention of such a specimen under the original description of *E. socialis*, so that *E. socialis* is not a synonym of this variety. Blakely gave Mueller's species full ranking, but retained *E. oleosa* var. *angustifolia* and quoted a specimen from Pinnaaroo, collected by J. M. Black, as the type.

Subsequent to the publication of the Key, Blakely appears to have decided that *E. oleosa* var. *angustifolia* should be given specific rank. There is a large amount of material in the Sydney Herbarium which he separated out under the name *E. lamprophylla*. This includes Black's Pinnaaroo specimen. The species was never published, it is a distinct variety but, without the characteristic buds, difficult to separate from the rest of *E. oleosa*. Since there is doubt concerning the bud shape in the original *E. oleosa*, specific ranking for this form would hardly be advisable. Mueller's specimen, mentioned by Maiden, is presumably the type.

Distribution is the same as for *E. oleosa sensu stricto*. It is particularly common on Eyre Peninsula and Kangaroo Island.

34. *EUCALYPTUS FLUCKTONIAE* Maiden in Jour. Roy. Soc. N.S.W., 49, 316 (1915).

Mallee or small tree. *Mature leaves* alternate, petiolate, lanceolate, 6-12 x 1.5-2.5 cm. *Umbels* axillary, 3-7-flowered, peduncles semiterete, broadened at top but not flattened. *Buds* urceolate-rostrate, pedicellate, 12-17 x 5-8 mm. *Operculum* with broad base, hemispherical or conical and with a long beak,

up to twice as long as the urceolate tube and broader at the junction. *Fruit* urceolate, broad at base and constricted below the wide orifice; disc narrow, valves as in *E. oleosa* but very brittle and usually broken off and hence appearing enclosed, 8-10 x 7-9 mm.; pedicels angular (pl. iv, fig. 3).

This species forms a link between *E. oleosa* and the Western Australian species *E. torquata*. It occurs from the Nullarbor Plain across Eyre and Yorke Peninsulas.

35. *EUCALYPTUS CALYCOGONA* Turcz. in Bull. Phys. Math. Acad. Petersb., 10, 338 (1852).

Mallee. *Mature leaves* alternate, petiolate, linear to lanceolate, 5-10 x 0.7-2 cm. *Umbels* axillary, 3-7-flowered, peduncles slender, terete or semiterete. *Buds* clavate, quadrangular, pedicellate, 6-10 x 4-6 mm.; with numerous oil glands. *Operculum* shortly conical, obtuse, acute or apiculate, not angular, shorter than the angular tube. *Fruit* cylindrical or urceolate, quadrangular but less sharply so than when in flower, smooth, pedicellate, 8-12 x 5-6 mm.; disc lining the top of the tube and obscured by the narrow persistent staminal ring; valves small and deeply enclosed (pl. iii, fig. 15).

Eyre and Yorke Peninsula, Murray Mallee and upper South-East.

- 35a. *EUCALYPTUS CALYCOGONA* var. *STAFFORDII* Blakely in Key to Euc., 265 (1934).

A coarser form than the above. *Mature leaves* lanceolate to broadly lanceolate, thick, 6-12 x 1.5-2.5 cm. *Umbels* as above. *Buds* 15 x 5-6 mm., including the pedicel, shape as above. *Operculum* conical acute, apex angular. *Stamens* white or pink. *Fruit* 14-16 x 7-9 mm.

Eyre Peninsula and, according to Blakely, also near Encounter Bay.

36. *EUCALYPTUS GRACILIS* F. Muell. in Trans. Vict. Inst., 1, 35 (1855).

Mallee or medium-sized tree. *Mature leaves* alternate, petiolate, narrow linear to lanceolate, oil glands conspicuous as black dots, 4-9 x 0.6-1.5 cm. *Umbels* axillary, 4-12-flowered, peduncles terete or semiterete. *Buds* clavate (with pedicel), not angular, with numerous oil glands, pedicellate, 3-5 x 4-5 mm. (pedicel about 3 mm.). *Operculum* hemispherical or patelliform, obtuse or apiculate, shorter than the obconical tube. *Fruit* ovoid to pyriform, smooth, pedicellate, 5-6 x 3-5 mm.; disc lining the top of the tube or oblique, the rim formed by the narrow ridge of the staminal ring; valves short and broad, enclosed or very near the orifice (pl. iii, fig. 14).

Eyre and Yorke Peninsulas, Flinders Range and south to the Clare hills, Murray Mallee and upper South-East.

- 36a. *EUCALYPTUS GRACILIS* var. *ERECTA* Blakely in Key to Euc., 266 (1934).

Leaves erect, narrow linear, shining, oil glands very numerous. This appears to be a dry country form. It is possible that it is not a very definite variety.

Eyre Peninsula, Murray Mallee and the northern edge of the mallee scrub.

37. *EUCALYPTUS INTERTEXTA* R. T. Baker in Proc. Linn. Soc. N.S.W., 25, 308 (1900).

Small to fairly large tree. *Mature leaves* alternate, petiolate, linear to lanceolate, 7-12 x 0.7-2 cm., bluish or subglaucous. *Umbels* in terminal or subterminal panicles or rarely solitary in upper axils, 4-6-flowered, peduncles slender, terete or semiterete. *Buds* obovoid, clavate on slender, subangular pedicels, 5-7 x 3-5 mm. *Operculum* conical, acute, somewhat narrower than the tube and shorter. *Tube* obconical and sometimes slightly constricted in to the orifice, with one or two lines continuous with the angles on the pedicels. *Fruit* obovoid or pyriform,

pedicellate 6-8 x 5-7 mm.; orifice contracted, (the persistent staminal ring commonly hiding the narrow disc; valves short, enclosed or near orifice (pl. iv, fig. 14).

Everard and Birksgate Ranges and south-eastwards to the Flinders Range, also west of Port Augusta.

37a. *EUCALYPTUS INTERTEXTA* var. *FRUTICOSA* Blakely and Jacobs in Key to Euc., 168 (1934).

Mallee. *Mature leaves* as above but rarely dull and bluish, more usually shining and yellowish-green when dried. *Umbels* as above. *Operculum* shortly conical and sometimes apiculate, due to the point on the thin pre-operculum which persists till or almost until flowering. *Fruit* as above.

This form is found on rock slopes in arid country, whereas the typical form occurs low on the slopes adjacent to creeks bordered by *E. camaldulensis*. It was based on a Northern Territory specimen but extends down to the northern Flinders Range around Hawker and Quorn.

38. *EUCALYPTUS COOLABAH* Blakely and Jacobs in Key to Euc., 245 (1934).

Tree. *Mature leaves* alternate, petiolate, narrow to broad lanceolate, 7-15 x 1-3 cm. *Umbels* in short terminal or subterminal panicles, 3-6-flowered, peduncles slender, subangular. *Buds* ovoid, pedicellate, 3-5 x 3-4 mm. *Operculum* conical, acute or apiculate, about the same length as tube or slightly longer. *Fruit* hemispherical or broadly turbinate, 3-4 x 4-5 mm., the rim of the tube thin and fragile with very thin disc; valves short, broad, obtuse, exsert and more or less incurved.

The South Australian material of this species was formerly placed with *E. microtheca* F. Muell. The differences between the two appear to be slight. It occurs in the northern parts of the State near Lake Eyre and the northern Flinders Range.

39. *EUCALYPTUS LEUCOXYLON* F. Muell. in Trans. Vict. Inst., 1, 33 (1855), *sensu stricto*.

Small or medium-sized tree. *Mature leaves* alternate, petiolate, narrow to broad lanceolate, 7-15 x 1-3 cm. *Umbels* axillary or lateral on leafless portions of branchlets or in short panicles, 3-flowered (except variety), peduncles terete or semiterete. *Buds* clavate, ovoid or cylindrical-rostrate, wrinkled when dry, pedicels normally long and flattened and angular above as they pass into the calyx tube, sometimes short and semiterete. *Operculum* conical, acute or rostrate with a sometimes angular point, as long as or longer than the obconical or turbinate tube. *Stamens* with translucent oil glands in the filaments, especially the outer anantherous ones. *Staminal ring* 1-2 mm. wide, conspicuous when the stamens fall, hiding the oblique disc, deciduous during the maturation of the fruit or remaining attached to one side of the rim. *Fruit* pyriform, ovoid or subglobular, on long terete or semiterete pedicels (except in short pedicelled forms); disc oblique but not covering the short broad enclosed valves. In the typical form the buds are 8-13 x 6-7 mm. and the fruits 10-15 x 8-13 mm. (pl. ii, fig. 7). This occurs in the southern Flinders Range, Mount Lofty Range, Murray lands and in the South-East and on Kangaroo Island.

This species shows considerable variation and a large number of forms have been named. Both red- and white-flowered individuals occur, but are not restricted to any particular variety. Some plants are glaucous, but not reliably so. Many of the forms seem to grade into one another, but despite this the following varieties are included.

39a. *EUCALYPTUS LEUCOXYLON* var. *MACROCARPA* J. E. Brown in For. Fl. S. Aust. (1882; *E. leucoxylon* var. *erythronema* F. Muell. in Miq. Ned Kruidk. Archief., 4, 127 (1856).

Buds 16-20 x 10 mm., pedicels very angular. Operculum rostrate. Fruit, 15-22 x 15-18 mm. (pl. ii, fig. 6).

There seems to be some room for doubt concerning the legitimacy of Brown's name. Maiden (Crit. Rev., 21, 91) accepts it because the variety includes both red- and white-flowered forms. This point had been mentioned in Brown's description, where it is stated that "we have ventured to apply the name *macrocarpa* . . . as being more directly specific, and, in order to individuate them from the red-flowering sports of the true representative of the species *Leucoxylon*." This latter fact is the more important as it means that Mueller's description is definitely inadequate, being "filamentis sanguineis." According to Maiden (l.c.) and Brown there is no doubt as to the synonymy of the two names. Maiden and Blakely have been followed in this paper because: (i) Mueller's description is inadequate; (ii) the wide variation within the species means that varietal names represent little more than arbitrary points in a series; and (iii) so little can be gained in this case by a strict application of the rules of priority. To waive Mueller's description because it is not diagnostic is an admittedly risky procedure, since what constitutes an adequate description has never been definitely stated and the great majority of the early descriptions leave much to be desired. However, in this case an argument can be made for either name, and therefore the status quo has been maintained.

The variety was based on specimens from Eyre Peninsula. It also occurs in the Mount Lofty Range and on Kangaroo Island. Intermediates occur in the Flinders and Mount Lofty Ranges.

39b. *EUCALYPTUS LEUCOXYLON* var. *ANGULATA* Benth. in Fl. Austral., 3, 210 (1866).

The relation between this variety, the preceding and var. *rugulosa* F. Muell. is not clear (c.f. Crit. Rev., 12, 91). Benthani's description states that the calyx tube is distinctly angled. In most large-flowered forms the pedicel is flattened as it passes into the tube and the two ribs thus formed, with two smaller ones between, pass upwards to be lost in the upper part of the tube. Blakely states that the fruits in this variety, which is not known to the writer, are subangular. In all material available the fruits are rounded, any angularity having been lost during maturation. Maiden considered (l.c.) var. *angulata* was not the same as var. *macrocarpa*, but gives no grounds for his opinion. Further collecting may elucidate this point, but the variety does not seem to be a sound one. It is reported to have come from the Mount Lofty Range.

39c. *EUCALYPTUS LEUCOXYLON* var. *PAUPERITA* J. E. Brown in For. Fl. S. Aust. (1882); *E. jugalis* Naudin in Second Mem., 37 (1891).

Umbels three or more flowered. Buds ovoid or pyriform, peduncles and pedicels shorter than in above varieties, 5-7 x 3-5 mm. Operculum conical or conical-apiculate rather than rostrate. Fruit globular turbinate to hemispherical, 6-7 x 6-8 mm., relatively wider and shallower than in other varieties (pl. ii, fig. 4-5).

This form does not seem to be sufficiently distinct to warrant specific rank. Some specimens are distinctive with more than three flowers per umbel and short pedicelled pyriform buds, but these grade into normal but small fruited forms of *E. leucoxylon*.

Mueller's original description of *E. leucoxylon* stated "tri-raro-quinque-floris." This referred to his variety *pluriflora* which, as stated by Maiden, is *E. calcicultrix* F. Muell.

From Clare north into the Flinders Range, also in the Mount Lofty Range and on Eyre Peninsula.

40. *EUCALYPTUS CALCICULTRIX* F. Muell. in *Miq. Ned. Kruidk. Archief.*, 4, 129 (1856).

Mallee or small tree. *Mature leaves* alternate, petiolate, lanceolate to broad lanceolate, the marginal nerve usually distant. *Umbels* axillary or clustered on leafless portions of the branchlets, 3-7-flowered, peduncles semiterete, 4-8 mm. long. *Buds* clavate on more or less angular pedicels 5-7 x 4-5 mm., the surface crumpled or wrinkled like that of a withered and shrunken apple. *Operculum* conical, acute or obtuse, slightly shorter than the tube. *Fruit* pedicellate, sometimes shortly so, pyriform or truncate-obovoid, 5-8 x 5-8 mm.; disc narrow, very oblique or lining the top of the tube, valves short and enclosed but not so deeply so as in *E. odorata* (pl. i, fig. 7).

E. calcicultrix occupies a position between *E. odorata* and the small fruited forms of *E. leucoxyton*, and it is significant that, while based on Mueller's *E. odorata* var. *calcicultrix*, it also includes his *E. leucoxyton* var. *pluriflora*. The species is a well-marked one and can be distinguished by the characteristic wrinkling or crumpling of the surface of the buds when dry, the usual retention of a staminal ring during the maturation of the fruit and by the marginal nerve of the lanceolate leaf being distant from the edge. Blakely's var. *porosa* based on *E. porosa* F. Muell. illustrates the tendency towards *E. leucoxyton* and does not warrant separation. Var. *obscura* appears to have been well named. There are two specimens in the Sydney Herbarium named *E. calcicultrix* var. *obscura*. Both were collected by Maiden at Bundaleer Forest, March 1897. One specimen is *E. fruticetorum*, which as stated below is *E. odorata* var. *angustifolia*, and this is also represented in the Melbourne Herbarium. The other appears to be that referred to as having "the general facies of *E. fasciculosa*" (Key to Euc., 225). This latter specimen probably belongs with *E. hemiphloia* var. *microcarpa*.

Eyre Peninsula, Yorke Peninsula, Flinders Range, Adelaide Plains, and Murray Mallee.

THE ODORATA COMPLEX

This, like the *dumosa* complex, has been the centre of considerable confusion and the arrangement in the Key to the Eucalypts is unfortunate. The true situation appears to be as follows: *E. odorata*, for which *E. cajuputea* F. Muell. is a synonym, is the tree form which is found around Adelaide and which becomes mallee-like as it goes north to Mount Remarkable and south to Encounter Bay. *E. odorata* var. *angustifolia* is synonymous with *E. fruticetorum* F. Muell. which is not distinct enough to warrant specific ranking. It appears to link *E. odorata* with the very narrow-leaved *E. viridis* R. T. Baker. The type specimen of Mueller's *E. odorata* var. *erythrandra* has been seen. As pointed out, in a private communication by a Melbourne authority, it is the same as *E. Lansdowneana* F. Muell. and J. E. Brown. The latter is a distinct species, having normally sessile and coarser buds and fruits in short panicles or clustered umbels. Blakely's description of this variety is erroneous and appears to have been based on a red-flowered specimen of *E. odorata*. In the type specimens of *E. odorata* (from Light's Pass) and of *E. cajuputea* (from the Flinders Range) the filaments appear to have been red, though it is not always easy to be certain of this character when dealing with dried material. These specimens are in the Melbourne Herbarium and have been seen. Blakely's *E. odorata* var. *refracta* (Key to Euc. 226) is an abnormality. Similar reflexed stamens have been observed in flowers of other species. Usually only some of the flowers on a branch are affected. This variety cannot be retained. Var. *macrocarpa* (l.c.) is *E. Lansdowneana*.

41. *EUCALYPTUS LANSDOWNEANA* F. Muell. and J. E. Brown in *For. Fl., S. Aust.*, pt. ix (1890). *E. odorata* var. *erythrandra* F. Muell. in *Miq. Ned. Kruidk. Archief.*, 4, 129 (1856).

Mallee. *Mature leaves* alternate, petiolate, thicker and coarser than those of *E. odorata*, lanceolate to broad lanceolate, 8-13 x 1-3.5 cm. *Umbels* always clustered and usually in short panicles or the umbels grouped close together on a leafless portion of the stem, 3-8-flowered, peduncles semiterete. *Buds* sessile or on short thick angular pedicels difficult to distinguish from the obconical and somewhat angular tube. *Operculum* conical, acute or obtuse, shorter than tube. *Fruit* sessile or shortly pedicellate, cylindrical or barrel-shaped, striate or bicostate, 8-10 x 7-9 mm.; disc very narrow, lining the top of the tube, valves short, deeply enclosed (pl. iv, fig. 8).

Southern Eyre Peninsula and Kangaroo Island.

42. *EUCALYPTUS ODORATA* Behr and Schlecht. in *Linnaea*, 20, 547 and 567 (1847), *sensu stricto*; *E. cajuput* F. Muell. in *Miq. Ned Kruidk. Archief.*, 4, 126 (1856).

Tree or mallee. *Mature leaves* alternate, petiolate, narrow to broad lanceolate (narrow in mallee forms), 6-14 x 1-2.5 cm. *Umbels* axillary or clustered on leafless portions of the branchlets, peduncles semiterete, 8-15 mm. long. *Buds* on angular pedicels 2-7 mm. long and passing without abrupt change into the slightly angular obconical tube, 6-8 x 3-5 mm.; disc lining the top of the tube, the rim thin, valves deeply enclosed, short (pl. iv, fig. 5).

Eyre and Yorke Peninsulas, southern Flinders Range, Adelaide Plains, Mount Lofty Range and south to Encounter Bay, Kangaroo Island and Murray Mallee.

- 42a. *EUCALYPTUS ODORATA* var. *ANGUSTIFOLIA* Blakely in *Key to Euc.*, 226 (1934); *E. fruticetorum* F. Muell. in *Miq. Ned. Kruidk. Archief.*, 4, 131 (1856).

Mallee. *Mature leaves* alternate, petiolate, narrow lanceolate, 5-14 x 0.5-1.5 cm., surface dull and subglaucous, especially when young though older leaves are like those of the above. *Buds* shortly pedicellate, smaller than in the above but subglaucous though similar in shape. *Fruit* turbinate, cupular or pyriform with striations running down into the short angular pedicel (pl. iv, fig. 6).

Port Lincoln, central Flinders Range between Quorn and Wirrabara.

43. *EUCALYPTUS VIRIDIS* R. T. Baker, in *Proc. Linn. Soc. N.S.W.*, 25, 316 (1900).

Mallee or small poorly-shaped tree. *Mature leaves* alternate, petiolate, very narrow, linear, 6-16 x 0.3-0.5 cm. *Umbels* axillary, 3-8-flowered, peduncles semiterete, 5-7 mm. long. *Buds* cylindrical or ovate, on short pedicels, 5-7 x 3-5 mm. *Operculum* shortly conical, smooth or slightly striate but not pinched in to form an angular point, as long as the tube which is cylindrical and which passes into the pedicel more abruptly than in any other members of the *odorata* complex. *Fruit* pedicellate, hemispherical to semi-globular, 4-6 x 4-5 mm.; disc very narrow and lining the rim, valves short and enclosed (pl. iv, fig. 7).

Flinders Range near Horrocks Pass and Quorn.

44. *EUCALYPTUS HEMIPHILLOIA* F. Muell. ex Benth. in *Fl. Austral.*, 3, 216 (1866), *sensu stricto*.

Tree. *Mature leaves* alternate, petiolate, lanceolate to broadly lanceolate, 7-14 x 1-3.5 cm. *Umbels* in panicles or in panicle-like groups on leafless portions of the branchlets, 4-8-flowered. *Buds* cylindrical-clavate, pedicellate, 7-10 x 5-6 mm., pedicels subangular and sometimes the striations pass up on to the tube. *Operculum* conical, smooth, acute or pointed, about as long as tube or shorter. *Fruit* pyriform urceolate or cylindrical, pedicellate, constricted at the orifice, 6-8 x 4-6 mm.; disc small and oblique or lining the top of the tube, the old staminal ring forming a narrow rim to the orifice; valves deeply enclosed (pl. iv, fig. 10).

Maiden notes (Crit. Rev., 11, 14) that Mueller in his Census gave *Fragm.* ii, 62 (1860-61) as the reference for the description of this species. However, the remarks in this volume of the *Fragmenta* hardly constitute a real description, and Blakely was right in giving the reference as above. On the other hand, Blakely gives *E. albens* Miq. in *Ned. Kruidk. Archief.*, 4, 138 (1856), despite the fact that Mueller in the *Eucalyptographia* (also quoted by Maiden) points out that the name, which was a misprint for *E. pallens* DC., was given without diagnosis, hence the correct reference should be *E. albens* Miq. ex Benth., *Fl. Aust.*, 3, 219 (1866). Blakely accepted *E. hemiphloia*, *E. albens* and *E. microcarpa* as distinct species, but the writer is in agreement with Maiden when he considered the last two to be varieties of the first, a decision he later revised. As noted by Blakely (*Key to Euc.*, 236), "in Victoria it (*i.e.*, *E. microcarpa*) seems to pass gradually into the typical form (*i.e.*, *E. hemiphloia*)." This is typical of the problem facing the student of the genus. Specimens which appear absolutely distinct are found on more extensive collecting to grade into one another. *E. albens* differs in its usually larger buds and fruits and in the glaucousness of the leaves, branchlets, buds and fruits. In no species of *Eucalyptus* does glaucousness prove to be a reliable character, and a study of the dimensions given for *E. hemiphloia* and *E. albens* in the *Key* and by Maiden (Crit. Rev., 58, 443) will show that there is a certain overlapping.

Southern Flinders Range between Laura and Mount Remarkable.

- 44a. *EUCALYPTUS HEMIPHLOIA* var. *MICROCARPA* Maiden in Crit. Rev., 47, 207 (1921); *E. microcarpa* Maiden in Crit. Rev., 58, 483 (1923).

Differs from the above mainly in its smaller buds and fruits which are pedicellate to sessile. *Buds* 6-7 x 3-4 mm. *Operculum* has an angular tip (also seen in species of the *odorata* complex). *Tube* subangular. *Fruit* cylindrical or slightly smaller at each end. 4-7 x 4-5 mm. (pl. iv, fig. 11).

Distribution as above.

- 44b. *EUCALYPTUS HEMIPHLOIA* var. *ALBENS* F. Muell. ex Maiden in Crit. Rev., 11, 20 (1914); *E. albens* Miq. ex Benth. in *Fl. Aust.*, 3, 219 (1866).

Differs from the typical form in being glaucous on all parts and in the usually larger buds and fruits. Blakely gives the following dimensions; *Buds* 10-15 x 5-8 mm. *Fruit* 9-12 x 8-10 mm. In most of the South Australian material these organs are smaller but still larger than the dimensions for *E. hemiphloia sensu stricto* (pl. iv, fig. 9).

Distribution as above.

45. *EUCALYPTUS LARGIFLORENS* F. Muell. in *Trans. Vict. Inst.*, 1, 54 (1855); *E. bicolor* (A. Cunn.) Hooker in *Mitchell's Jour. Trop. Aust.*, 390 (1848).

Tree. *Mature leaves* alternate, petiolate, lanceolate, surface dull and faintly bluish, 7-13 x 1-2 cm. *Umbels* in axillary or terminal panicles, 3-8-flowered, peduncles slender. *Buds* obovoid or clavate on slender pedicels, 3-5 x 2-3 mm. *Operculum* hemispherical or almost conical, shorter than tube. *Fruit* cylindrical or pyriform, the orifice slightly constricted, pedicellate, 3-4 x 3-4 mm.; disc very narrow, valves enclosed and short.

Along the River Murray. Also occasionally in the Flinders Range.

46. *EUCALYPTUS BEHRIANA* F. Muell. in *Trans. Vict. Inst.*, 1, 34 (1855).

Mallee or small tree. *Mature leaves* alternate, petiolate, ovate or broadly lanceolate, 7-12 x 1.5-5.5 cm. *Umbels* 3-6-flowered, in terminal panicles which may be open or short and compact. *Buds* sessile, cylindrical to obovoid, 5-6 x 2-3 mm. *Operculum* hemispherical or shortly and obtusely conical. *Fruit* sessile or almost

so, hemispherical or obovoid, 3-5 x 3-5 mm.: disc narrow, valves short, enclosed or just below the orifice.

Blakely gives 5-7 mm. as the length of the fruit, but none as large are present in South Australian specimens. Maiden figures (Crit. Rev., pl. 48, fig. 6) some larger fruits, but the disc is quite different from that in other material of the species and the identity is therefore in doubt.

Eyre Peninsula, southern Flinders Range, Murray Desert and Kangaroo Island.

47. *EUCALYPTUS FASCICULOSA* F. Muell. in Trans. Vict. Inst., 1, 34 (1855).

Medium-sized tree. *Mature leaves* alternate, petiolate, lanceolate to broadly lanceolate, 8-18 x 1.5-3.5 cm. *Umbels* in axillary or terminal panicles. *Buds* clavate on subangular pedicels, 4-6 x 3-4 mm. (pedicels 3-5 mm. long), usually with numerous oil glands. *Operculum* shortly conical and narrower than top of tube. *Fruit* pedicellate, obconical, cylindrical or pyriform with a thin rim lined by the disc, valves short and enclosed (pl. i, fig. 6).

Mount Lofty Range to Encounter Bay, Murray Bridge, Upper South-East.

48. *EUCALYPTUS CLADOCALYX* F. Muell. in Linnaea, 15, 388 (1852).

Small to medium-sized tree. *Mature leaves* alternate, petiolate, lanceolate to broadly lanceolate, 8-14 x 1.5-3 cm. *Umbels* clustered on leafless portions of the stems or in panicles, peduncles terete. *Buds* cylindrical, urceolate, pedicellate, 10 x 4-6 mm. *Operculum* hemispherical, apiculate, much shorter than tube but sometimes a little wider, 3 x 4-6 mm. *Fruit* ovoid or cylindrical-urceolate, having a constricted orifice, almost smooth or becoming rugose or costate on drying, 10-15 x 5-10 mm.; disc forming a narrow rim, valves deeply enclosed (pl. i, fig. 5).

Eyre Peninsula, southern Flinders Range and Kangaroo Island.

49. *EUCALYPTUS GAMOPHYLLA* F. Muell. in Fragm., xi, 40 (1878).

Glaucous mallee. *Mature leaves* opposite, sessile or amplexicaule, orbicular, lanceolate or cuneate when the pairs are joined, 5-8 x 1-2 cm. *Umbels* poorly formed, singly or in short panicles, in the upper axils or terminal. Individual umbels with few flowers. *Buds* clavate or pyriform, pedicellate, 5-7 x 4-6 mm. *Operculum* hemispherical, much shorter than the obconical or pyriform tube. *Fruit* campanulate, pyriform to almost urceolate, 8-11 x 6-8 mm.; rim sharp around the narrow oblique disc, valves short, broad and triangular, near orifice or enclosed.

Blakely states that this is a very glaucous species, but our material was only just glaucous. This character is never very dependable.

Near the north-western corner of the State.

SPECIES NOT INCLUDED IN THE KEY

There is a group of tropical species which is known to extend into South Australia. Material of these is by no means satisfactory, since buds, fruits and leaves are rarely included on the same specimen and notes regarding habit and bark character are usually lacking. Consequently there is a certain doubt concerning the true identity of the specimens, and the species have, therefore, been omitted from the key. However, an account of the South Australian Eucalypts would be incomplete without some reference to them.

In his Flora of South Australia, Black includes *E. pyrophora* Benth. and *E. terminalis* F. Muell. (p. 420), and in his additional notes (p. 694) it is stated that the White Wash Gum of Central Australia is *E. papuana* F. Muell., not *E. terminalis* F. Muell. In a later paper, by J. B. Cleland, for which Black identified the plants (6), there is a reference to *E. dichromophloia* F. Muell., which has

been recorded for the Mann and Musgrave Ranges by Black (3), and, in the same journal, a paper by Blakely (4) describes *E. papuana* var. *aparrerinja*. In the Key, Blakely lists *E. ferruginea* F. Muell. as South Australian but gives a Central Australian locality.

All these species come in the Corymbosae and all belong to the Macantherae. Without adequate material and field notes it is difficult to distinguish between some of them. Until further collecting is done it will be difficult to decide which of them should be recorded for this State.

Another species of interest is *E. gongylocarpa* Blakely (4), for which one South Australian specimen is recorded with the type description. This came from "25 miles S.S.W. of Mount Watson," but consists of leaves only and, in Blakely's opinion, represents the juvenile state of the species. This requires checking. *E. trivalva* Blakely, l.c., and *E. orbifolia* F. Muell. (4) (7) may also occur in this State.

E. Kalangadoensis Maiden and Blakely is described as a probable hybrid. The type material appears to represent an unusually large form of *E. viminalis* var. *Huberiana*. Further collecting may determine the status of this form.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the financial assistance given by the authorities of the University of Adelaide, which made possible a visit to the important collections in the National Herbaria at Melbourne and Sydney. Reference must also be made to the helpful co-operation of the staffs of these institutions, both during the visits and at other times.

Mr. J. M. Black and Professor J. B. Cleland kindly lent their valuable collections, which include a number of type and other important specimens. The Eucalypts among the specimens of the Tate and the Elder Exploring Expedition Collections were also consulted in the Herbarium of the Botany Department of the University of Adelaide.

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Frequent reference is also made to Blakely's "Key to the Eucalypts" and to Maiden's "Critical Revision of the Genus *Eucalyptus*."

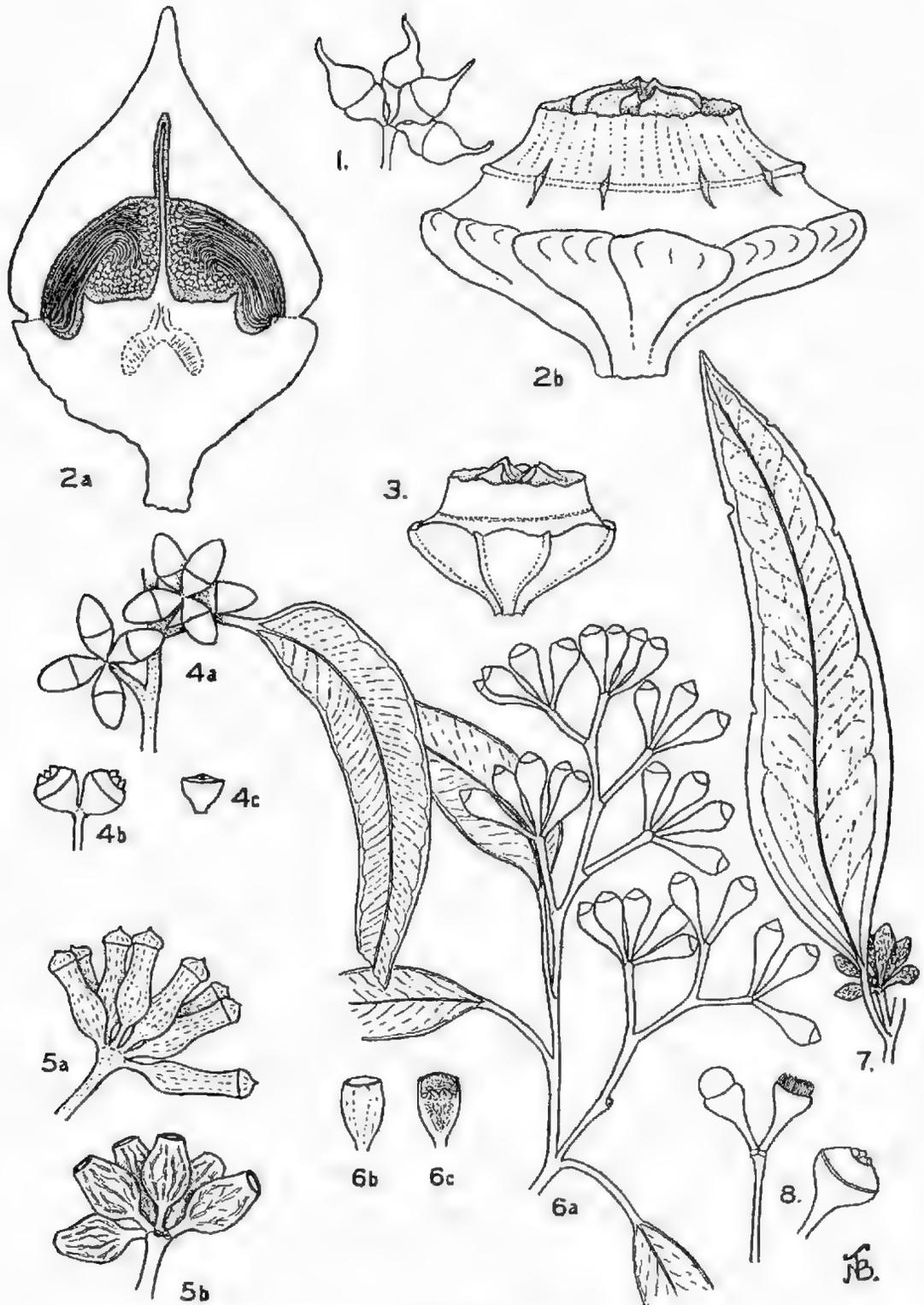


PLATE I

- | | |
|---|---|
| 1. <i>E. oxymitra</i> (from type in Tate Herb.) | 5. <i>E. cladocalyx</i> |
| 2. <i>E. pyriformis</i> | 6. <i>E. fasciculosa</i> |
| 3. <i>E. pachyphylla</i> | 7. <i>E. calcicultrix</i> |
| 4. <i>E. Morrisii</i> | 8. <i>E. Ewartiana</i> (from portion of type in
J. M. Black's collection.) |

(All drawings natural size.)

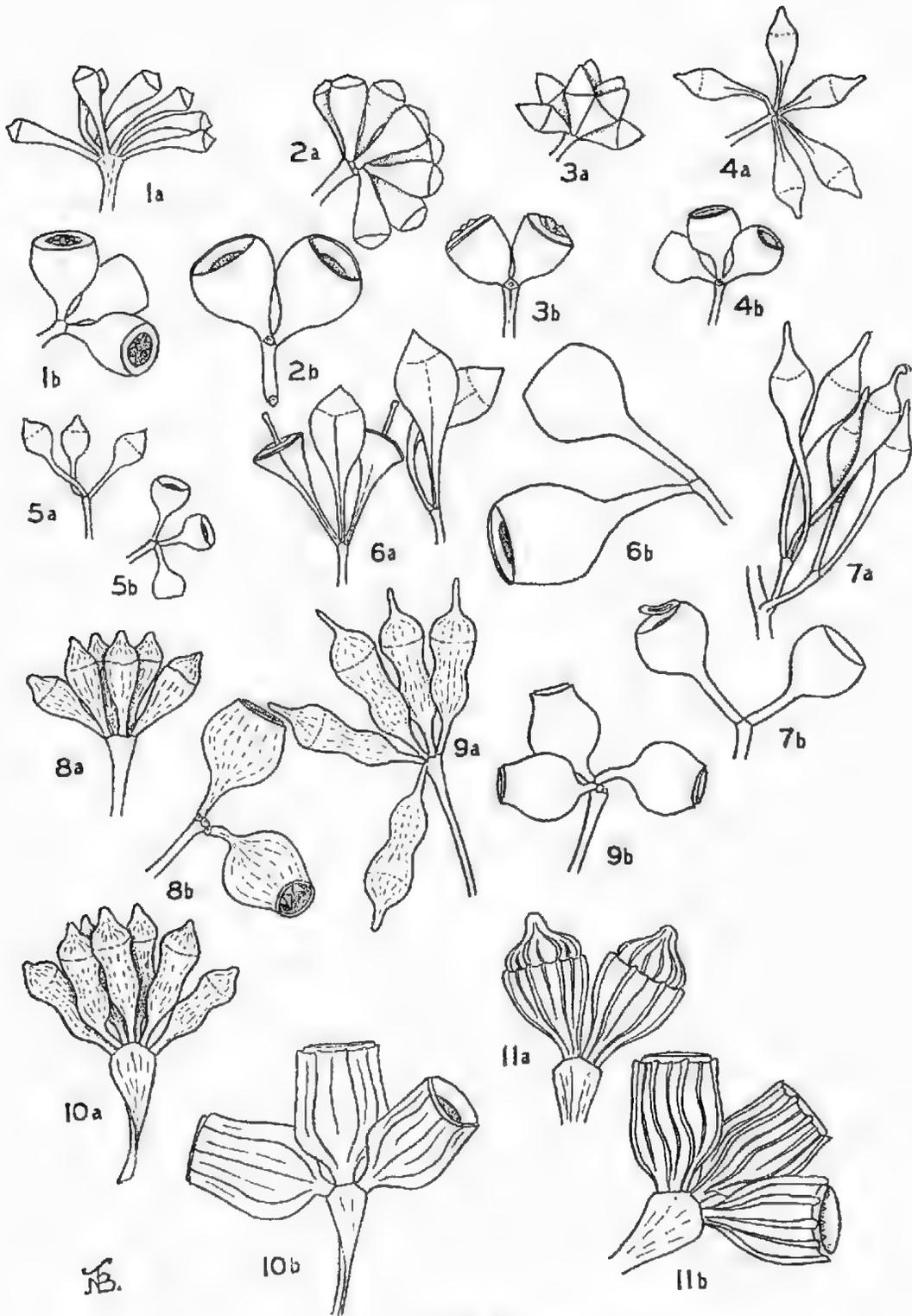


PLATE II

1. *E. remota*
2. *E. obliqua* var. *megacarpa*
3. *E. diversifolia*
4. *E. leucoxylon* var. *pauperita*
5. *E. leucoxylon* var. *pauperita*
6. *E. leucoxylon* var. *macrocarpa*

7. *E. leucoxylon* sensu stricto
8. *E. incrassata* sensu stricto
9. *E. incrassata* sensu stricto
10. *E. incrassata* var. *costata*
11. *E. incrassata* var. *angulosa*

(All drawings natural size.)

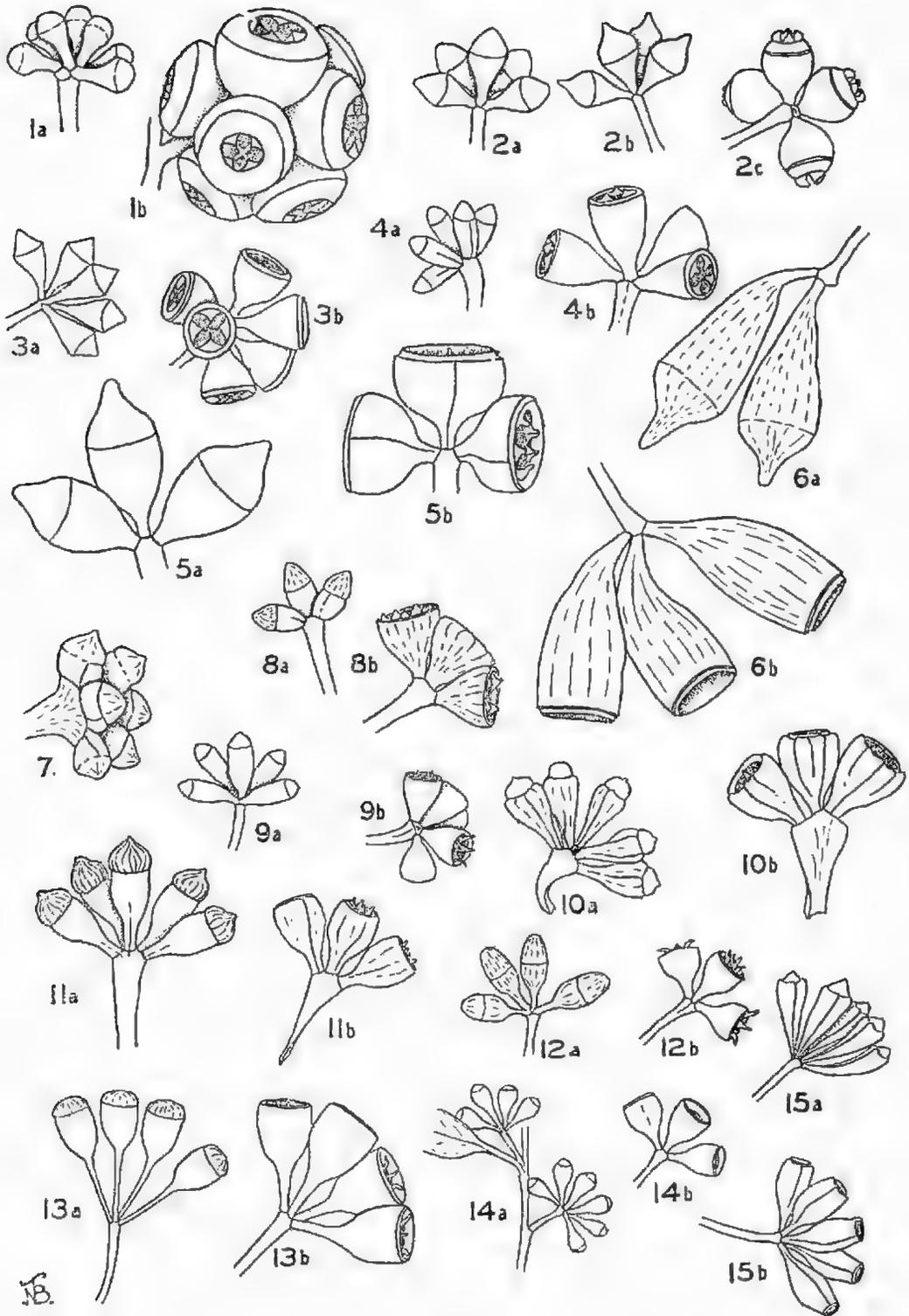


PLATE III

1. *E. Baxteri*
2. *E. viminalis* var. *Iluberiana*
3. *E. ovata*
4. *E. elaeophora*
5. *E. cosmophylla*

6. *E. pimpiniana*
7. *E. conglobata*
8. *E. anceps*
9. *E. dumosa*
10. *E. rugosa*

11. *E. pileata*
12. *E. brachycalyx*
13. *E. concinna*
14. *E. gracilis*
15. *E. calycogona*

(All drawings natural size.)

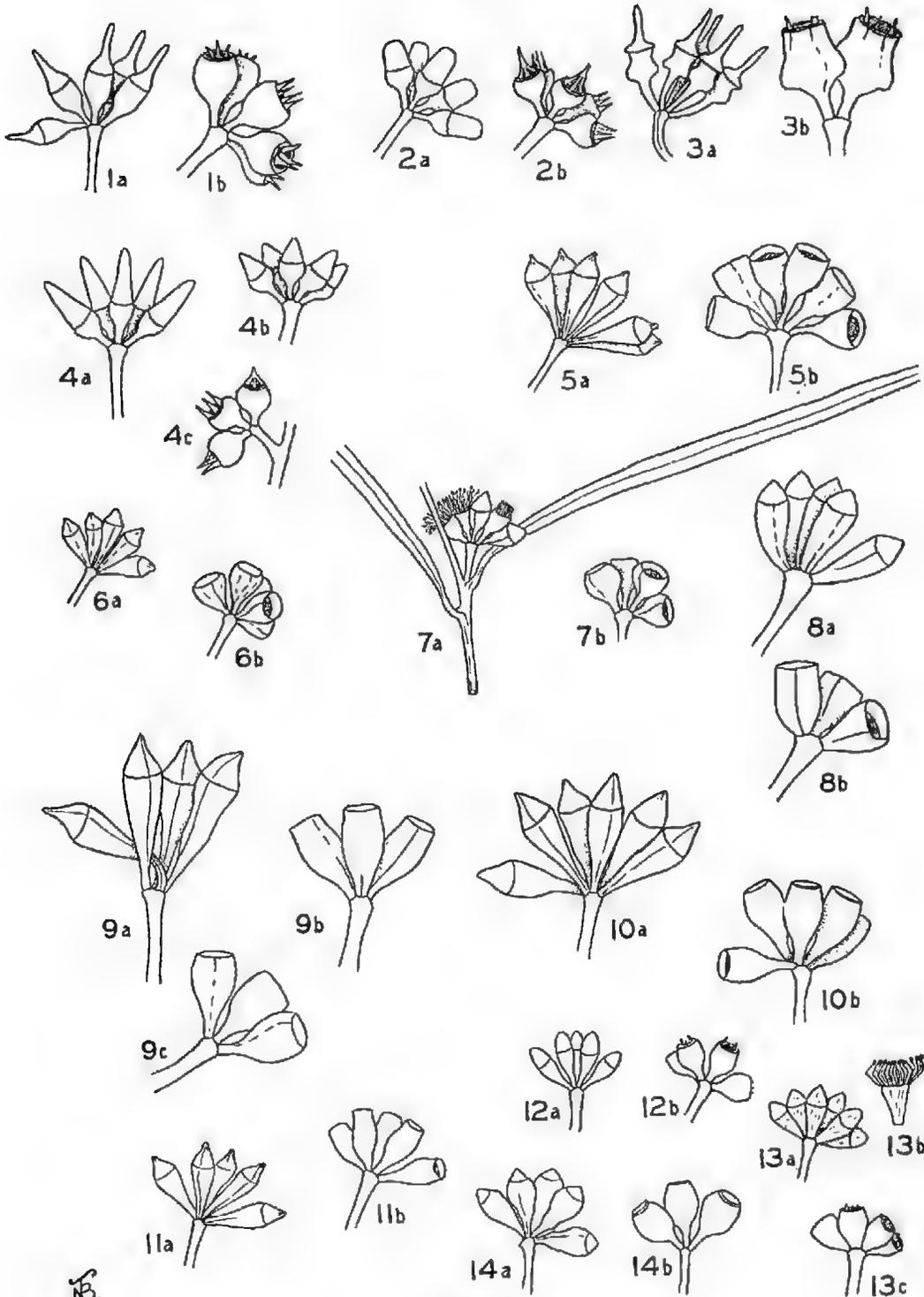


PLATE IV

- | | |
|---|---|
| 1. <i>E. oleosa</i> var. <i>glauca</i> | 8. <i>E. Lansdowneana</i> |
| 2. <i>E. oleosa</i> var. <i>angustifolia</i> | 9. <i>E. hemiphloia</i> var. <i>albens</i> |
| 3. <i>E. Flocktoniae</i> | 10. <i>E. hemiphloia</i> sensu stricto |
| 4. <i>E. oleosa</i> sensu stricto | 11. <i>E. hemiphloia</i> var. <i>microcarpa</i> |
| 5. <i>E. odorata</i> | 12. <i>E. leptophylla</i> |
| 6. <i>E. odorata</i> var. <i>angustifolia</i> | 13. <i>E. uncinata</i> |
| 7. <i>E. viridis</i> | 14. <i>E. intertexta</i> |

(All drawings natural size.)

FUNCTIONAL SYNTHESIS IN PEDOGENESIS

BY C. G. STEPHENS

Summary

Soil is composed of weathered rock material modified by additions of organic matter derived from vegetable and animal life. Despite the obvious association and contributions of rock, climate and organic matter, there have been in relatively modern times different genetical classifications of soils which have rested purely on geological, climatic or organic factors of soil formation. Largely because of the language difficulty these monogenetic classifications were but slightly influenced by the work and theories of Dokuchaiev until well after the beginning of this century, four or five decades since his earlier publications on the genesis of soils. There seems little doubt that Dokuchaiev was the first to fully realize the function of more than one factor in soil formation, and that the factors were not independent of each other. In this connection Neustruev (1927) states: "...it should be noted that though Dokuchaiev had established such factors of soil formation as climate, parent rock, relief, vegetation and age of the country, he still, in the first place, emphasised the idea that it is their interaction which leads to definite conditions of soil formation." Ototzky (1946) quote Dokuchaiev as follows: "Knowing all the physico-geographical elements of a certain locality, it is easy (!) to predict which soil covers it."

FUNCTIONAL SYNTHESIS IN PEDOGENESIS

By C. G. STEPHENS*

[Read 10 April 1947]

Soil is composed of weathered rock material modified by additions of organic matter derived from vegetable and animal life. Despite the obvious association and contributions of rock, climate and organic matter, there have been in relatively modern times different genetical classifications of soils which have rested purely on geological, climatic or organic factors of soil formation. Largely because of the language difficulty these monogenetic classifications were but slightly influenced by the work and theories of Dokuchaiev until well after the beginning of this century, four or five decades since his earlier publications on the genesis of soils. There seems little doubt that Dokuchaiev was the first to fully realize the function of more than one factor in soil formation, and that the factors were not independent of each other. In this connection Neustruev (1927) states: ". . . it should be noted that though Dokuchaiev had established such factors of soil formation as climate, parent rock, relief, vegetation and age of the country, he still, in the first place, emphasised the idea that it is their interaction which leads to definite conditions of soil formation." Otorzky (1946) quotes Dokuchaiev as follows: "Knowing all the physico-geographical elements of a certain locality, it is easy (!) to predict which soil covers it."

Dokuchaiev gave the formula

$$P = f(K, O, G, V),$$

in which P stands for soil (pochva), K for climate (klimat), O for organisms (organism), G for subsoils (gornaya poroda) and V for age (vosrast) of the soil.

According to Neustruev it was Sibirtsev who first established the frequently "predominant rôle of climate," "the idea of zonality of soils and zonal types of soil formation." Sibirtsev also distinguished "a division of intrazonal soils" to which, in addition, he applied the term semi-zonal, thus acknowledging their partial dependence "on climate and their occurrence in definite zones beyond which they are found but rarely, and that in peculiar conditions."

A recent mathematical treatment of the rôle of factors in soil genesis is that given by Jenny (1941) in his book, "Factors of Soil Formation." He expresses the relationship between soil properties (and hence the soil which is an ensemble of soil properties) and the environment by two equations:

$$s = f'(cl', o', r', p, t),$$

$$\text{and } s = \bar{f}(cl, o, r, p, t \text{ ---})$$

in which the symbols cl' , o' , r' , p and t represent soil climate, soil organisms, soil relief, parent material and time, and cl , o and r represent environmental climate, organisms and relief; s is any soil property, and the soil-forming factors represented by the symbols are postulated as independent variables, *i.e.*, "they are the independent variables that define the soil system."

From the second of the above equations Jenny derives an equation of partial differentials, namely:

$$ds = \left(\frac{\partial s}{\partial cl} \right)_{o, r, p, t} dcl + \left(\frac{\partial s}{\partial o} \right)_{cl, r, p, t} do + \left(\frac{\partial s}{\partial r} \right)_{cl, o, p, t} dr$$

$$+ \left(\frac{\partial s}{\partial p} \right)_{cl, o, r, t} dp + \left(\frac{\partial s}{\partial t} \right)_{cl, o, r, p} dt$$

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The interpretation of this equation is that the total change of any soil property, and hence differences between soils, depends on and is a function of the sum of the changes of the soil-forming factors; also, assuming that it is possible to assign a numerical scale to each of the variables, the magnitudes of the partial differentials are true indices of the importance of the various factors.

In reality it is not possible to derive the values of the partial differentials because of actual and uncontrollable variation in one or more of the remaining variables, and because it is extremely difficult, if not impossible, to assign a numerical scale to some of the variables, particularly *o* and *p*. In addition, *cl*, *o*, *r*, and *p* are, or can be, multiple factors and yield groups of functions; for example, the ratio of precipitation to evaporation (*P/E*) and temperature (*T*) are largely used to characterise *cl*. Furthermore, the variables, despite their being assigned an independent status to facilitate the mathematical approach, are in nature not completely independent, relief for instance, as is well known to geomorphologists, being a function of parent material and climate, but having a partially independent relationship with soil. The treatment is thus to a degree philosophical, rather than rigidly mathematical. Hence it is necessary to work out the significance and rôle of the various soil-forming factors on a statistical, graphical, or diagrammatic basis.

Jenny illustrates the function of each of the soil-forming factors by discussing them in turn in their relationships to various soil characteristics. He does not attempt to show the effects of interaction or illustrate the variables operating together; rather his efforts are directed towards separating and illustrating the effects of the individual variables.

More recent work by Jenny (1946) illustrates the relationships of soil series and types mapped in various soil surveys to the individual soil-forming factors, particularly how various sequences of soils are related to changes in the value or composition of one of the variables. He postulates "five canonical functions of pedology" where four of the variables remain constant, thus:

Climofunctions	-	-	$s = f (cl)$	<i>o, r, p, t</i>
Biofunctions	-	-	$s = f (o)$	<i>cl, r, p, t</i>
Topofunctions	-	-	$s = f (r)$	<i>cl, o, p, t</i>
Lithofunctions	-	-	$s = f (p)$	<i>cl, o, r, t</i>
Chronofunctions	-	-	$s = f (t)$	<i>cl, o, r, p</i>

Designating an ensemble of *s* values by *E(s)* he writes:

$$\text{Soil} = E(s) = f (cl, o, r, p, t, \dots)$$

and defines the various soil sequences as follows:

Climosequences	-	$E(s) = f (cl)$	<i>o, r, p, t</i>
Biosequences	-	$E(s) = f (o)$	<i>cl, r, p, t</i>
Toposequences	-	$E(s) = f (r)$	<i>cl, o, p, t</i>
Lithosequences	-	$E(s) = f (p)$	<i>cl, o, r, t</i>
Chronosequences	-	$E(s) = f (t)$	<i>cl, o, r, p</i>

Toposequences include clinosequences and hydrosequences, the former covering the effect of the slope factor (*i*) and the latter the effect of the water table factor (*w*) on soil formation.

Each of the soil sequences is illustrated by reference to maps and diagrams relating to soil series defined in soil surveys. Examples quoted are as follows:

Chronosequence: (Tujunga), Hanford, Greenfield, Ramono, Placentia, (San Joaquin) series.

Lithosequence: Colma, Ilugo, Sweeney, Sheridan series.

Toposequences: See *Clinosequence* and *Hydrosequence*.

Clinosequence: Sheridan sandy loam, shallow phase, Sheridan sandy loam, deep phase.

Hydrosequence: Panoche clay, Oxalis clay, Levis clay.

Climosequence: Panoche, Sorrento series.

Biosequence: Parr, Octagon, Miami series.

Jenny states that every homogeneous soil type or series belongs theoretically to each of the five canonical functions and illustrates this by pointing out that the Panoche series is a recognisable member of more than one soil sequence. He thus indicates a method of recognising the rôle of more than one variable in determining the soil series or type.

Recently, in Wilde's "Forest Soils and Forest Growth" (1946), Dokuchaiev was quoted as follows: "The soil is a result of reactions and reciprocal influences of parent rock, climate, topography, plants, animals and age of the land." Wilde's formulation following this is

$$S = \int (g, e, b) dt.$$

in which S is the soil, g is geological substratum, e is environmental influences, b is biological activity, and t is time. This equating of the soil as an integral of the soil-forming factors against time has a distinct appeal as a more precise formulation than that of Dokuchaiev or that of Jenny. In particular the value of some of the variables has changed with the passage of time: for instance certain soils largely owe their morphological characteristics to a climate operating in past geological time, e.g., lateritic soils were formed in Australia most probably in the Pliocene, and as they exist in "fossil" form today are not particularly affected by or responsive to the prevailing climate. Wilde apparently does not regard g, e and b as independent variables.

The purpose of the paper presented here is to record a diagrammatic method of synthesis of the rôle of the soil-forming factors and to relate the components of the diagrams both to the independent variables of the Jenny equations and to the partially dependent and partially independent variables which the soil-forming factors actually comprise in nature.

Let the variables which determine the soil (S) be represented as follows:

C for climate

O for organisms

R for shape of the land surface

W for height and other features of the water-table

P for parent material

T for time

In nature these are not completely independent variables and their known dependencies are set out in Table I.

TABLE I

A change in C	may cause a change in	O, R, W, P, S	but not in	T
" " O	" " " "	C, W, P, S	" " "	T, R
" " R	" " " "	C, O, W, P, S	" " "	T
" " W	" " " "	O, P, S	" " "	T, C, R
" " P	" " " "	O, R, W, S	" " "	T, C
" " T	" " " "	C, O, R, W, P, S		
" " S	" " " "	O, R, W, P	but not in	T, C

A complete list of the possible relationships between any two of the variables is given by the partial differentials in Table II.

TABLE II

$\frac{\partial S}{\partial C}$	$\frac{\partial S}{\partial O}$	$\frac{\partial S}{\partial R}$	$\frac{\partial S}{\partial W}$	$\frac{\partial S}{\partial P}$	$\frac{\partial S}{\partial T}$
$\frac{\partial C}{\partial S}$	$\frac{\partial C}{\partial O}$	$\frac{\partial C}{\partial R}$	$\frac{\partial C}{\partial W}$	$\frac{\partial C}{\partial P}$	$\frac{\partial C}{\partial T}$
$\frac{\partial O}{\partial S}$	$\frac{\partial O}{\partial C}$	$\frac{\partial O}{\partial R}$	$\frac{\partial O}{\partial W}$	$\frac{\partial O}{\partial P}$	$\frac{\partial O}{\partial T}$
$\frac{\partial R}{\partial S}$	$\frac{\partial R}{\partial C}$	$\frac{\partial R}{\partial O}$	$\frac{\partial R}{\partial W}$	$\frac{\partial R}{\partial P}$	$\frac{\partial R}{\partial T}$
$\frac{\partial W}{\partial S}$	$\frac{\partial W}{\partial C}$	$\frac{\partial W}{\partial O}$	$\frac{\partial W}{\partial R}$	$\frac{\partial W}{\partial P}$	$\frac{\partial W}{\partial T}$
$\frac{\partial P}{\partial S}$	$\frac{\partial P}{\partial C}$	$\frac{\partial P}{\partial O}$	$\frac{\partial P}{\partial R}$	$\frac{\partial P}{\partial W}$	$\frac{\partial P}{\partial T}$
$\frac{\partial T}{\partial S}$	$\frac{\partial T}{\partial C}$	$\frac{\partial T}{\partial O}$	$\frac{\partial T}{\partial R}$	$\frac{\partial T}{\partial W}$	$\frac{\partial T}{\partial P}$

Reference to Table I and a consideration of the lack of effect of changes in C, O, R, W, P and S on the change of T show that $\frac{\partial T}{\partial S}, \frac{\partial T}{\partial C}, \frac{\partial T}{\partial O}, \frac{\partial T}{\partial R}, \frac{\partial T}{\partial W}, \frac{\partial T}{\partial P}$ are of no consequence in soil formation and that T is a completely independent variable. Similarly $\frac{\partial C}{\partial W}, \frac{\partial C}{\partial P}, \frac{\partial R}{\partial O}, \frac{\partial R}{\partial W}$ do not operate. Hence the relationship between a soil and the soil forming factors is probably best expressed like Wilde's equation as:

$$S = \int f (C, O, R, W, P) dT$$

in which T is independent and C, O, R, W and P can have both dependent and independent status.

The function of these soil-forming factors can be qualitatively (and sometimes quantitatively) but precisely indicated both as independent and interacting variables by the diagrammatic and mathematical representation of the relationships of the soils mapped in soil surveys to the variations in the factors which characterise the environment of the area surveyed. Provided the environment is studied in the necessary detail during the course of a soil survey, it is possible to determine in some degree the relative importance of the different soil-forming factors in the genesis of the different soil series or types. This has been done in some soil surveys in Australia, with the result that it is now possible to present useful diagrammatic expressions of the dependence and interaction of the soil-

forming factors. The comparison of a soil map based strictly and entirely on field observation of soil morphology and distribution with topographic, hydrographic, climatic, geological and vegetation maps and a study of the Tertiary and Recent geomorphology of the same area are generally most revealing regarding the functions of climate, organisms, relief, water-table, parent material and time in soil formation.

The construction of diagrams to illustrate the importance of the factors and the order in which they have operated calls for some ingenuity, but it has been found possible in a relatively simple arrangement to integrate the functions of the variables operating in the formation of different soil series and types occurring in the same locality. Examples of three such diagrams relating to widely separated surveys of various sizes are illustrated in fig. 1, 2 and 3. Two of these diagrams, in a provisional and rudimentary form, and devoid of any mathematical interpretation, were published previously in the bulletins describing the relevant soil surveys; namely in:

1. C.S.I.R. (Australia) Bulletin No. 150, 1942, "The Soils of the Parishes of Longford, Cressy, and Lawrence, County Westmorland, Tasmania."
2. C.S.I.R. (Australia) Bulletin No. 188, 1945, "A Soil, Land-Use and Erosion Survey of Part of County Victoria, South Australia."

The third diagram relates to the following:

3. Transactions of the Royal Society of South Australia, 67, (2), 1943, 191-199, "The Pedology of a South Australian Fen."

In their present form the diagrams give qualitative expression to the variables of the Jenny equations and provide a means of recognition of his soil sequences, which are naturally segregated in different portions of the diagrams. They also confirm the crude additive character of the soil-forming factors expressed by his equation of partial differentials. In addition they provide a framework or reference grid on which can be recognised the appropriate place at which the partial differentials of the partially dependent and interacting variables C, O, R, W, and P operate in determining the course of soil development, in relation to the independent variable T. Inspection of the diagrams shows how a "lateral analysis" relates the various steps in soil formation to the independent Jenny variables and how a "vertical (time) analysis" reveals the dependent reaction of the natural variables and their ultimate control of soil formation. The diagrams should provide a useful starting point in the quantitative evaluation of the factors C, R, W and T, which lend themselves to such treatment.

Fig. 1 is a pedogenetic diagram of the soils of the eastern portion of County Victoria in the wheat-growing and sheep-raising country of South Australia. It includes all of the soils mapped over an area of about 600 square miles, showing how each soil series is a synthesis of the functions of the variables dealt with above. The morphology of the soils, a soil map, a topographical map and diagram, a rainfall map and other climatic data and details of the geology and vegetation of the area were published in the soil survey bulletin mentioned previously. In addition, in this diagram the contribution of calcareous loess to the morphology of two of the soil series is shown; this following the recent work of Crocker (1946).

In the first column on the right-hand side of the diagram is shown the relationship of the various steps of the diagram to the Jenny variables. Recognition of his soil sequences is easy, for example the Caltowie, Canowie and Bundaleer series comprising a climosequence. In addition, soils whose genesis is dominated by one or more variables can be recognised. For example, both the Yangya silty-loam and the Beetaloo series are formed on calcareous materials in

all localities in the area, irrespective of the change of the leaching factor under a change of rainfall from 14 to 24 inches per annum; *i.e.*, the morphological characters of the two soils are predominantly governed by the geological factors relief and parent material, climatic variation in the region surveyed producing no correspondingly significant variation in profile characteristics. However, on passing further into the adjacent lower rainfall country, the climatic factor operating on this parent material does become significant, for at rainfall levels of 12 inches per annum and less a soil devoid of the nearly black sub-surface layer characteristic of the Yangya silty loam is formed. Such a soil has been described at Melton by Prescott and Skewes (1938).

Soils dominated by the climatic factor are the Caltowie, Canowie and Bundaleer series, and, corresponding to approximately the same climatic variation but on different parent material, the Pirie, Yarcowie and Belalie series. The Caltowie, Yarcowie, Canowie, Belalie and Bundaleer series comprise the mallee, red-brown earth and podsollic zonal soils of the region. Retention of calcareous loess in the Caltowie and Yarcowie series, as well as being a function of climate, is also governed by relief, and similarly both variables operate in the accumulation of cyclic salt in the Pirie series.

There are two aspects of time as a soil-forming factor which are important. First, as used in the body of the diagrams, lapse of time since initiation of soil formation is a real measure of actual age of the soil. However, such a time lapse does not necessarily precisely specify the maturity aspect of soil development, since maturity can be reached at various rates. Maturity is a characteristic of the soil itself and should be regarded as a dependent variable comprising one of the S values which make up the soil ensemble. In the diagrams the soils are classified as immature, mature, over-mature and senescent. Concerning the classification of the solonchak—the Pirie series—the designation as immature is in conformity with the possible development of this soil to a solonetz and ultimately a solod, but since it is in equilibrium with the present accession of cyclic salt, it may equally well be considered as mature.

In the second column on the right hand side and at appropriate places in the diagram partial differentials indicate differentiation of certain of the variables with respect to change of other variables. For example, the establishment of different parent materials in the various sites where soil formation ensues is

shown to be dependent on the partial differentials $\frac{\partial R}{\partial P}$, $\frac{\partial R}{\partial C}$, $\frac{\partial P}{\partial R}$, $\frac{\partial P}{\partial C}$ while the effect of climate and organisms (restricted to vegetation in the diagram) is indicated by the differentials $\frac{\partial O}{\partial C}$, $\frac{\partial S}{\partial O}$ & $\frac{\partial S}{\partial C}$. The functions of this latter group

of differentials is dealt with more comprehensively following the discussion of fig. 2.

Fig. 2 is a pedogenetic diagram of the soils of the Longford-Cressy district which lies in the Launceston Tertiary Basin in northern Tasmania. It relates to all the soils mapped over an area of approximately 100 square miles in a region devoted to mixed farming. The details of the morphology of the soils, a soil map, a cross sectional diagram showing the relationship of the soil to topographical and geological features and climatic and vegetation data were published in the soil survey bulletin referred to above.

As in fig. 1 the relationship of the various steps of soil formation to the independent variables of the Jenny equation is shown. Also the function of the partial differentials is illustrated by the upper portion of the diagram involving $\frac{\partial R}{\partial P}$, $\frac{\partial R}{\partial C}$, $\frac{\partial P}{\partial R}$ & $\frac{\partial P}{\partial T}$ and the lower $\frac{\partial C}{\partial T}$, $\frac{\partial O}{\partial C}$, $\frac{\partial S}{\partial O}$ & $\frac{\partial S}{\partial C}$.

This diagram is of particular interest because of the age of some of the soils, i.e., time varies widely, and consequently there has been a correspondingly large variation in the climate to which some of the soils have been subject. Hence, unlike fig. 1, where geographical variation in climate was of the greatest significance, this diagram refers to a restricted area of considerable chronological variation of that function and its corresponding effect on the development of the older soils. Consequently some of the soils are senescent.

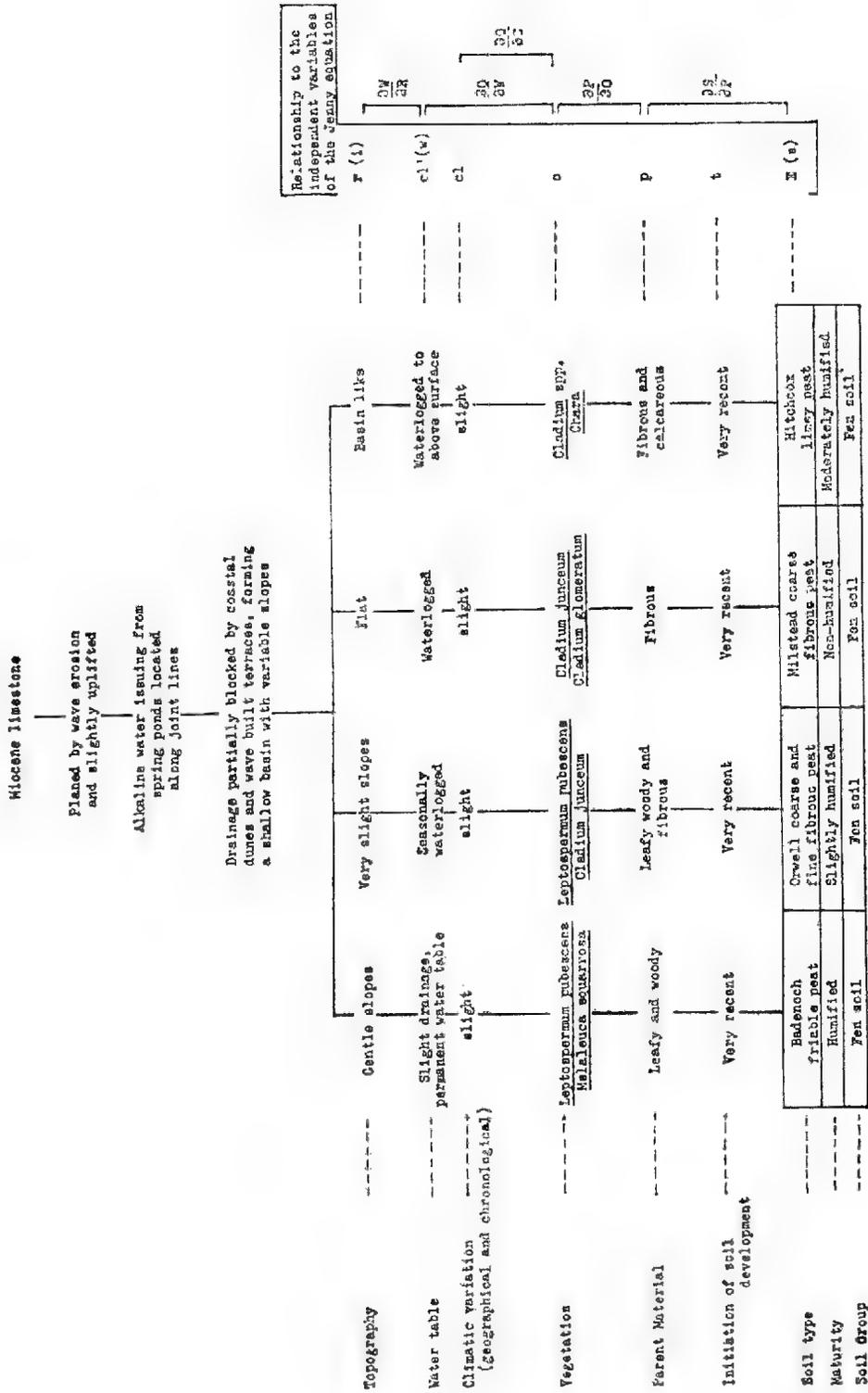
It is appropriate to point out at this point that since podzolisation is largely an irreversible process, and since there is a variation of climate with passage of time, the soil will not fully respond to the lowered leaching factor (regrade) in drier periods. In fact, further soil development is probably only induced when the leaching factor exceeds a value near its previous maximum. Hence the

influence of $\frac{\partial S}{\partial C}$ on soil formation is largely as a discontinuous integral function.

In fig. 1 and 2 the function of the organisms variable has been only partially indicated, dependence of the soil, both on the vegetation and directly on the climate being indicated. Fig. 4 shows for one soil, the Woodstock sand, a more comprehensive treatment of the operation of the time, climate, organism and soil variables and indicates the dependent reaction of climate on time and of organisms and soil on climate with an interaction between organism and soil. If consideration of O is restricted to the vegetation, this type of diagram if applied to each soil provides an ecogenetic treatment as well as a pedogenetic one. It is

apparent that soil is a function of $\frac{\partial C}{\partial T}$, $\frac{\partial S}{\partial C}$, $\frac{\partial S}{\partial O}$ & $\frac{\partial S}{\partial T}$. $\frac{\partial S}{\partial T}$ covers the alteration of the soil for constant values of C and O, that is, maturation under a steady environment. Vegetation on the other hand is a function of $\frac{\partial C}{\partial T}$, $\frac{\partial O}{\partial C}$, $\frac{\partial O}{\partial S}$ & $\frac{\partial O}{\partial T}$ the last term including the effects of evolution, i.e. in this case the development and extinction of species in the area since Pliocene times where such genesis has been independent of the environment.

The *Eucalyptus salicifolia* woodland associated with the Woodstock sand is an edapho-climatic climax; hence $\frac{\partial O}{\partial C}$ & $\frac{\partial O}{\partial S}$ have played co-dominant roles in its formation. In the case of a climatic complex $\frac{\partial O}{\partial C}$ plays the more prominent part and the same vegetation association may extend over a number of soil types; for an edaphic climax $\frac{\partial O}{\partial S}$ is the more significant function.



The partial differentials show the relationships of the interacting natural variables

Fig. 3. PEDOGENETIC DIAGRAM OF THE SOILS OF EIGHT HILL CREEK SWAMP, SOUTH AUSTRALIA.

The third figure is a pedogenetic diagram of the soils of Eight Mile Creek Swamp, a coastal fen formation in the lower south-east of South Australia. The diagram relates to the four named soil types found on the fen proper, which covers an area of about 3,500 acres. The details of the morphology of these soils, a soil map, a cross-sectional diagram of the fen showing the relationships of the soils to very small changes in relief, and climatic and geological data are included in the publication referred to above. In addition, the ecological relationships are described in the text and figure of a paper on the vegetation of the fen by C. M. Eardley (1943), who considers the age of this peat formation to be less than 5,500 years. The simplicity of this diagram distinguishes it from the other two to a marked degree. This simplicity is due to the dependent sequence of events following the establishment of the topographical factor. This determines the position of the water-table, which in turn is the selecting factor operating on the climatically and geographically available species and thus determines the plants growing on any location. The plants, in turn, determine the nature of the parent materials which, all being of about the same age, give rise respectively to the four soil types. The establishment of the relief factor is a simple process as compared to the geomorphological processes involved in the establishment of the parent material and relief factors in the two former diagrams.

As seen on the diagram, it is possible to indicate the relevance of the Jenny variables, but quite obviously the variables involved are not independent but rather dependent on a fore-runner variable modified in one case by the effect of the local climate in determining the total number and type of species available to colonise the area. The dependence of the variables is shown clearly by the sequence of partial differentials.

This diagram indicates that the same four soils comprise simultaneously a hydrosequence, a biosequence and a lithosequence.

Considering along general lines the above diagrams and temporarily retaining both a dependent and independent status for T at well as for C, O, R, W & P, we may derive from

$$S = f(C, O, R, W, P, T)$$

the following equations of partial differentials.

Where T is independent and C, O, R, W and P are functions of T and of some other set of independent variables

$$\frac{\partial S}{\partial T} = \frac{\partial S}{\partial C} \frac{\partial C}{\partial T} + \frac{\partial S}{\partial O} \frac{\partial O}{\partial T} + \frac{\partial S}{\partial R} \frac{\partial R}{\partial T} + \frac{\partial S}{\partial W} \frac{\partial W}{\partial T} + \frac{\partial S}{\partial P} \frac{\partial P}{\partial T} + \frac{\partial S}{\partial T}$$

Similarly when P is independent and C, O, R, W and T are functions of P and of the other set of independent variables

$$\frac{\partial S}{\partial P} = \frac{\partial S}{\partial C} \frac{\partial C}{\partial P} + \frac{\partial S}{\partial O} \frac{\partial O}{\partial P} + \frac{\partial S}{\partial R} \frac{\partial R}{\partial P} + \frac{\partial S}{\partial W} \frac{\partial W}{\partial P} + \frac{\partial S}{\partial P} + \frac{\partial S}{\partial T} \frac{\partial T}{\partial P}$$

Similarly for W, R, O and C in turn

$$\frac{\partial S}{\partial W} = \frac{\partial S}{\partial C} \frac{\partial C}{\partial W} + \frac{\partial S}{\partial O} \frac{\partial O}{\partial W} + \frac{\partial S}{\partial R} \frac{\partial R}{\partial W} + \frac{\partial S}{\partial W} + \frac{\partial S}{\partial P} \frac{\partial P}{\partial W} + \frac{\partial S}{\partial T} \frac{\partial T}{\partial W}$$

$$\frac{\partial S}{\partial R} = \frac{\partial S}{\partial C} \frac{\partial C}{\partial R} + \frac{\partial S}{\partial O} \frac{\partial O}{\partial R} + \frac{\partial S}{\partial R} + \frac{\partial S}{\partial W} \frac{\partial W}{\partial R} + \frac{\partial S}{\partial P} \frac{\partial P}{\partial R} + \frac{\partial S}{\partial T} \frac{\partial T}{\partial R}$$

$$\frac{\partial S}{\partial O} = \frac{\partial S}{\partial C} \frac{\partial C}{\partial O} + \frac{\partial S}{\partial O} + \frac{\partial S}{\partial R} \frac{\partial R}{\partial O} + \frac{\partial S}{\partial W} \frac{\partial W}{\partial O} + \frac{\partial S}{\partial P} \frac{\partial P}{\partial O} + \frac{\partial S}{\partial T} \frac{\partial T}{\partial O}$$

$$\frac{\partial S}{\partial C} = \frac{\partial S}{\partial C} + \frac{\partial S}{\partial O} \frac{\partial O}{\partial C} + \frac{\partial S}{\partial R} \frac{\partial R}{\partial C} + \frac{\partial S}{\partial W} \frac{\partial W}{\partial C} + \frac{\partial S}{\partial P} \frac{\partial P}{\partial C} + \frac{\partial S}{\partial T} \frac{\partial T}{\partial C}$$

These comprise a set of simultaneous equations which mathematically define the soil. Allowance must be made for T being independent so that on causal

grounds $\frac{\partial T}{\partial C}$, $\frac{\partial T}{\partial O}$, $\frac{\partial T}{\partial R}$, $\frac{\partial T}{\partial W}$, $\frac{\partial T}{\partial P}$ and 1 may be reduced to a constant — say K_1 .

For similar reasons $\frac{\partial R}{\partial W}$, $\frac{\partial R}{\partial P}$ and 1 may be represented by K_2 and $\frac{\partial R}{\partial W}$ & $\frac{\partial R}{\partial O}$ and 1

by K_3 . The soil, specified by the very complex integral of the above equations, can be most simply represented by the sum:

$$\begin{aligned} & \frac{\partial S}{\partial C} + \frac{\partial S}{\partial O} + \frac{\partial S}{\partial R} + \frac{\partial S}{\partial W} + \frac{\partial S}{\partial P} + \frac{\partial S}{\partial T} \\ &= \frac{\partial S}{\partial C} \left(\frac{\partial C}{\partial O} + \frac{\partial C}{\partial R} + K_1 + \frac{\partial C}{\partial T} \right) + \frac{\partial S}{\partial O} \left(\frac{\partial O}{\partial C} + 1 + \frac{\partial O}{\partial R} + \frac{\partial O}{\partial W} + \frac{\partial O}{\partial P} + \frac{\partial O}{\partial T} \right) \\ &+ \frac{\partial S}{\partial R} \left(\frac{\partial R}{\partial C} + K_2 + \frac{\partial R}{\partial P} + \frac{\partial R}{\partial T} \right) + \frac{\partial S}{\partial W} \left(\frac{\partial W}{\partial C} + \frac{\partial W}{\partial O} + \frac{\partial W}{\partial R} + 1 + \frac{\partial W}{\partial P} + \frac{\partial W}{\partial T} \right) \\ &+ \frac{\partial S}{\partial P} \left(\frac{\partial P}{\partial C} + \frac{\partial P}{\partial O} + \frac{\partial P}{\partial R} + \frac{\partial P}{\partial W} + 1 + \frac{\partial P}{\partial T} \right) + \frac{\partial S}{\partial T} \left(K_1 \right) \end{aligned}$$

This expression includes partial differentials such as $\frac{\partial S}{\partial C}$, $\frac{\partial S}{\partial O}$ etc. corresponding to the effects of the independent variables of the Jenny equations. The other terms express the dependent relationships between the variables involved in soil formation.

The above equations and diagrams show the involved manner in which the soil-forming factors integrate with one another in the pedogenic process. Although the diagrams refer to more or less restricted localities, it is obvious that some measure of similar interpretation applies to the broader classification of soils such as the soil groups, and points to the fact that it is futile to attempt too simple a

genetic classification of the morphologically defined great soil groups. Sufficient exploration has now been made to leave no doubt that on a morphological basis there is a limited number (probably less than fifty) of great soil groups. The relationship of these groups to their genetic factors is, however, not simple.

Although climate does play a dominant rôle in the genesis of certain of the soil groups, it has been established that the groups do not lie in exactly similar climatic zones and the boundaries of adjacent groups interdigitate to a considerable degree in the different continents. In this regard the senescent and fossil character of some soils is important; as an extreme example the lateritic podsol soils of southern Australia extend into arid regions and, besides illustrating the above point, are a good indication of the largely irreversible character of the soil-forming process, only the slightest detectable reversal of lateritic podsol genesis being associated with the drier periods of the climatic cycle. It seems, therefore, that, if it is essential to have a genetic classification of soils correlated with the morphological one, the arrangement will need to be on a multidimensional basis. Such a tabulation is not readily constructed.

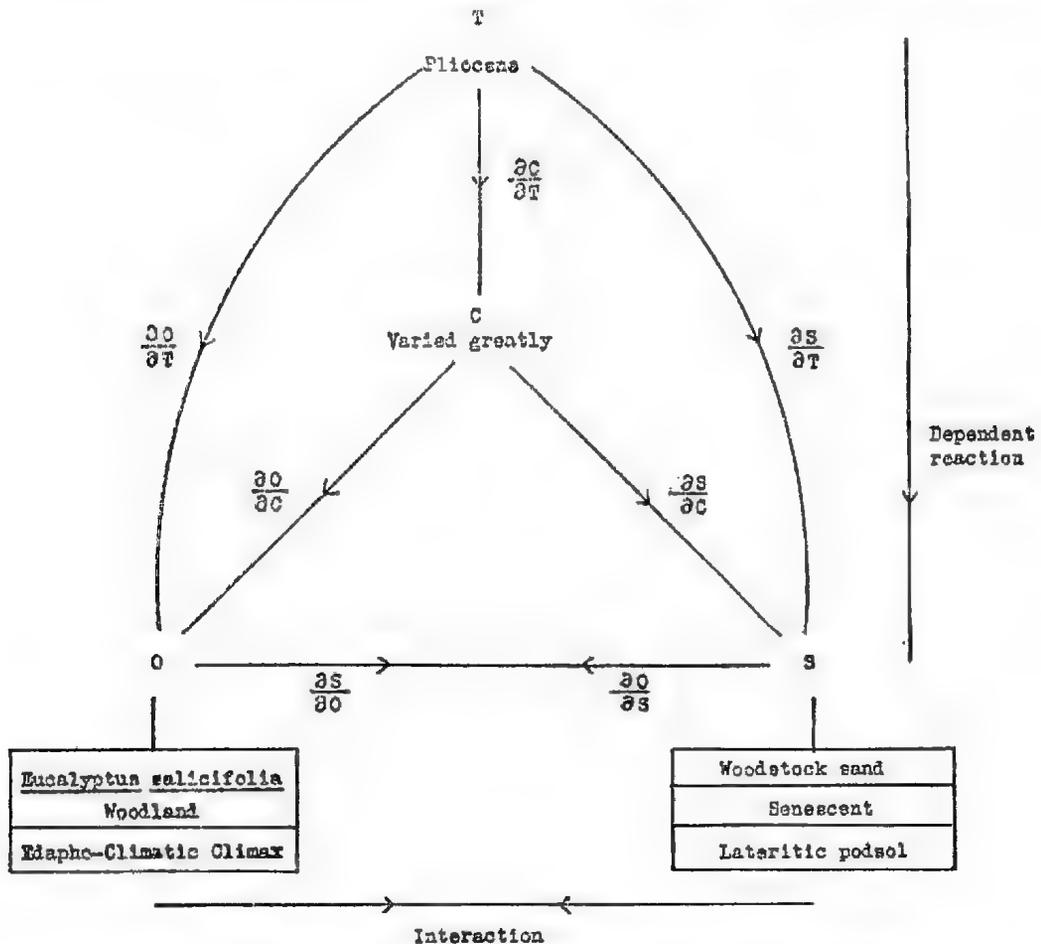


Fig. 4. DETAILS OF THE OPERATION OF THE TIME, CLIMATE, ORGANISM AND SOIL VARIABLES IN THE PEDOGENETIC DIAGRAM OF THE WOODSTOCK SAND.

Another consequence of the lack of appreciation of the number of variables involved in the genesis of even the great soil groups has been the repeated attempts to seek near perfect correlation between large scale climatic and soil maps. Similar correlations are sought between climatic and vegetation maps. On maps of a continental scale, the mapping of soil and vegetation boundaries is of necessity based to some considerable degree on imperfect correlations of these features with climate, topography and parent material. Subsequent studies of climate frequently point to correlations of certain lines between climatic categories with boundaries of soils and vegetation in fallacious interpretation of the degree of importance of the climatic factor. It is obvious that until continental soil maps can be prepared almost entirely on a morphological basis the effect of the climatic factor cannot be fully assessed. For that reason the study of smaller areas with precise soil mapping, and in which there is a significant geographical and/or chronological variation of climate, is of the greatest importance.

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ON THE WEIGHTS OF SOME AUSTRALIAN MAMMALS

By H. H. FINLAYSON

Summary

At the suggestion of Professor J. B. Cleland, whose researches into the alimentation of aboriginal man in this country have now entered upon a gravimetric phase, I herewith record the weight of some eighty-eight species and sub-species of mammals of Australian occurrence.

ON THE WEIGHTS OF SOME AUSTRALIAN MAMMALS

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[Read 8 May 1947]

At the suggestion of Professor J. B. Cleland, whose researches into the alimentation of aboriginal man in this country have now entered upon a gravimetric phase, I herewith record the weight of some eighty-eight species and subspecies of mammals of Australian occurrence.

The published data on this head is scanty and of doubtful value. It has been chiefly derived from the statements of bushmen and other rural observers, whose approach to the matter is sometimes tinged by that frivolity which, in the ichthyological field, has become proverbial. Even when the intention is of the best, the weights so derived are usually of the "estimated" variety, and though supposed ability in the difficult feat of estimating weights is often a matter of pride, some gross errors have been introduced in this way.

All weights quoted in the sequel have been personally determined by the writer in the field with the balance, upon recently killed animals, and are recorded in grammes and kilos.⁽¹⁾

It is not proposed here to discuss fully the scientific value of body weight as a character in the descriptive treatment of mammals, except to remark that its value and appropriateness in a general account of an animal is so great as to lift it almost to the rank of a descriptive necessity. No other quantitative datum conveys so easily an impression of general bulk, and in conjunction with linear dimensions its graphic value in illustrating differences of body build in different species, or of sexual dimorphism in the same species, is very great.

On the other hand, its almost universal neglect by taxonomists is not without sound reason, owing, in the first place, to the great difficulty of adequately correlating body weight with growth phase without a much more intimate acquaintance of the animal in life than falls to most systematic writers. In many marsupials also, concordant criteria of maturity as derived from epiphyseal condition in the skeleton, cranial sutures, and dental phase, do not correspond with the maximum values for either linear dimensions or body weight, and the latter may either markedly increase or diminish after skeletal or dental maturity is attained. A second difficulty arises from the massive error introduced into the observed weight by unascertained variations in the weight of the stomach contents; particularly in large herbivores; and a third, from the influence of climatic, seasonal and general ecological factors, which cannot be brought under statistical control as geographic or other racial variation.

In the list which follows, species have been treated on as wide a geographical basis as the field data allowed, but the use of trinomials has been limited for the most part to cases where the differentiation is marked, or at least has been fully defined. Several growth stages have been included, wherever possible, and the terms immature, subadult, adult, and aged, which

⁽¹⁾ To the main body of the data I have subsequently added approximate values for a few species of exceptional interest, where weights of freshly killed animals were not available. These values were obtained by weighing preserved material of known history and correcting the result with a modulus of dehydration, extracted from the loss of weight undergone by similar specimens weighed fresh in the field and submitted to the same process of preservation for the same length of time. These citations are differentiated as "approx."

are appended to each citation, are chosen after a consideration of the criteria named above and are subject to the limitations there noted. In most cases these terms have been further amplified by the addition of the head and body length in millimetres. The maximum weight found in the field for the adult of each species has always been included in the citation, but this does not necessarily mean that much higher weights may not be reached.

Finally, it is desired to emphasise that though each individual observation is accurate, the body of data which is collectively represented by them is of an interim and tentative character only, and is here assembled to meet a general or popular want, rather than a systematic one. In its present form it is quite inadequate for (as an example) the resolution of problems of specific, still less of subspecific, identity.

Fuller data will be provided in monographic treatment of many of the species here mentioned, and some already so dealt with may be traced in the list of references.

MONOTREMATA

Ornithorhynchus anatinus Shaw

- (a) Olangolah Creek, Otway Peninsula, Victoria; imm. ♀; H. and B. 311 mm.; wt. 900 g.
- (b) Macquarie River, East Tasmania; subad. ♀; H. and B. 382 mm.; wt. 1.36 kg.
- (c) Murray River, South Australia; ad. ♂; H. and B. 504 mm.; wt. 2.75 kg.

Echidna aculeata Shaw

- (a) Yavan Creek, Tumut district, New South Wales; ♂; H. and B. 470 mm.; wt. 2.72 kg.
- (b) Olangolah Creek, Otway Peninsula, Victoria; imm. ♂; H. and B. 406 mm.; wt. 1.82 kg.
- (c) Heathmere district, West Victoria; ad. ♂; H. and B. 530 mm.; wt. 5.90 kg.
- (d) Flinders Island, Bass Strait, Tasmania; ♀; H. and B. 450 mm.; wt. 3.64 kg.
- (e) Arthur River, West Tasmania; ♀; H. and B. 500 mm.; wt. 4.32 kg.
- (f) Macquarie River, East Tasmania; ♂; H. and B. 485 mm.; wt. 3.19 kg.
- (g) James Range, Central Australia; ♂; H. and B. 468 mm.; wt. 2.50 kg.
- (h) Kooringa, Mid-north South Australia; wt. 2.61 kg.

MARSUPIALIA

DASYURIDAE

Sminthopsis crassicaudata crassicaudata Gould

- (a) Moutajup, Grampian Range area, West Victoria; ad. ♀; H. and B. 82 mm.; wt. 11 g.
- (b) Murray Mallee, South Australia; ad. ♂; H. and B. 84 mm.; wt. 15 g.
- (c) *Ibid.*; ad. ♀; H. and B. 84 mm.; wt. 14 g.

Sminthopsis crassicaudata centralis Thomas (1)

- (a) West of Appamunna, Lower Diamantina River, South Australia; ad. ♀; H. and B. 83 mm.; wt. 10 g.

Sminthopsis leucopus Gray

- (a) Heathmere, West Victoria; ad. ♂; H. and B. 98 mm.; wt. 32 g.

Antechinomys spenceri Thomas

- (a) East of Erliwunyawunya, Musgrave Range, North-West South Australia; imm. ♀; H. and B. 85 mm.; wt. 14 g.

Chaetocercus cristicauda Krefft

- (a) Chundrinna, Everard Range, North-West South Australia; subad. ♀; H. and B. 133 mm.; wt. 68 g.
 (b) *Ibid.*; ad. ♂; H. and B. 160 mm.; wt. 122 g.
 (c) South of Koonapandi, Musgrave Range, North-West South Australia; subad. ♀; H. and B. 130 mm.; wt. 60 g.

Chaetocercus cristicauda hillieri Thomas (2)

- (a) Cooncheri, Lower Diamantina River, South Australia; ad. ♂; H. and B. 190 mm.; wt. 175 g.

Phascogale flavipes Waterhouse

- (a) Waitpinga, Fleurieu Peninsula, South Australia; ad. ♂; H. and B. 112 mm.; wt. 49 g.
 (b) *Ibid.*; ad. ♀; H. and B. 104 mm.; wt. 24 g.
 (c) Mackenzie Creek, Grampian Range, West Victoria; imm. ♂; H. and B. 93 mm.; wt. 23.5 g.

Dasyurus vivverinus Shaw

- (a) Cradle Valley, North-west Tasmania; subad. ♀; H. and B. 298 mm.; wt. 690 g.
 (b) North Macquarie River, East Tasmania; ad. ♂; H. and B. 350 mm.; wt. 1.37 kg.
 (c) Tooms Lake, East Tasmania; ad. ♂ (melan.); H. and B. 355 mm.; wt. 1.37 kg.

Dasyurus geoffroyi Gould

- (a) Chundrinna, Everard Range, North-West South Australia; ad. ♀; H. and B. 290 mm.; wt. 550 g.

Dasyurus maculatus Kerr

- (a) Welcome River, North-west Tasmania; imm. ♂; H. and B. 425 mm.; wt. 1.60 kg.
 (b) *Ibid.*; ad. ♀; H. and B. 564 mm.; wt. 2.04 kg.
 (c) Cradle Valley, North-west Tasmania; ad. ♂; H. and B. 500 mm.; wt. 2.96 kg.

Sarcophilus harrissi Boitard

- (a) Welcome River, North-west Tasmania; imm. ♀; H. and B. 442 mm.; wt. 2.50 kg.
 (b) Arthur River, West Tasmania; imm. ♂; H. and B. 415 mm.; wt. 3.23 kg.
 (c) *Ibid.*; ad. ♀; H. and B. 550 mm.; 4.09 kg.
 (d) *Ibid.*; ad. ♂; H. and B. 615 mm.; 8.67 kg.

Myrmecobius fasciatus fasciatus Waterhouse

- (a) Narrogin, South-west district Western Australia; ad. ♂; H. and B. 242 mm.; wt. 293 g. (approx.).

Myrmecobius fasciatus rufus Wood Jones (3)

- (a) Oolarinna, Everard Range, South Australia; ad. ♀; H. and B. 262 mm.; wt. 347 g. (approx.).

PERAMELIDAE

Perameles gunni Gray

- (a) Ross, East Tasmania; subad. ♀; H. and B. 299 mm.; wt. 450 g.
 (b) Dunkeld, West Victoria; ad. ♀; H. and B. 313 mm.; wt. 550 g.

Isoodon auratus Ramsay

- Pundi, 70 miles west of Everard Range, North-west South Australia; subad. ♂; H. and B. 235 mm.; wt. 260 g.

Isoodon obesulus Shaw

- (a) West Sister Island, Bass Strait, Tasmania; ad. ♂; H. and B. 338 mm.; wt. 1.36 kg.
 (b) Blue Hill, Bothwell district, Tasmania; ad. ♂; H. and B. 357 mm.; wt. 1.36 kg.
 (c) *Ibid.*; ad. ♀; H. and B. 355 mm.; wt. 1.13 kg.

Thalacomys lagotis Reid

- (a) Kings Creek, George Gill Range, Central Australia; ad. ♀; H. and B. 335 mm.; wt. 1.37 kg.
 (b) Ewellina, Musgrave Range, North-west South Australia; ad. ♂; H. and B. 428 mm.; wt. 1.70 kg.
 (c) *Ibid.*; imm. ♂; H. and B. 268 mm.; wt. 450 g.

Thalacomys lagotis sagitta Thomas (4)

- (a) Goyder's Lagoon, Lower Diamantina River, South Australia; aged ♂; H. and B. 385 mm.; wt. 1.56 kg.
 (b) *Ibid.*; ad. ♀; H. and B. 291 mm.; wt. 660 g.
 (c) *Ibid.*; imm. ♂; H. and B. 212 mm.; wt. 210 g.

Thalacomys minor miscivus Finlayson (5) (6)

- (a) Cooncheri, Lower Diamantina River, South Australia; ad. ♂; H. and B. 241 mm.; wt. 435 g.
 (b) *Ibid.*; ad. ♀; H. and B. 247 mm.; wt. 312 g.
 (c) *Ibid.*; imm. ♂; H. and B. 193 mm.; wt. 212 g.

Choeropus castanotis Gray

- (a) Macdonnell Range, Central Australia; imm. ♀; H. and B. 165 mm.; wt. 153 g. (approx.).

Notoryctes typhlops Stirling

- (a) Ooldea district, South Australia; ad. ♀; H. and B. 114 mm.; wt. 66 g. (approx.).
 (b) Liddle's Hills, Bascow Range area, Central Australia; H. and B. 120 mm.; wt. 71 g. (approx.).

Notoryctes typhlops caurinus Thomas

- Sturt Creek, Kimberley Division, Western Australia; imm. ♂; H. and B. 94 mm.; wt. 47 g. (approx.).

PHALANGERIDAE

Acrobales pygmaeus Shaw (7)

- (a) Coomoooolaroo, Dawson Valley, Queensland; ad. ♂; H. and B. 75 mm.; wt. 14 g. (approx.).
 (b) Fitzroy River, Rockhampton district, Queensland; ad. ♀; H. and B. 73 mm.; wt. 12 g. (approx.).

Dromicia concinna Gould

- (a) Heathmere, West Victoria; ad. ♀; H. and B. 91 mm.; wt. 21.5 g.
- (b) Meningie, Lake Alexandrina, South Australia; ad. ♂; H. and B. 81 mm.; wt. 19 g.
- (c) Torrensvale, Fleurieu Peninsula, South Australia; ad. ♀; H. and B. 77 mm.; wt. 16 g.

Petaurus breviceps Waterhouse (8)

- (a) Penola, South-East district, South Australia; ad. ♂; H. and B. 163 mm.; wt. 130 g.
- (b) *Ibid.*; aged ♀; wt. 90 g.

Trichosurus vulpecula Kerr

- (a) Cradle Valley, North-west Tasmania; ad. ♀ (grey phase); H. and B. 495 mm.; wt. 4.10 kg.
- (b) *Ibid.*; imm. ♂ (grey phase); H. and B. 400 mm.; wt. 1.81 kg.
- (c) Gorae, West Victoria; ad. ♂; H. and B. 546 mm.; wt. 3.63 kg.
- (d) Heathmere, West Victoria; subad. ♀; H. and B. 362 mm.; wt. 1.75 kg.
- (e) Pecaree, South-East district of South Australia; ad. ♂; H. and B. 440 mm.; wt. 3.07 kg.
- (f) A garden, Adelaide, South Australia; subad. ♂; H. and B. 405 mm.; wt. 1.75 kg.
- (g) Palana, Flinders Island, Bass Strait, Tasmania; ad. ♀; H. and B. 502 mm.; wt. 4.09 kg.
- (h) Choorlabinna, Musgrave Range, North-west South Australia; ad. ♂; H. and B. 390 mm.; wt. 1.37 kg.
- (i) Eewellina, Musgrave Range, North-west South Australia; ad. ♀; H. and B. 372 mm.; wt. 1.48 kg.
- (j) Wollara, Basedow Range area, Central Australia; subad. ♂; H. and B. 313 mm.; wt. 910 g.
- (k) Thangool, Callide Valley, Queensland; subad. ♀; H. and B. 410 mm.; wt. 1.36 kg. (9).

Trichosurus caninus Ogilby

- (a) Upper Ryan's Creek, North-east Victoria; ad. ♀; H. and B. 508 mm.; wt. 2.73 kg.
- (b) *Ibid.*; subad. ♂; H. and B. 476 mm.; wt. 2.16 kg.

Petauroides volans volans Kerr (10)

- (a) Green Hills Forest, Batlow district, New South Wales; ad. ♀; H. and B. 440 mm.; wt. 1.36 kg.
- (b) *Ibid.*; subad. ♂; H. and B. 415 mm.; wt. 1.02 kg.

Pseudochirus laniginosus Gould

- (a) Hatherleigh, South-East district, South Australia; ad. ♂; H. and B. 305 mm.; wt. 800 g.
- (b) *Ibid.*; ad. ♀; H. and B. 318 mm.; wt. 800 g.
- (c) Glencorrie, Fleurieu Peninsula, South Australia; imm. ♂; H. and B. 161 mm.; wt. 140 g.
- (d) A garden, Adelaide, South Australia; subad. ♂; H. and B. 270 mm.; wt. 550 g.

- (e) Williamstown, North Mount Lofty Range, South Australia; ad. ♂; H. and B. 300 mm.; wt. 700 g.
 (f) Penrice, Lower North district, South Australia; ad. ♀; H. and B. 310 mm.; wt. 700 g.

Pseudochirus cooki Desmarest

- (a) Blue Hills, Bothwell, Tasmania; ad. ♀; H. and B. 357 mm.; wt. 1.36 kg.
 (b) Macquarie River, East Tasmania; imm. ♂; H. and B. 290 mm.; wt. 570 g.
 (c) *Ibid.*; subad. ♀; H. and B. 325 mm.; wt. 900 g.

Phascolarctos cinereus adustus Thomas (11)

- (a) Kariboe Creek, Callide Valley, Queensland; aged ♂; H. and B. 665 mm.; wt. 6.36 kg.
 (b) Coomoooolaroo, Dawson Valley, Queensland; aged ♀; H. and B. 635 mm.; wt. 5.45 kg.

Phascolarctos cinereus victor Troughton (12)

- (a) French Island, Westernport Bay, Victoria; ad. ♂; H. and B. 830 mm.; wt. 14.09 kg.
 (b) *Ibid.*; ad. ♀; H. and B. 730 mm.; wt. 8.82 kg.
 (c) *Ibid.*; imm. ♂; H. and B. 673 mm.; wt. 7.27 kg.

Tarsipes rostratus Gervais and Verreaux

- (a) South-west Western Australia; ad. ♂; H. and B. 78 mm.; wt. 13 g. (approx.).
 (b) *Ibid.*; ad. ♀; H. and B. 81 mm.; wt. 17 g. (approx.).

MACROPODIDAE

Hypsiprymnodon moschatus Ramsay

- (a) Gorge Range, Ingham district, North Queensland; ad. ♂; H. and B. 325 mm.; wt. 500 g. (approx.).

Potorous tridactylus Kerr

- (a) Upper Macquarie River, East Tasmania; ad. ♂; H. and B. 385 mm.; wt. 1.81 kg.
 (b) Blue Hills, Bothwell, Tasmania; ad. ♀, H. and B. 350 mm.; wt. 1.36 kg.
 (c) *Ibid.*; imm. ♂; H. and B. 305 mm.; wt. 950 g.
 (d) Gorae, West Victoria; imm. ♂; H. and B. 305 mm.; wt. 690 g.
 (e) *Ibid.*; imm. ♂, H. and B. 336 mm.; wt. 950 g. (13).⁽²⁾

Caloprymnus campestris Gould (14) (15)

- (a) Cooncheri, Lower Diamantina River, South Australia; ad. ♀; H. and B. 277 mm.; wt. 1.06 kg.
 (b) *Ibid.*; subad. ♂; H. and B. 282 mm.; wt. 850 g.
 (c) *Ibid.*; imm. ♀; H. and B. 163 mm.; wt. 195 g.

Bettongia lesueuri Quoy and Gaimard

- (a) Yaringa, south-west of George Gill Range, Central Australia; subad. ♀; H. and B. 285 mm.; wt. 910 g.
 (b) Desolation Glen, Rawlinson Range, Western Australia; subad. ♀; H. and B. 245 mm.; wt. 770 g.

⁽²⁾ The weight formerly quoted (850 g.) was a typographical error.

Bettongia cuniculus Ogilby

- (a) Macquarie River, East Tasmania; ad. ♂; H. and B. 325 mm.; wt. 1.59 kg.

Aepyprymnus rufescens Gray (16)

- (a) Thangool, Callide Valley, Queensland; ad. ♂; H. and B. 383 mm.; wt. 2.50 kg.
 (b) *Ibid.*; subad. ♀; H. and B. 387 mm.; wt. 3.19 kg.

Lagorchestes hirsutus Gould

- (a) South of Koonapandi, Musgrave Range area, North-west South Australia; ad. ♀; H. and B. 338 mm.; wt. 1.70 kg.
 (b) *Ibid.*; subad. ♂; H. and B. 325 mm.; wt. 1.59 kg.
 (c) Pundi, west of Everard Range, North-west South Australia; imm. ♂; H. and B. 200 mm.; wt. 275 g.

Lagorchestes conspicillatus Gould

- (a) Maree Plain, north of James Range, Central Australia; ad. ♀; H. and B. 400 mm.; wt. 3.00 kg.
 (b) *Ibid.*; subad. ♂; H. and B. 400 mm.; wt. 3.00 kg.

Petrogale penicillata herberti Thomas (17)

- (a) Spring Creek, Taroom district, Queensland; ad. ♂; H. and B. 535 mm.; wt. 5.90 kg.
 (b) *Ibid.*; subad. ♀; H. and B. 515 mm.; wt. 5.00 kg.

Petrogale xanthopus Gray

- (a) Oraparinna, Flinders Range, South Australia; ad. ♀; H. and B. 570 mm.; wt. 7.50 kg.
 (b) *Ibid.*; subad. ♂; H. and B. 550 mm.; wt. 6.36 kg.
 (c) Mount Norwest, Willouran Hills, South Australia; aged ♀; H. and B. 490 mm.; wt. 6.13 kg.

Petrogale lateralis Gould (18)

- (a) Erliwunyawunya, Musgrave Range, North-west South Australia; ad. ♂; H. and B. 498 mm.; wt. 5.00 kg.
 (b) King's Creek, George Gill Range, Central Australia; subad. ♀; H. and B. 425 mm.; wt. 3.63 kg.
 (c) Glen Edith, west of James Range, Central Australia; aged ♀; H. and B. 465 mm.; wt. 3.50 kg.

Macropus (Thylogale) eugenii Desmarest

- (a) Rocky River, Kangaroo Island, South Australia; imm. ♀; H. and B. 475 mm.; wt. 4.09 kg.
 (b) *Ibid.*; subad. ♀; H. and B. 495 mm.; wt. 5.00 kg.
 (c) *Ibid.*; ad. ♂; H. and B. 600 mm.; wt. 7.95 kg.

Macropus (Thylogale) flindersi Wood-Jones

- (a) Flinders Island, Eyre Peninsula, South Australia; ad. ♂; H. and B. 545 mm.; wt. 6.13 kg.
 (b) *Ibid.*; ad. ♀; H. and B. 462 mm.; wt. 5.00 kg.

Macropus (Thylogale) billardieri Desmarest

- (a) West Sister Island, Bass Strait, Tasmania; ad. ♂; H. and B. 623 mm.; wt. 9.09 kg.

- (b) Flinders Island, Bass Strait, Tasmania; ad. ♀ H. and B. 570 mm.; wt. 7.50 kg.
- (c) Marcus River, North-west Tasmania; young ad. ♂; H. and B. 520 mm.; wt. 6.36 kg.
- (d) Macquarie River, East Tasmania; subad. ♀; H. and B. 442 mm.; wt. 3.18 kg.
- (e) Blue Hills, Bothwell, Tasmania (central); subad. ♂; H. and B. 427 mm.; wt. 2.72 kg.
- (f) Macquarie River, East Tasmania; imm. ♂; H. and B. 349 mm.; wt. 1.36 kg.

Macropus (wallabia) ruficollis ruficollis Desmarest (19)

- (a) Yavan Creek, Tumut district, New South Wales; imm. ♀; H. and B. 627 mm.; wt. 8.18 kg.
- (b) Heathmere, West Victoria; ad. ♂; H. and B. 785 mm.; wt. 24.09 kg.
- (c) Mount Abrupt, Granpian Range, Victoria; ad. ♀; H. and B. 685 mm.; wt. 13.63 kg.
- (d) Black Range, South-East district, South Australia; ad. ♂; H. and B. 703 mm.; wt. 16.81 kg.
- (e) Furner, South-East district, South Australia; ad. ♀; H. and B. 662 mm.; wt. 14.09 kg.

Macropus (wallabia) ruficollis bennetti Waterhouse

- (a) Macquarie River, East Tasmania; imm. ♀; H. and B. 545 mm.; wt. 5.90 kg.
- (b) Welcome River, North-west Tasmania; imm. ♀; H. and B. 620 mm.; wt. 9.09 kg.
- (c) Palana, Flinders Island, Bass Strait, Tasmania; imm. ♂; H. and B. 613 mm.; wt. 10.67 kg.
- (d) *Ibid.*; ad. ♀; H. and B. 655 mm.; wt. 14.09 kg.
- (e) Stanley Point, Flinders Island, Bass Strait, Tasmania; ad. ♂; H. and B. 770 mm.; wt. 24.54 kg.
- (f) Arthur River, West Tasmania; ad. ♂; H. and B. 740 mm.; wt. 22.72 kg.

Macropus (wallabia) ualabatus ualabatus Lesson and Garnot

- (a) Blunt's Gully; Ryan's Creek, North-east Victoria; aged ♂; H. and B. 800 mm.; wt. 18.18 kg.
- (b) Hillas Brook, Tumut district, New South Wales; ad. ♀; H. and B. 760 mm.; wt. 14.79 kg.
- (c) *Ibid.*; imm. ♂; H. and B. 500 mm.; wt. 4.31 kg.

Macropus (wallabia) agilis Gould (20)

- (a) Serpentine Creek, Rockhampton district, Queensland; subad. ♂; H. and B. 725 mm.; wt. 17.73 kg.
- (b) *Ibid.*; subad. ♀; H. and B. 643 mm.; wt. 12.27 kg.

Macropus (wallabia) dorsalis Gray (21)

- (a) Mount Lookerbie, Dawson Valley, Queensland; imm. ♀; H. and B. 450 mm.; wt. 3.18 kg.
- (b) *Ibid.*; imm. ♂; H. and B. 540 mm.; wt. 5.45 kg.
- (c) *Ibid.*; subad. ♂; H. and B. 570 mm.; wt. 7.73 kg.
- (d) Spring Creek, Upper Dawson Valley, Queensland; ad. ♂ 720 mm.; wt. 15.90 kg.

Macropus (wallabia) greyi Gray (22)

- (a) Clay Wells, South-East District, South Australia; aged ♀ (emaciated); H. and B. 648 mm.; wt. 5.97 kg.

Macropus (wallabia) parryi Bennett (23)

- (a) Drumburle, Grevillea Plateau, Queensland; ad. ♂; H. and B. 805 mm.; 22.72 kg.
 (b) *Ibid.*; ad. ♀; H. and B. 790 mm.; 15.45 kg.
 (c) *Ibid.*; imm. ♀; H. and B. 597 mm.; 8.64 kg.
 (d) *Ibid.*; imm. ♀ (large pouch young); H. and B. 405 mm.; 1.82 kg.

Macropus giganteus giganteus Zimmermann (24)

- (a) Coomoooolaroo, Dawson Valley, Queensland; aged ♂; H. and B. 1,110 mm.; wt. 50.09 kg.
 (b) Drumburle, Grevillea Plateau, Queensland; subad. ♀; H. and B. 835 mm.; wt. 22.70 kg.
 (c) Yavan Creek, Tumut district, New South Wales; subad. ♂; H. and B. 950 mm.; wt. 30.90 kg.
 (d) Gorae, West Victoria; imm. ♀; H. and B. 724 mm.; wt. 10.68 kg.
 (e) Jimmy's Creek, Grampian Range, Victoria; subad. ♂; H. and B. 900 mm.; wt. 25.23 kg.

Macropus giganteus melanops Gould

- (a) Padthaway, South-East district, South Australia; imm. ♀; H. and B. 576 mm.; wt. 5.45 kg.
 (b) Lake Wangary, Eyre Peninsula, South Australia; imm. ♂; H. and B. 850 mm.; wt. 20.90 kg.
 (c) Coombe, Ninety Mile Plains, South Australia; subad. ♂; H. and B. 870 mm.; wt. 25.90 kg.
 (d) Point Turton, Yorke Peninsula, South Australia; ad. ♂; H. and B. 1,055 mm.; wt. 46.82 kg.

Macropus giganteus fuliginosus Desmarest

- (a) Rocky River, Kangaroo Island, South Australia; ad. ♂; H. and B. 1,247 mm.; wt. 62.27 kg.
 (b) *Ibid.*; ad. ♀; H. and B. 845 mm.; wt. 25.22 kg.

Macropus giganteus tasmaniensis Le Souef

- (a) Mount Morrison, Ross district, Tasmania; imm. ♂; H. and B. 775 mm.; wt. 18.18 kg.
 (b) Quoin, Ross district, Tasmania; ad. ♀; H. and B. 835 mm.; wt. 22.74 kg.
 (c) Little Tier, North Macquarie River, Tasmania; ad. ♂; H. and B. 970 mm.; wt. 43.18 kg.

Macropus rufus Desmarest (25)

- (a) Old Boolcoomatta, North-east of South Australia; aged ♂; H. and B. 1,397 mm.; wt. 77.27 kg.
 (b) Tcherricoonanyi, Lower Diamantina River (25), South Australia; ad. ♀; H. and B. 970 mm.; wt. 33.18 kg.
 (c) Donald's Well, Musgrave Range, South Australia; imm. ♂; H. and B. 880 mm.; wt. 20.04 kg.
 (d) Wollara, Basedow Range area, Central Australia; imm. ♀; H. and B. 580 mm.; wt. 7.72 kg.

Macropus robustus robustus Gould (26)

- (a) Coomooboolaroo, Dawson Valley, Queensland; imm. ♀; H. and B. 570 mm.; wt. 6·81 kg.

Macropus robustus erubescens Selater

- (a) Mount Norwest, Willouran Hills, South Australia; ad. ♂; H. and B. 1,020 mm.; wt. 50·00 kg. (27).
 (b) *Ibid.*; ad. ♀; H. and B. 800 mm.; wt. 22·72 kg.
 (c) *Ibid.*; imm. ♂; H. and B. 740 mm.; wt. 15·68 kg.
 (d) Oparinna, Flinders Range, South Australia; subad. ♂; H. and B. 970 mm.; wt. 37·73 kg.

Macropus robustus woodwardi Thomas

- (a) Deception Creek, James Range, Central Australia; ad. ♂; H. and B. 890 mm.; 40·22 kg.
 (b) Ernabella, Musgrave Range, South Australia; imm. ♂; H. and B. 748 mm.; wt. 20·00 kg.
 (c) *Ibid.*; imm. ♀; H. and B. 715 mm.; wt. 15·45 kg.
 (d) Oparinna, Musgrave Range, South Australia; imm. ♂ (pouch young); H. and B. 355 mm.; wt. 909 g.

PHASCOLOMYIDAE

Phascolomys mitchelli Owen

- (a) Hillas Brook, Tumut district, New South Wales; aged ♂; H. and B. 960 mm.; wt. 23·18 kg.
 (b) Pecaree, South-East district, South Australia; subad. ♂; H. and B. 800 mm.; wt. 19·54 kg.
 (c) *Ibid.*; subad. ♀; H. and B. 850 mm.; wt. 21·81 kg.

Phascolomys ursinus Shaw

- (a) Palana, Flinders Island, Bass Strait, Tasmania; ad. ♀; H. and B. 830 mm.; wt. 21·36 kg.
 (b) *Ibid.*; ad. ♂; H. and B. 807 mm.; wt. 16·59 kg.
 (c) *Ibid.*; imm. ♀; H. and B. 660 mm.; wt. 7·27 kg.

Phascolomys tasmaniensis Spencer and Kershaw

- (a) Cradle Valley, North-west Tasmania; ad. ♂; H. and B. 935 mm.; wt. 27·22 kg.
 (b) *Ibid.*; ad. ♀; H. and B. 875 mm.; wt. 22·72 kg.
 (c) Quoin, Ross district, Tasmania; subad. ♂; H. and B. 805 mm.; wt. 20·90 kg.
 (d) Meadsfield, Bothwell, Tasmania; imm. ♀; H. and B. 695 mm.; wt. 9·77 kg.

Lasiorhinus latifrons Owen.

- (a) Portee, River Murray, South Australia; ad. ♂; H. and B. 991 mm.; wt. 25·45 kg.
 (b) *Ibid.*; ad. ♀; H. and B. 1,020 mm.; wt. 27·27 kg.

MONODELPHIA

Pteropus scapulatus Peters

- (a) Coomooboolaroo, Dawson Valley, Queensland; ad. ♀; H. and B. 230 mm.; wt. 280 g. ca. (28).

- (b) Cape Kersaint, Kangaroo Island, South Australia; ad. ♂; H. and B. 190 mm.; 270 g.

Arctocephalus cinereus Peron

- (a) Outer Waldegrave Island, Eyre Peninsula, South Australia; imm. ♂; H. and B. 1,000 mm.; wt. 21.36 kg.

Canis familiaris dingo Blumenbach

- (a) Oparinna, Musgrave Range, South Australia; ad. ♂; H. and B. 870 mm.; 14.09 kg.
 (b) Ooleebinna, Musgrave Range, South Australia; ad. ♂; cranial length 211 mm.; wt. 16.36 kg.

Vulpes vulpes Linne

- (a) Oraparinna, Flinders Range, South Australia; ad. ♀; H. and B. 550 mm.; wt. 6.16 kg.
 (b) Dashwood's Gully, Mount Lofty Range, South Australia; aged ♂; H. and B. 700 mm.; wt. 5.68 kg.

Cervus (Dama) dama Linne

- (a) Little Tier, North Macquarie River, Tasmania; imm. ♀ (feral); H. and B. 1,000 mm.; wt. 19.09 kg.

Oryctolagus cuniculus Linne

- (a) Moutajup, Grampian Range area, West Victoria; ad. ♂; H. and B. 495 mm.; wt. 1.75 kg.
 (b) Dashwood's Gully, Mount Lofty Range, South Australia; ad. ♂; H. and B. 465 mm.; wt. 2.16 kg.
 (c) Cooncheri, Lower Diamantina River, South Australia; imm. ♀; H. and B. 400 mm.; wt. 680 g.
 (d) Chundrinna, Everard Range, South Australia; ad. ♂; H. and B. 425 mm.; wt. 2.04 kg.
 (e) Spilsby Island, Spencer's Gulf, South Australia; ad. ♂; H. and B. 485 mm.; wt. 1.70 kg.

Lepus europaeus Linne

- (a) Julia Range, Lower North district, South Australia; ad. ♀; H. and B. 590 mm.; wt. 3.07 kg.
 (b) Point Turton, Yorke Peninsula, South Australia; ad. ♀; H. and B. 615 mm.; wt. 3.18 kg.

Rattus villosissimus villosissimus (Waite) (29)

- (a) Appamunna, Lower Diamantina River, South Australia; ad. ♂; H. and B. 188 mm.; wt. 185 g.
 (b) *Ibid.*; imm. ♂; H. and B. 140 mm.; wt. 90 g.
 (c) *Ibid.*; ad. ♀; H. and B. 195 mm.; wt. 175 g.

Rattus greyi greyi Gray

- (a) Callawonga Creek, Fleurieu Peninsula, South Australia; ad. ♂; H. and B. 139 mm.; wt. 82 g.
 (b) Boat Harbour Creek, Fleurieu Peninsula, South Australia; ad. ♂; H. and B. 157 mm.; wt. 112 g.
 (c) *Ibid.*; ad. ♀; H. and B. 139 mm.; wt. 90 g.
 (d) *Ibid.*; imm. ♀; H. and B. 122 mm.; wt. 51 g.

Rattus greyi peccatus (Troughton)

- (a) Heathmere, West Victoria; ad. ♀; H. and B. 159 mm.; wt. 100 g.
- (b) *Ibid.*; ad. ♂; H. and B. 169 mm.; wt. 130 g.

Rattus lutreola lutreola Gray (30)

- (a) Rat Island, Lake Alexandrina, South Australia; ad. ♂; H. and B. 173 mm.; wt. 190 g.
- (b) *Ibid.*; ad. ♀; H. and B. 178 mm.; wt. 190 g.
- (c) Wannon River, Yarram Gap, Grampian Range, Victoria; subad. ♀; 162 mm.; wt. 148 g.
- (d) Blackfellows Creek, Fleurieu Peninsula, South Australia; subad. ♂; H. and B. 156 mm.; wt. 130 g.
- (e) Heathmere, West Victoria; imm. ♀; H. and B. 134 mm.; wt. 70 g.
- (f) Mount Clay Range, West Victoria; imm. ♀; H. and B. 98 mm.; wt. 26 g.

Rattus rattus rattus Linné.

- (a) Mackenzie River, Grampian Range, Victoria; ad. ♀; H. and B. 179 mm.; wt. 168 g.

Rattus rattus alexandrinus Geoffroy

- (a) Jimmy's Creek, Grampian Range, Victoria; ad. ♂; H. and B. 189 mm.; wt. 178 g.
- (b) A garden, Adelaide, South Australia; ad. ♀; H. and B. 190 mm.; wt. 190 g.

Rattus norvegicus Erxleben

- (a) Meadsfield, Bothwell district, Tasmania, ad. ♂; H. and B. 262 mm.; wt. 445 g.
- (b) A garden, Adelaide, South Australia; subad. ♀; H. and B. 206 mm.; wt. 200 g.
- (c) *Ibid.*; imm. ♂; H. and B. 145 mm.; wt. 100 g.

Mus musculus Linne (31)

- (a) A house, Adelaide, South Australia; ad. ♂; H. and B. 83 mm.; wt. 19 g.
- (b) *Ibid.*; ad. ♀; H. and B. 86 mm.; wt. 22 g.
- (c) Boat Harbour Creek, Fleurieu Peninsula, South Australia; ♂; H. and B. 83 mm.; wt. 11.5 g.
- (d) Ernabella, Musgrave Range, South Australia; ad. ♂; H. and B. 80 mm.; wt. 9 g.

Pseudomys (Pseudomys) higginsii Trouessart (32)

- (a) Cradle Valley, North-west Tasmania; ad. ♂; H. and B. 132 mm.; wt. 75 g. (approx.).

Pseudomys (Pseudomys) minnie Troughton (33)

- (a) Appamunna, Lower Diamantina River, South Australia; aged ♂; H. and B. 131 mm.; wt. 80 g.
- (b) *Ibid.*; ad. ♀; H. and B. 134 mm.; wt. 75 g.
- (c) *Ibid.*; imm. ♂; H. and B. 115 mm.; wt. 44 g.

Pseudomys (Thetomys) nanus Gould (34)

- (a) Koonapandi, Musgrave Range, South Australia; ad. ♂; H. and B. 101 mm.; wt. 28.5 g.

Pseudomys (Laggadina) hermannsburgensis hermannsburgensis Waite (35)

- (a) Wollara, Basedow Range area, Central Australia; ad. ♂; H. and B. 74 mm.; wt. 14.5 g.
 (b) Ernabella, Musgrave Range, South Australia; ad. ♀; H. and B. 80 mm.; wt. 13 g.
 (c) Chundrinna, Everard Range area, South Australia; subad. ♀; H. and B. 71 mm. wt. 7.5 g.

Pseudomys (Gyomys) apodemoides Finlayson (36-37)

- (a) Coombe, Ninety Mile Plains, South Australia; ad. ♂; H. and B. 86 mm.; wt. 16 g.
 (b) *Ibid.*; ad. ♀; H. and B. 93 mm.; wt. 18 g.
 (c) *Ibid.*; imm. ♂; H. and B. 70 mm.; wt. 9 g.

Mastacomys fuscus Thomas (38)

- (a) Cradle Valley, North-west Tasmania; ad. ♀; H. and B. 168 mm.; wt. 160 g. (approx.).

Hydromys chrysogaster fulvolavatus Gould

- (a) Fulham, Torrens Creek, South Australia; ad. ♂; H. and B. 343 mm.; wt. 985 g.
 (b) *Ibid.*; ad. ♀; H. and B. 310 mm.; wt. 700 g.
 (c) Mosquito Creek, South-East district, South Australia; imm. ♂; H. and B. 292 mm.; wt. 390 g.
 (d) Furner, South-East district, South Australia; imm. ♀; H. and B. 293 mm.; wt. 425 g.

Hydromys chrysogaster var. (39)

- (a) Innamincka, Barcoo River, South Australia; ad. ♀; H. and B., 355 mm.; wt. 500 g.

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THE CHARNOCKITIC AND ASSOCIATED ROCKS OF NORTH-WESTERN SOUTH AUSTRALIA

BY ALLAN F. WILSON

Summary

This paper is the first of a proposed series dealing with the geology of the Musgrave Ranges. Some features of the major rock types are outlined below, and other papers are in preparation which will amplify and supplement this introductory account. Ultimately the petrogenesis of this new series of "Charnockitic" rocks will be treated.

**THE CHARNOCKITIC AND ASSOCIATED ROCKS OF
NORTH-WESTERN SOUTH AUSTRALIA**

PART I THE MUSGRAVE RANGES—AN INTRODUCTORY ACCOUNT

By **ALLAN F. WILSON***

[Read 8 May 1947]

PLATES II TO IV AND GEOLOGICAL MAP

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A. INTRODUCTION

This paper is the first of a proposed series dealing with the geology of the Musgrave Ranges. Some features of the major rock types are outlined below, and other papers are in preparation which will amplify and supplement this introductory account. Ultimately the petrogenesis of this new series of "Charnockitic" rocks will be treated.

PREVIOUS WORK

A bibliography of previous workers in the Musgrave Ranges is appended. The two most notable contributions to our knowledge are those of Basedow (1905) and Jack (1915). Basedow's account covers the reconnaissance of the South

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Australian Government North-West Prospecting Expedition of 1903 which penetrated further west than the Musgraves, into the Mann and Tomkinson Ranges and to the Western Australian border. Jack's work was carried out in an abnormally dry season (1914). Consequently most of his time was spent to the south-east of the author's area. Notwithstanding, the accounts of both Basedow and Jack contain valuable observations, to which reference will be made in later papers.

LOCALITY AND TERRAIN

The Musgrave Ranges are the easternmost of a series of rugged east-west mountain chains in the far North-West of South Australia.

These ranges begin in the east with bold desert-red Sentinel Hill (180 miles west of the Adelaide to Alice Springs railway line at Finke, Northern Territory). [See locality plan, p. 199.] As one continues westward from Sentinel Hill the Musgraves grow in magnitude and area, but are never more than 30 miles from north to south. They reach their culmination in the mountains in the vicinity of Mount Woodroffe, 5,000 feet above sea level, and 3,000 feet above the desert plain. This range continues west for over 100 miles, but a spur passes west-north-west through Opparinna and thence into the Petermann Ranges within the Northern Territory. To the west of the Musgraves, the Mann and then the Tomkinson Ranges continue almost into Western Australia.

A characteristic feature of the Musgrave Ranges is the abrupt manner in which most of the mountains rise from the plain. Groups of precipitous island-like hills punctuate the flat plains, which are bounded on either side by precipitous mountain ranges. Such rugged scenery creates a strong impression of some Norwegian fiord. This illusion is greatly accentuated by the lengthening shadows of evening.

The main area under consideration (see map) comprises the ranges from Kenmore Park (approximately longitude $132^{\circ} 30' E.$), westward for 50 miles to Mount Woodroffe and Erlywanyawanya (approximately longitude $131^{\circ} 40'$). Latitude $26^{\circ} 15' S.$ runs through the centre of the ranges. Most detailed work, however, was done within a few miles of the Presbyterian Mission Station at Ernabella.

The period of the two field operations undertaken in the Musgraves was during the most exhausting time of the year—that of the Central Australian summer. The first occasion was during December 1943, January and February 1944, followed by a second in December 1945 and January 1946, these periods being the only times available for the purpose. With Ernabella as the base of the survey, the ranges were investigated by horse, camel, and motor truck, but largely on foot. Transport difficulties and seasonal conditions limited the most intensive work to a radius of 10 miles from the base. Considerable reconnaissance and some detailed work was carried out over a wide area, as far west as Mount Woodroffe and Erlywanyawanya, and Kenmore Park in the east. Positions of camp sites and consequent geological work were often hampered by water difficulties.

CONCERNING MAPS AND METHODS

In 1892 Carruthers published a map of the north-west of South Australia, on a scale of $\frac{1}{8}$ inch to 1 mile. This appears to have been the basis of maps used by all later expeditions to the north-west. When a map of the Central and Eastern Musgraves was needed, existing maps, which had their uses for general purposes, were inadequate for more detailed work. Hence I was compelled to make my own maps, and used rough theodolite and compass methods for speed. The six-trigged points of Carruthers which fell within my area were incorporated.

with the exception of that of Mount Everard. The actual location of the latter is unknown to the author and to all at Ernabella. Nor do the natives know of any trigged mountain in the plotted position of Mount Everard. The map of the vicinity of Ernabella was prepared on a scale of 4 inches to 1 mile. The larger area was prepared on a scale of $\frac{3}{4}$ inch to 1 mile, using some of Carruthers' data when my own data and time were insufficient. Numerous panoramic photographs were used to check as much detail as possible. Some truck mileages were incorporated.

Owing to difficulty in location of parts of the track from Ernabella to Kenmore Park, reliance had to be placed on truck mileages and compass readings. With the truck "mileages" in need of calibration certain parts must be regarded as sketch maps. This applies also to the area just north of Alarka, the vicinity of the "pass" to the east of Ombaganda, near Fig Tree Gully Soak and Upan Downs.

A prismatic compass has only limited use in these ranges. The magnetic variation was found to be $4\frac{1}{2}^{\circ}$ to the east of true north. The rocks of the area greatly affect the compass, so much so that great care must be taken if that instrument is to be used among the mountains. When on the plains, accurate readings can be obtained. The magnetic variation is usually very erratic. Even on the same hill I have noticed a difference of up to 5° to 6° between readings taken sitting and standing, although exactly in the same place. Bearings taken when one is enclosed in rugged ravines are often well-nigh useless. Many bearings were found, on checking, to be hopelessly inaccurate. The only way to take a reasonable compass reading was found to be by standing in such a position that the interfering rock is equally distributed on all sides. Such being the case, a compass survey was often found most tedious. Some type of sun-compass would doubtless be easier to manage.

Aboriginal names were used on the map where possible. Care must be taken with these, however, for native place-names are rarely as precise in meaning as our own. For instance, while pointing to Mount Spec, the author was told that its aboriginal name is "Inindi." But it was later discovered that the mountain has no particular native name, but that "Inindi" refers to the "region" of the rock hole situated at a considerable distance to the south-west. The probable explanation is that to the aboriginal the formidable and barren Mount Spec has no need for a name, so when pestered by the white man for one, the nearest he can give is "Inindi." Similarly, "Tjatjanja" (or "Tjatja") probably refers to a rock hole the south of the mountain given that name. "Itjimpiri" to the aboriginal denotes the series of rock holes to the east of the imposing mountain mass which the missionaries at Ernabella call Mount Itjimpiri.

In the absence of suitable aboriginal names several were coined. The origin of most of these will be obvious, but some need explanation. "Trudinger Pass" (suitable for horses but found difficult for camels) was named after Ronald Trudinger, friend and host at the Ernabella Mission. "Brock Pass" (probably negotiable with camels) was named after Richard Brock, who accompanied the author on the second expedition. "Henderson Rock Hole" is a fine water about which the aboriginals apparently know very little because it is just above a big cliff and away from normal hunting grounds. It was discovered while descending Mount Woodroffe and was named after Ronald Henderson, who skilfully drove the truck through the nearby difficult Brown's Pass.

The large bare water catchments of the Musgrave Ranges make rock holes fairly common, but very few are reliable. On the accompanying map all reasonably useful waters are shown, that is, those which were found with some water during the two dry seasons of the author's visit.

When vertical aerial photographs are taken⁽²⁾ many parts of the accompanying map will, of course, need to be somewhat modified. However, it is considered that the map is a definite contribution to our present knowledge of the area, and little difficulty should be experienced in locating any position marked on the map. Therefore, apart from the geology represented, the location of various features of the area (rock holes, passes, etc.) seems to justify its publication.

THE TERM "CHARNOCKITE"

The ranges comprise a complex mixture of gneisses and ancient but later deep-seated non-gneissic igneous rocks. Numerous dolerite dykes cut all of these earlier systems. All rocks of the Musgrave Ranges are of Precambrian age excepting, of course, the thick mantle of Recent red desert sands and loams of the valleys between the ranges.

Most of the Musgrave Ranges rocks, both the gneissic and non-gneissic types, are hypersthene-bearing. Notable papers have been published in recent years treating Charnockites from several regions of the world, and it appears from the diverse origins which are claimed for these hypersthene-bearing igneous rocks, gneisses and granulites, that the term "Charnockite" has lost much of what it was originally intended to convey. However, for the present, until petrogenetic relationships in the Musgrave Ranges have been more fully interpreted, these rocks may well be called "The Charnockites and associated rocks of North-Western South Australia."

B. THE MAJOR ROCK TYPES

I. THE GNEISSES

UMBYARRA TO KENMORE PARK

At Umbyarra Bore ancient gneisses were first noticed on the track west from Finke. Umbyarra is 64 miles west of Finke in the Northern Territory. They outcrop as low hills amid remnants of horizontal sandstones of the late Mesozoic and early Cainozoic. At Umbyarra some pegmatites were observed, but most of these are barren. One pegmatite contains good crystals of muscovite and some tourmaline. The general trend of the pegmatites is N25° E. To the west the gneisses are more extensive, though they rarely form any more than low hills and inconspicuous outcrops in the mulga scrub.

About 2 miles west of Umbyarra Bore a prominent but low range of hills, about a mile and a half to the north of the track, was visited. This is probably typical of similar low lines of hills which protrude at intervals from the surrounding flat country. The hills consist of a non-foliated biotite-bearing granite; the flanks of the hills show excellent contacts with the ancient gneisses. Numerous chunks of gneiss were noticed to be partly "assimilated" by the granite. A few barren pegmatites are present.

Similar granitic gneisses continue to the west, but become more heavily injected by east-west dolerite dykes towards "The Gap," 122 miles from Finke, and approximately on the South Australian-Northern Territory border. At "The Gap" the gneisses show considerable crush. The dolerites are similar to those of the Musgrave Ranges. Basedow made observations concerning parts of this area of the "Ayers Ranges" (Basedow 1905, p. 78).

(2) Within a few days of presenting this paper to the Society a batch of 27 low-level oblique aerial photographs were sent to the author by courtesy of the Australian Geographical Society. These were taken with a view to publication in "Walkabout," the organ of the society, hence the prime purpose of the photographs was not cartographic. They show the northern part of the Ranges near Mount Woodroffe, Trudinger Pass, Alaka, Taljaritja and Wedge Hill. The photographs reasonably confirmed the accuracy of the map in these regions. A few minor alterations were made.

At Beefwood Creek, 135 miles west of Finke and a few miles south of the Northern Territory border, an interesting pyroxene granite intrudes the acid gneisses.

From Beefwood Creek the types of gneiss vary more frequently. The most common is granitic, but intermediate and basic types are plentiful. At Kenmore Park, nearly 180 miles west of Finke and just within the area covered by the map, the variety of gneisses is great. Garnet-bearing and/or hypersthene-

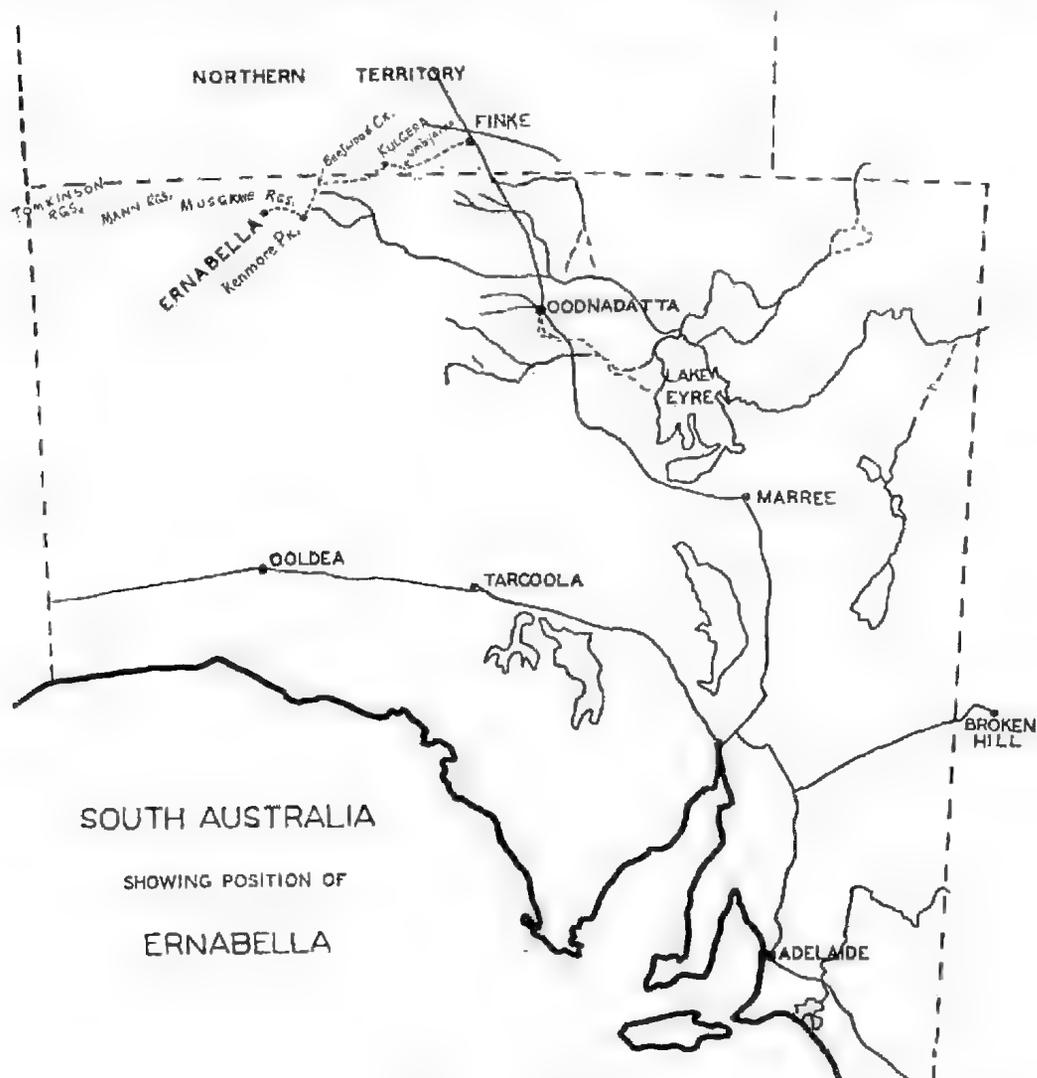


Fig. 1 Locality Plan

bearing gneisses are abundant. The general trend of all of these gneisses from Umbyarra to Kenmore Park is north to south. The dip varies from 60° - 70° to the east or west.

THE MAJOR AREA AND GENERAL FEATURES OF THE GNEISSES

The area to the west of Kenmore Park was studied in more detail. From the map, the importance in this area of gneisses and granulites is readily seen. Most of these gneissic rocks are a dove-grey colour with streaks of dull dark brown pyroxene and occasional black shining amphibole.

The map shows that the gneisses commonly have a north-south strike⁽³⁾ with a steep dip to the east. Towards the north-western part of the area, however, the strike of the gneisses swings around from a few degrees west of north to take on an almost east-north-east trend near Kuna-unpunja and Wardulka. The dips are such as to suggest that the western half of the area is part of the western limb of a south-pitching syncline. Anomalous dips and strikes are not uncommon, but most of these are close to junctions with the non-gneissic igneous rocks.⁽⁴⁾ These may represent minor buckling, reversal of dip and possible overthrusting related to the origin of the igneous rocks. Further detailed work is needed in critical areas.

The question of the origin of these gneissic rocks is difficult, and it would be premature at this stage of the investigation of the rocks of this region to state final conclusions as to their petrogenesis. However, certain suggestions are put forward, and these are linked with the ideas of "palingenesis" and "granitization" considered as having acted on a grand scale (see p. 209).

From the field evidence the author considers that the area consists of a series of ancient highly metamorphosed sediments whose eventual granitization has brought about most of the non-gneissic igneous rocks. However, in hand specimen, the sedimentary origin of the gneisses is usually not so obvious.

The following observations on some of these gneisses are not primarily concerned with the setting out of petrogenetic relations. These will appear in subsequent papers.

However, the order of the gneissic types is probably chronological: that is, the rocks first described are the oldest.

- (1) Gneisses showing sedimentary origin.
- (2) Gneisses not showing obvious sedimentary origin.
 - (a) Acidic gneisses without fluorescing zircon.
 - (b) More basic gneisses without fluorescing zircon.
- (3) Gneisses not showing obvious sedimentary origin, but showing fluorescing zircon.

(1) GNEISSES SHOWING SEDIMENTARY ORIGIN.

The gneisses showing an obvious sedimentary origin are not plentiful. The recognition of rocks as of sedimentary origin can often be difficult. In this area of charnockitic rocks, plutonic conditions resulting in palingenesis and granitization are assumed to have been in force for considerable periods. Rocks of the arkose type, if present under such conditions, could be presented in such a form as to defy recognition of their origin. Argillaceous and highly calcareous rocks probably could be more easily identified.

No rock was found which obviously came from a highly calcareous rock, but there are some for which an argillaceous origin is suspected. These areas are of limited extent:

- (1) part of the complex gneissic system to the south-west of Mount Caruthers;

⁽³⁾ The term "gneiss" is here used for rocks showing varying degrees of banding. The word "gneiss" is preferred to "foliated rock," since the banding is considered to represent the bedding planes of the original sediments, now gneissified. The terms "dip" and "strike" are therefore used to describe this banding. No schists were noted.

⁽⁴⁾ The term "non-gneissic igneous rock" is meant to convey the idea that the major igneous rocks of this area have been derived from sediments, the gneissic structure of which has become obliterated in the process of formation of the "igneous" masses.

- (2) possibly the greater part of the gneisses to the north-west of Palpatjara Well;
- (3) small patches 1 mile to the north-west of Taljaritja and 1½ miles to the west-south-west of Taljaritja;
- (4) patches 1 mile north-west of Top Springs;
- (5) patches up the Ernabella Creek from Top Springs;
- (6) some of the gneisses to the north-east of Eriwanyawanya Rock Hole;
- (7) 2½ miles due west of Mount Carruthers;
- (8) 1 mile north-east of Taljaritja Well.

These rocks contain variable amounts of at least four of the following minerals:—garnet, cordierite, sillimanite, biotite and a green spinel. The garnet is always visible in hand specimen as pink rounded crystals, usually about 2 mm. in diameter. The cordierite in the field is not noticeable in most specimens, though the presence of a "greasy" dull yellowish-brown with the garnet leads one to suspect that mineral. (But "greasiness" is by no means necessarily indicative of cordierite, for most of the hypersthene-bearing rocks of this area show some "greasiness".) Only in one locality, (7), has macroscopic sillimanite been observed. It occurs as brown crystals up to 2 cm. long. The dull dark green spinel shows very high absorption, so much so that with a cursory glance at a slide, one could quite easily overlook it, grouping it with the iron ores. It usually occurs intergrown with iron ores. Sillimanite is commonly aligned within the spinel, but at localities (7) and (8) the sillimanite also occurs as plentiful euhedral crystals. In all of these rocks biotite is plentiful. However, in the normal gneisses and non-gneissic charnockites to be mentioned below, biotite occurs usually as a very minor accessory.

It should be stated that the presence of garnet in acidic rocks must not be taken as necessarily indicative of direct sedimentary origin in this region. Garnet has been noted in many other places, but usually near the junctions of the main Ernabella non-gneissic "igneous" mass and in the gneisses around certain "cupolas" to the east (*e.g.*, Spinifex Hill), and often in mylonized zones.

Some analytical data and petrographic descriptions have been assembled, but will be withheld for inclusion in later papers. However, it may be stated that in the analysis of an "injection gneiss" over 5% corundum is indicated in the norm.

The author considers that the rocks which show evidence of sedimentary origin are often greywackes of perhaps relatively high alumina content, and that later investigation may show that large tracts of the gneisses can claim palinogenetic relationships with arkosic rocks.

(2) GNEISSES SHOWING NO OBVIOUS SEDIMENTARY ORIGIN.

(a) Acidic Gneisses without Fluorescing Zircon.

Many specimens representing over 800 localities have been carefully studied under ultra-violet light. In large numbers, a zircon has been revealed as tiny points of orange light. Sometimes the crystals are up to 5 mm., but usually of the order of 1 mm. in length. In most of the gneisses, however, no fluorescence was observed, and petrographic work has revealed that a somewhat different non-fluorescing zircon (?) exists in these rocks. The author hopes that it may be possible to trace petrogenetic relationships by making use of this zircon criterion. The areas represented by the fluorescing zircons are indicated in the sketch map, p. 202. In hand specimen, little indication is given of the presence or otherwise of the fluorescing zircon. However, those with fluorescing zircon do seem to exhibit a somewhat more "igneous" appearance.

The present indications are, however, that the gneisses without the fluorescing zircon are somewhat older than those with the fluorescing zircon. Investigation into this interesting phenomenon is at present only in the early stages.

A number of modes have been established by the Rosiwal method, and some analytical work has been undertaken. (Details will appear later.) From this it was found that all gradations from granitic to granodioritic rocks occur within this acid group. An average type (adamellitic) occurs at the little rock hole, 2 miles west of Top Springs.

This group of gneissic and sometimes granulitic rocks are dove-grey and of a greasy lustre. The dark minerals are usually concentrated into rough, more or less continuous plates throughout the rock, and there are usually some rude bands of feldspathic material. These strike north-south, with a fairly steep dip which varies from east to west. The rocks are usually fine-medium grained. Microscopically these gneisses and granulites usually show rather rounded yet

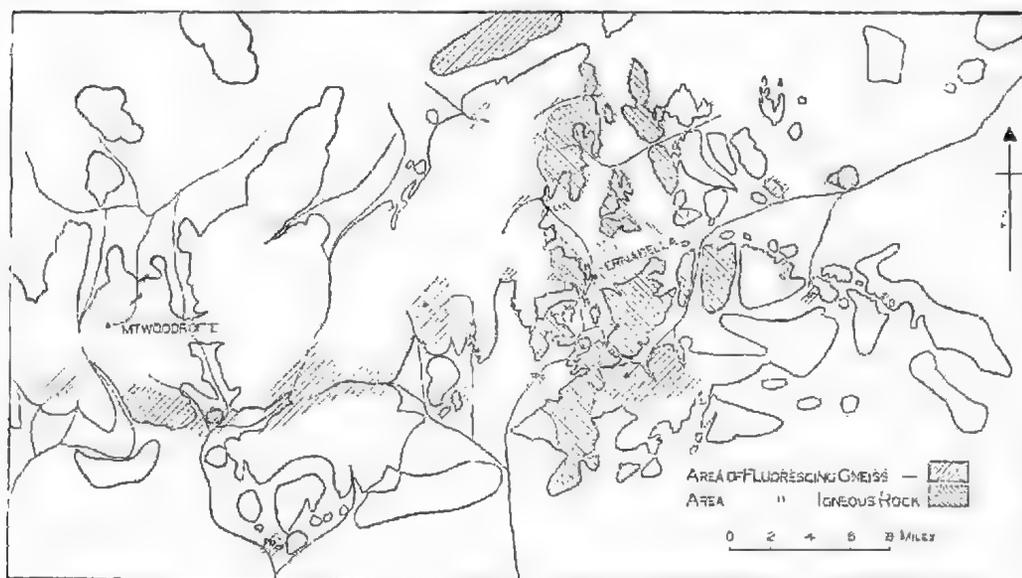


Fig. 2

interlocking grains, with the ferromagnesian of slightly smaller dimensions than the salies. Some quartz grains are particularly ragged and associated with myrmekite, while others protrude as small irregular "fingers" through the rock.

The plagioclases are usually twinned on albite and pericline laws with composition about andesine (An.35). They are variable in amount, but are commonly plentiful. Myrmekite is often associated. Quartz at times contains numerous non-orientated needles. Shadowy extinction is common. The "fingers" of quartz are mentioned above.

The potash feldspar is usually abundant and represented by an orthoclase micropertthite, but sometimes by a poorly twinned microcline micropertthite. The proportion of the other minerals varies greatly, but hypersthene is usually the commonest. The pleochroism is strong in rusty pinks and greenish-greys, with a slightly variable optic axial angle (negative) of about 80° . This pyroxene often shows considerable cracks filled with greenish alteration products. A pale green non-pleochroic monocline pyroxene (probably diopside) is usually present, but hypersthene predominates.

Hornblende is sometimes relatively plentiful but is often absent. Pleochroism is usually yellowish-grey, light brown, dirty green, with $Z\wedge c$ 23° - 25° .

Magnetite is often abundant and at times an important constituent. Secondary magnetite is commonly developed near hypersthene. Biotite is associated in small amount with the iron ores. Pleochroism is pale straw-yellow to orange-brown.

Zircons (?): present indications are that all of these crystals, which are non-fluorescent, are usually murky and tending to be brownish and much cracked. Apatite is commonly present.

On chemical analysis, a typical gneissic rock revealed the normal features of an "igneous" rock of adamellitic composition. Such rocks could well be called acidic gneissic charnockites.

(b) Intermediate and more Basic Gneisses without Fluorescing Zircon.

These are best represented by some of the dark gneisses at Gilpin's Well, although patches of similar rocks occur near Kuna-unpunja, Brown's Pass, and elsewhere.

In these rocks the gneissic structure is usually marked and is revealed on the weathered surface by streaks of tiny greyish ragged quartz crystals, and shiny magnetite. On fresh surfaces, specimens are a bluish dark grey (contrast the "dove grey" of acidic gneisses) with the typical greasy lustre of the other hypersthene-bearing types.

Microscopically these rocks are granoblastic, with an average grain size of the plagioclase just under 1 mm. in diameter, and that of the ferromagnesian about 0.5 mm. Modal proportions are Plagioclase 65%, Hypersthene 14%, Diopside, 7%, Quartz under 5%, and Hornblende, etc., 9% (Gilpin's Well).

The plagioclase is usually a well-twinned labradoritic antiperthite (An.45) with plentiful opaque needle inclusions. The hypersthene is fresh and displays the usual strong pleochroism.

The monoclinic pyroxene is pale bluish green-grey, non-pleochroic, and has $Z\wedge c$ = about 45° .

Quartz usually occurs as the finger-like protuberances so commonly seen in the more acidic gneisses. The mineral often has needle inclusions similar to those in the plagioclase.

Magnetite is usually quite plentiful in these rocks. The zircon (?) is non-fluorescing and of the murky type, noted above in the acidic gneisses. Some apatite and biotite are commonly present and associated with the magnetite. Potash feldspar and hornblende are very uncommon.

Such rocks could well be called quartz-dioritic gneissic charnockites.

(3) GNEISSES SHOWING NO OBVIOUS SEDIMENTARY ORIGIN AND CONTAINING FLUORESCING ZIRCON.

From the sketch map on p. 202 it can be seen that these gneissic rocks appear to occupy mainly:—

- (a) an east-west belt from south of Mount Woodroffe through south Trudinger Pass and Brock Pass to the Inindi area;
- (b) the east-west Mount Cuthbert Range to the north;
- (c) the east-west belt from Mount Ferdinand to Ombagunda; and
- (d) many other minor localities.

The strike of these gneisses is still the same north to south of the whole region, with the dip exceeding 45° east or west, excepting in the area near the Wardulka Rock Hole [Locality (b)]. Here the gneisses take on a more of an east-west trend.

As was suggested above (p. 201), it seems that these gneissic rocks are a little coarser (though still far from coarse-grained) and look more "igneous" than the gneisses, free from the fluorescing zircon.

As in the first group of gneisses, this group shows gradations from the highly acid to the granodioritic and quartz-dioritic types. The normal grain size is found to be about 1 mm. in diameter, with the ferromagnesian perhaps a little smaller.

The rocks show the customary greasiness of all the hypersthene-bearing rocks of this region. In most, the typical dove-grey colour is evident, though some specimens show more of a fawn-grey, owing, perhaps, to alteration.

Orthoclase microperthite is usually plentiful, but microcline microperthite is only occasionally present. At times, an acid andesine is the dominant feldspar. This plagioclase is commonly antiperthitic. A quick method for distinguishing the perthitic from antiperthitic feldspar was noted. This consists in viewing them under considerably reduced illumination. The antiperthitic particles then appeared pale pink, while those of the perthite remained colourless.

Quartz occurs as ragged tongues and scattered like millet-seed throughout the potash feldspar in various rocks. Occasionally non-orientated needle-inclusions are developed in the mineral.

The dominant ferromagnesian minerals are a typical pleochroic hypersthene and a pale bluish-green non-pleochroic diopside. These are commonly arranged in rough bands which are separated by the salic-rich bands. Common hornblende has been noticed, but it is not typical of these gneisses. Iron ores are often plentiful and are commonly interlocked with the pyroxenes.

Apatite occurs in variable amount, but mostly associated with the pyroxenes and iron ores. Several crystals of zircon of the fluorescent type occur in all slides. The fluorescing zircon is clear and colourless under convergent light, whereas the non-fluorescing zircons (?) are almost always murkier and, under convergent light, usually show a very pale pinkish-fawn tint.

II. THE NON-GNEISSIC CHARNOKITES

Large areas of non-gneissic rocks⁽⁵⁾ are shown on the map. Most of these would usually be called igneous rocks. Though these are younger than the gneissic rocks, the final period of crystallisation of the non-gneissic "igneous" rocks is probably not far removed from that of some of the gneissic types.

At present these non-gneissic rocks may be divided into four divisions. In this scheme the oldest types are listed first. The four divisions are:—

- (1) The Mount Woodroffe and Trudinger Pass Intermediate and Basic Rocks.
- (2) The Upan Downs Granitic Rocks.
- (3) The Norite to the south-west of Tjatjanja.
- (4) The Ernabella Granodioritic Massif.

(1) THE MOUNT WOODROFFE-TRUDINGER PASS INTERMEDIATE AND BASIC ROCKS.

(a) *The Mount Woodroffe Area.*

The map indicates that on all sides of the Mount gneissic rocks predominate, but near the summit considerable areas of quartz-dioritic and dioritic rocks occur. There are basic and ultrabasic patches in places. Directional characters were not noted in any of these charnockitic rocks on Mount Woodroffe. However, the strike and dip of the surrounding gneisses, and the comparison with the basic

⁽⁵⁾ See footnote (*) on p. 200.

rocks which continue in a north-easterly direction to Trudinger Pass, suggest that these rocks probably comprise a large sill-like structure. This is more evident in the range between Brown's Pass and Landmark Hill. Directional characters were not noted in any of these rocks, but some may be expected when field work can be carried out on the cross-section of the apparent sill structure.⁽⁶⁾ Reconnaissance only has been possible in this area up to the present.

In hand-specimen the rocks of Mount Woodroffe are medium-grained, consisting of pale amethyst grey and greasy but shiny plagioclase, mottled with patches of dull black pyroxene.

Twin striae are not easily seen in the plagioclase in hand-specimen, but under the microscope albite-twins are plentiful. This antiperthitic feldspar (70%) is a mid-andesine.

Hypersthene usually occurs as large tabular rounded crystals about 4 mm. x 3 mm. It is very strongly pleochroic. Diailage is also present. Quartz is noted in accessory amount. Potash feldspar has not yet been seen except as the antiperthitic lenses. Zircon is quite rare and of the non-fluorescing type.

Hypersthenites appear as patches up to an acre in area on the sides of Mount Woodroffe. Another outcrop occurs in Brown's Pass between the Woodroffe rocks and the basic rocks stretching north-east to Trudinger Pass. These ultrabasic rocks are commonly associated with magnetite and very coarse dioritic and noritic rocks similar in appearance to those of the summit described above. The hypersthenites are fresh, dense homogeneous medium-grained, greasy and very dark grey rocks. Microscopically, they are found to consist almost entirely of pyroxene, most of which is a strongly pleochroic hypersthene. There is a little non-pleochroic pale green diailage. Plagioclase is usually present in extremely small amount, as tiny interstitial particles. Very little primary iron is present in slides studied to date, but in the field, solid boulders of magnetite are common as floaters near the hypersthenites. Directional features were not observed.

(b) *The Trudinger Pass Basic Rocks.*

As suggested above, these noritic rocks are linked with the Mount Woodroffe rocks. The outcrops in the Pass were noted during a particularly arduous reconnaissance on camel, and time could not be spent trying to determine the relation of these rocks to the gneisses.

The grain size of this basic suite varies greatly. Some textures are those of the very coarse norites, others are doleritic, but the average is that of a medium-grained norite. The composition varies somewhat from a charnockitic basic diorite to a typical norite. In hand-specimen the diorites are similar to those of Mount Woodroffe, but a little darker. They are also comparable microscopically. In hand-specimen the norites, however, are coarse dull brownish-black heavy rocks composed mainly of large dull grey plagioclases, poikilitically including numerous small greasy grains of pyroxene. Albite-twinning is not obvious in hand-specimen. There are several large clots of dull greasy dark brown pyroxene crystals.

Microscopically, these norites consist of over 60% basic andesine with the rest of the rock composed of hypersthene and diailage, whose properties are similar to those of the Mount Woodroffe rocks. Iron ores are not plentiful. No fluorescing zircons occur in these rocks.

⁽⁶⁾ The aerial photographs (see footnote, p. 198) suggest that there is very little gneissic structure in these rocks. Some of that suggested in the photographs of the north-west flank of Mount Woodroffe may be linked with the profound mylonitization known to occur along the northern flank of the Mount.

(2) THE UPSAN DOWNS GRANITIC ROCKS.

Little work has been done in the Upan Downs area. These medium-grained granites are characterised by large flesh-coloured feldspar crystals. Considerable crush has taken place, and in some localities beautiful crush-augen gneisses are developed (*e.g.*, the Pass one mile to the north-east of Victor's Well, and at Erlywanyawanya Rock Hole to the south-west of Mount Woodroffe). These rocks contain no fluorescing zircon.

At the rock hole in Brock Pass a granite occurs among contorted and partly "assimilated" gneisses. This granite shows fluorescing zircon, thus, although shown on the map by the symbol used for the Upan Downs Granite, it may well represent another epoch.

(3) THE NORITE TO THE SOUTH-WEST OF TJATJANJA.

These norites comprise a considerable belt on the spur two or three miles south-west of Tjatjanja. The rocks from this locality vary in grain size, ranging from coarse norite to micronorite. Normally the rocks are mottled greasy, dark blue-grey medium-grained, and the abundance of a resplendent bronzy biotite is the most striking feature. [Noted by Jack (1915, p. 18)].

The plagioclase shows prominent albite-twin striae. Under the microscope, half of the rock appears to consist of an acid labradorite. It is often associated with the hypersthene poikilitically. The plagioclase is an antiperthite. Hypersthene and diallage are present in equal amount. Magnetite is scarce, as also is some interstitial orthoclase micropertthite. No fluorescing zircon was noted.

A small orthite-bearing pegmatite similar to that at Koli Koli (see p. 208) cuts these norites near the northern-most junction with the charnockitic granite of the Tjatjanja spur. This alone suggests that these basic rocks are older than those of the Ernabella massif.

(4) THE ERNABELLA GRANODIORITIC MASSIF.

This rock type occurs as a great meridional belt with Ernabella near the centre. Though the belt is granitic around Tjatjanja to the south, the massif, taken as a whole, is probably granodioritic.

The map shows "cupolas" of similar material in several other places, notably among the gneisses:—

- (a) South and north-east of Koli Koli rock hole to the west.
- (b) South of the Stony Jump Up to the east.
- (c) Bald Hill and Spinifex Hill further to the east.

It is regretted that owing mainly to difficulty of terrain and climatic conditions, many of the junctions between the gneisses and the non-gneissic acid rocks could not always be studied as well as one would desire. They have been located on the map, however, to facilitate future investigation.

The best junctions were found on the western side of the massif in the Mount Carruthers area near Ernabella, and at Alaka to the north. In these localities large sheets of fresh rock are exposed in the water-courses, and the study of xenoliths and other phenomena is facilitated thereby. The eastern junctions are not readily studied. Many of these occur beneath sandy valleys. The junctions in the Tjatjanja area are relatively broad zones, but xenoliths are not common.

In the *Mount Carruthers area* the trend of the xenoliths in the Ernabella massif is between N. 25° E. and N. 35° E. with an approximate dip of the rude xenolithic lenses of 70° to the east. Small aplitic veins are often found with

identical dip and strike of the xenoliths, but the pegmatite veins are almost always trending W. 10° N. and dipping south 75° - 80° . The strike of the gneisses is usually north-south, hence these xenoliths are usually at an angle of approximately 25° to the gneisses. This may indicate some pre-crystallisation movement of the non-gneissic "igneous mass" relative to the gneisses, from which it was probably derived by granitisation.

In the *Alaska Rock Hole* area, xenoliths are common. The trend is between North and N. 18° E., the usual being about N. 15° E. No evidence of aplitic or pegmatitic activity was found.

In all localities where xenoliths could be studied, a great diversity of xenolithic rock types was apparent. The xenoliths which are most obvious are amphibolitic, but on closer investigation partly assimilated elongated fragments of gneisses of all types outlined above are found to be the more abundant. Xenoliths in the area south-west of Mount Carruthers were traced to their probable equivalents *in situ* in some instances. A common size for the lens-shaped xenoliths is about 20 cms. x 5 cms. x 10 cms. Many larger and smaller ones were found.

A feature of many of the acidic inclusions is the presence of biotite which has developed throughout the lens. Basic inclusions usually show a marked reaction rim of hornblende. It is hoped later to publish some microscopic observations on the xenoliths.

The conspicuous paucity of pegmatites, aplites and quartz veins indicates the special "dry" conditions under which these post-gneiss hypersthene-bearing acidic rocks crystallised.

The Rocks of the Ernabella Massif, whether granitic or granodioritic are very similar in most of their characters. In hand-specimen they are medium-grained, greasy bluish dark grey granitic rocks composed of bluish-grey feldspars of medium size, small blue-greyish glassy quartz irregularly scattered, and small ragged areas of greasy dark brown ferromagnesians. In several localities large phenocrysts of plagioclase are present (up to 6 cms. x 2 cms.), and these with the rest of the plagioclase usually show splendid albite-twin striae. Phenocrysts of the pyroxenes are found at times.

Under the microscope these rocks are holocrystalline and more or less allotriomorphic granular. For the most part the ferromagnesians are of somewhat smaller dimensions than the salic constituents (average of rock 1.5 mm. to 2 mm. long).

The plagioclase (50%) is a mid-andesine and well twinned. It is sometimes a little antiperthitic. Orthoclase micropertite (about 20%) contains rounded quartz inclusions (millet-seed type) in considerable number. These inclusions are uncommon in the plagioclase.

Quartz (15%) is ragged and interstitial except when included in the potash feldspar. Myrmekite is plentiful. The tongued character of the quartz (so common in the gneisses) is an uncommon feature of these non-gneissic charnockitic rocks.

Preferred orientation of the dark minerals is not present to any marked degree either in the field or in microslide.

Hypersthene is not so notably pleochroic as in most gneisses and rocks of the Mount Woodroffe area. A weakly pleochroic or non-pleochroic pale greenish-grey monoclinic pyroxene (probably a species of diopside) is plentiful. There is no apparent age difference in the two pyroxenes. Apatite and magnetite are plentiful. Hornblende occurs, but usually in small amount and has crystallised after the pyroxenes. Hornblende is plentiful, however, in the cupola phases, for instance, at Spinifex Hill and Bald Hill.

Biotite occurs as small flanking crystals on some of the patches of magnetite. Zircon is plentiful and is of the fluorescent type.

Analytical and petrographic data have been collected, but are being withheld for the present. It should be noted that this rock type has all the characters of a "normal igneous rock." It is hoped to show later the paligenetic relation of this "igneous type" to the gneisses.

III. PEGMATITES

Poorly defined small pegmatites outcrop throughout the Ernabella plain among the charnockitic granodiorites. Only occasionally are they found among the gneissic rocks. The Musgrave Ranges, as a whole, are very poor in pegmatites. An intensive search was made for these, and specimens and notes have been taken of each one found. Aplites are much rarer. Most pegmatites are usually only about one foot wide, and less than three or four chains long. Their strike is almost always West 10° North, with a dip South 75° - 80° . In places dolerite dykes are found cutting across these pegmatites.

The minerals noted are set out in approximate order of abundance. *Haematite* is often in well crystallised masses. *Biotite* is usually much contorted, and ragged books occur up to 7 cms. in diameter. Large *zircon*s are often found embedded. No muscovite has been found anywhere in the ranges.

Hornblende—This mineral is the dominant mineral of many pegmatites, and has been noted as large black shining crystals up to 8 cms. in length. *Garnet* occurs in some of the pegmatites as dull greasy reddish-brown rounded subhedral crystals up to 3 cms. across.

Orthite (Allanite)—Occasional small pockets of large tabular crystals were noted in a few of the pegmatites of the Ernabella plain. The mineral is jet black, and has no cleavage but a pitch-like conchoidal fracture. Specific gravity is about 3.5, and hardness roughly 6.5. Though too weak to affect the electroscope, a very weak radio-activity was revealed after an exposure of up to three weeks on photographic plates. Throughout the ranges only a few pounds of the mineral were obtained, though a thorough search was made. Analytical work is in progress to use this mineral in age-determination. *Zircon* is present in certain pegmatites, as black or dark brown euhedral crystals, up to 2 cms. long. Though very weakly radioactive (about the same as the orthite), they do not fluoresce under ultra-violet light. This is remarkable, for the *zircon*s of the parent rock, the charnockitic granodiorites of Ernabella fluoresce in orange. Preliminary investigations with autoradiographs indicate that the fluorescence decreases regularly as the radioactivity and depth of dark brown increase. *Apatite* occurs as tiny euhedral pale blue crystals, but is rare. *Tourmaline* was found in only a few cases, and is of the common black variety.

Among the gneisses true pegmatites are rarely found. At Koli Koli Rock Hole an interesting but quite small hornblende pegmatite occurs, in which nail-like crystals of orthite and an orange-fluorescing euhedral resinous "zircon" occur. Similar pegmatites at Irawanja and Arkalanja show neither orthite nor zircon.

Work is in progress on the pegmatites.

IV. DOLERITE DYKES

Cutting all of the other rock types, but probably not far removed in age from the Ernabella massif, is a large suite of dolerites. A common trend is a few degrees south of west, with a dip to the south of 60° - 70° . Another set is present near Ernabella, with an approximate north-south strike and dip to the east of 25° - 40° . Similar dyke-rocks occur all the way to Unbyarra, about 140 miles to the east, and according to Dr. Jack, far to the south-east into the Everard Ranges, and beyond. Dr. Jack observed (Jack, 1915, pp. 15, 18) in these regions to the south-east, that the basic dykes cut the gneissic and non-gneissic rocks, but not

those of the Adelaide Series (Proterozoic—the "Cambrian" of the earlier geologists). These dyke rocks, as seen in the Musgraves, consist essentially of labradorite lathes, with hypersthene, diallage and olivine combining to give the typical ophitic texture of dolerite. Specimens from about one hundred dykes have been collected for description.

V. MYLONITIZATION

Most rock types of the Musgrave Ranges have been mylonitized in places. A large collection of material showing transition types has been made for future work. Pseudo-tachylytes are well developed.

Both gneissic and non-gneissic types may show a crushing and a rolling out. They are often found to grade through a crush zone of mylonitized augen-gneisses to dense hallefinta types. The gneisses so formed are not to be confused with the gneisses outlined above. The crushed rocks are only in association with major fault zones.

Though considerable areas of crushed rocks may be of later origin, most of this mylonitization seems to have taken place after the pegmatites were emplaced, and is probably associated with the widespread epidotization noted with the jointing which led to the dolerite intrusions.

The coincidence of the west-south-west trend of the dolerite dykes and major zones of mylonitization is evident in the following cases.

Intense mylonitization (with pseudotachylytes), epidotization and basic dyke injection are plentiful throughout:—

- (1) the tectonic valley stretching from Upan Downs through the valley just north of Tjatjanja and Mount Ferdinand to the Gilpin's Well and Big Hill localities;
- (2) the tectonic valley from Taljaritja Well through Top Springs and along the creek south of One Tree Hill; and
- (3) the great tectonic valley running along Tietkin's Creek, through Naljawara, Ernabella, Brock Pass and into the Oowallinna area.

There is also a coincidence of these same features with the weaker development of the north-south basic dykes in the Ernabella area.

It is apparent that the conditions which allowed typical mylonites to form must have been considerably different from those prevailing at the depths where the charnockites crystallised. Hypersthene is always absent from these mylonitized rocks, and hornblende and garnet with biotite and marked mortar structure are characteristic.

C. CONCLUSION AND SUMMARY

The Musgrave Ranges consist of a complex series of many rock types, all of Precambrian age. Present indications are that the chronological order of the major rock groups seems to be the following:—

1. *Gneisses showing sedimentary origin* and represented by garnet, cordierite, spinel and sillimanite gneisses, and containing no fluorescing zircon. This group is thought to represent the oldest rocks in this area.
2. *Hypersthene-bearing Gneisses* NOT showing obvious sedimentary origin but containing NO fluorescing zircon.
3. *Hypersthene-bearing Gneisses* NOT showing obvious sedimentary origin but containing a fluorescing zircon.

4. *Hypersthene-bearing non-gneissic Intermediate and Basic Rocks of Mount Woodroffe and Trudinger Pass.* These have no fluorescing zircon.
5. *The Upsan Downs Granitic Rocks.* These have no fluorescing zircon.
6. *Hypersthene-bearing non-gneissic Granites and Granodiorites of the Ernabella Massif.*

These "igneous" rocks contain fluorescing zircon and xenoliths of the gneisses.

7. *Pegmatites of the Ernabella area.*
8. *Mylonitisation and Basic dyke injection.*

The hypersthene-bearing rocks may be called *charnockites*. The position in the above sequence of the numerous altered basic dykes and masses of several epochs has yet to be determined.

The gneisses of group 2 are thought to represent, in part, the granitized equivalents of the ancient sediments. The gneisses of group 3, with their fluorescing zircon, are tentatively considered to represent possibly a superimposed metamorphism (with the introduction of considerable new material) of some of the earlier gneisses. This is well seen at Kuna-unpunja, where patches of the relatively coarsely-grained and more granitic rocks of group 3 cut across acid, intermediate and basic types of group 2. Similar directional features are always present in both groups, but those of group 3 are almost always much less marked.

A criterion suggested for the differentiation of the gneisses of group 2 and group 3, therefore, rests on the critical problem of the origin and introduction of the fluorescing zircon. The non-gneissic igneous rocks of group 6 may indicate a relatively mobile and somewhat contaminated equivalent of the gneisses of group 3, because these, as stated, contain plentiful fluorescing zircon and xenoliths of all types of gneiss. The rocks of group 4 and 5 contain no fluorescent zircon and are thought to have crystallised after those of group 3.

The ubiquity of hypersthene, the relative rarity of hornblende and biotite and the marked paucity of pegmatites signify the "dry" conditions under which these charnockitic rocks finally crystallised.

D. ACKNOWLEDGMENTS

I wish to express my indebtedness primarily to Professor Sir Douglas Mawson, and also to Messrs. A. W. Kleeman and H. E. E. Brock of the Geology Department of the University of Adelaide, for interest and advice in many matters. D. R. Bowes kindly made two chemical analyses. Without the willing co-operation of the Superintendent (the late Rev. J. Love), staff, and natives of the Presbyterian Mission Station at Ernabella, the field work during the two seasons would have been impossible. Mr. Trudinger, in particular, rendered valuable hospitality. Finally, I must thank R. Brock for his outstanding assistance while accompanying me on the second expedition to the area.

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Fig. 1. Looking north-north-west from Naljawara, $3\frac{1}{2}$ miles east of Ernabella. Note how island-like hills of non-gneissic charnockitic granodiorite punctuate the plain.



Fig. 2. North-north-east approach to Trudinger Pass, taken two miles south-west of Kuna-unpunja. Most of the rocks are of gneissic charnockite, with norite in the pass. Tjakunja on left; Landmark Hill on right in distance.



Fig. 3. Mount Spec, taken from northern junction of mica norite to south-west of Tjatjanja. Most rocks are acidic and intermediate gneissic charnockites.



Fig. 4. Non-gneissic charnockitic granodiorite cut by parallel dolerite dykes. South-west tip of hills, two miles west of Palpatjara Well.



Fig. 1. Looking north from Mount Carruthers, showing north-south gneissic charnockites in distance on left, Top Springs and Ernabella Creek gorge in centre in distance, and Mount Itjinpiri and other non-gneissic charnockitic granodiorite areas to the right.



Fig. 2. Looking north from east side of Razor Hill, nine miles north-north-east of Ernabella. Razor Hill consists of non-gneissic charnockitic granodiorite; hills to right are gneissic and in part show obvious sedimentary origin.



Fig. 1. Looking east from summit of Mount Woodroffe (over 5,000 feet, highest mountain in South Australia). Mount Spee is flat-topped mountain on left in distance. A stunted species of "spinifex" (*Triodia*) is abundant.

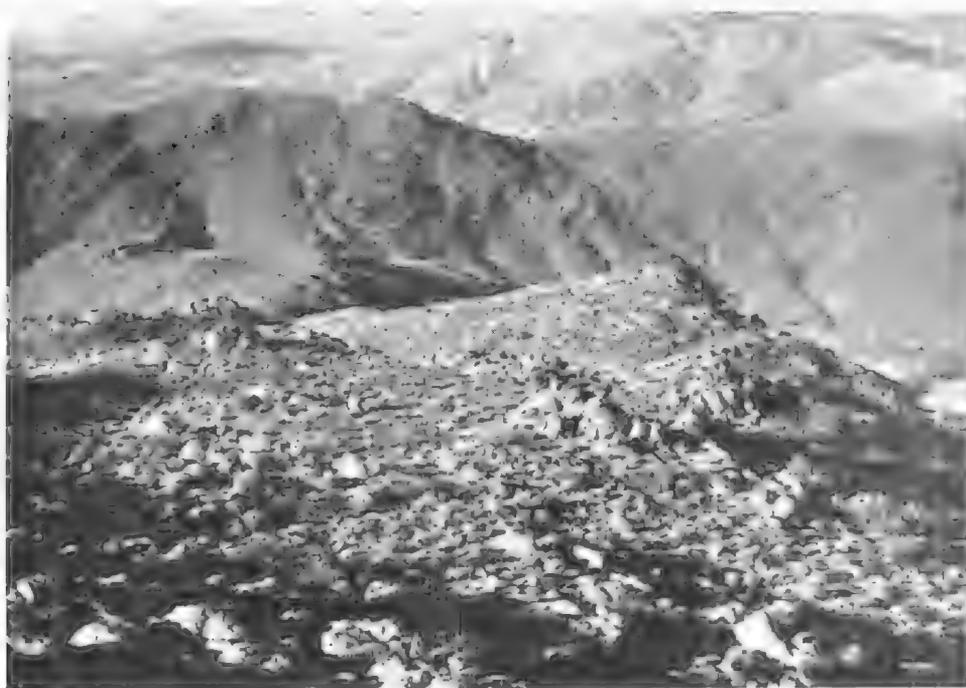
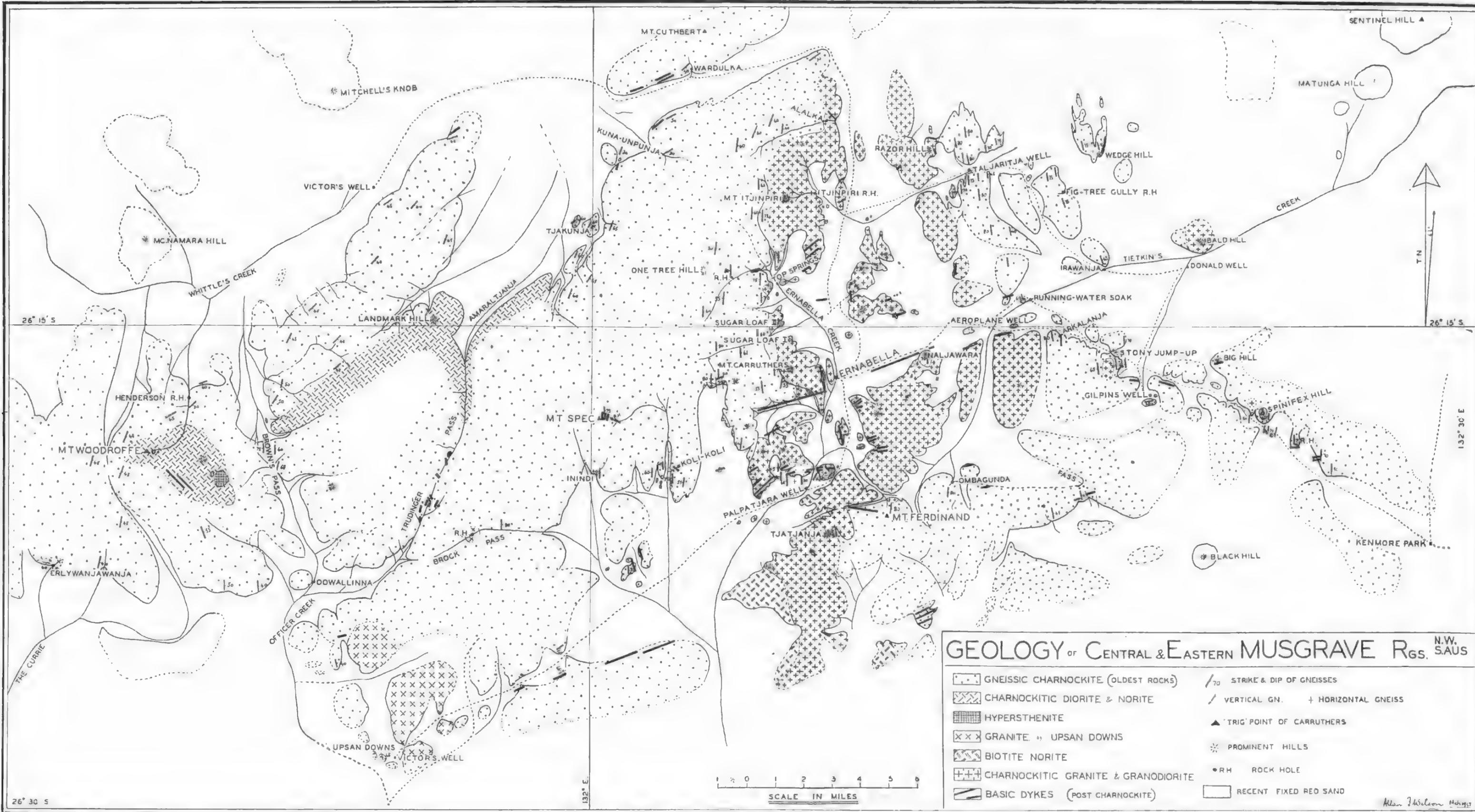


Fig. 2. Looking west from summit of Mount Woodroffe. Foreground of non-gneissic charnockitic quartz-diorite with gneissic granitic charnockite on right. Major vegetation—stunted species of *Triodia*.



GEOLOGY OF CENTRAL & EASTERN MUSGRAVE RANGES, N.W. S.AUS.

- | | |
|-------------------------------------|------------------------------------|
| GNEISSIC CHARNOCKITE (OLDEST ROCKS) | STRIKE & DIP OF GNEISSES |
| CHARNOCKITIC DIORITE & NORITE | VERTICAL GN. HORIZONTAL GNEISS |
| HYPERSTHENITE | 'TRIG' POINT OF CARRUTHERS |
| GRANITE - UPSAN DOWNS | PROMINENT HILLS |
| BIOTITE NORITE | R.H. ROCK HOLE |
| CHARNOCKITIC GRANITE & GRANODIORITE | RECENT FIXED RED SAND |
| BASIC DYKES (POST CHARNOCKITE) | |

26° 30' S

0 1 2 3 4 5 6
SCALE IN MILES

Alan Wilson 1947

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EARLY CAMBRIAN (?) JELLYFISHES FROM THE FLINDERS RANGES, SOUTH AUSTRALIA

BY REG. C. SPRIGG

Summary

A richly fossiliferous horizon has been discovered within the massive Pound Quartzite formation which underlies the Cambrian Archaeocyathinae limestones in the Flinders Ranges, South Australia. The fossils occur as impressions on surfaces of flaggy quartzite. The five genera and species described are almost certainly all pelagic Coelenterates, and while several forms are referred to the class Scyphozoa, it is possible that one or more species may be more correctly assigned as Hydromedusae. The more problematical forms may prove to be pneumatophores or swimming bells.

EARLY CAMBRIAN (?) JELLYFISHES FROM THE FLINDERS RANGES,
SOUTH AUSTRALIA

By REG. C. SPRIGG *

[Read 8 May 1947]

PLATES V TO VIII

ABSTRACT

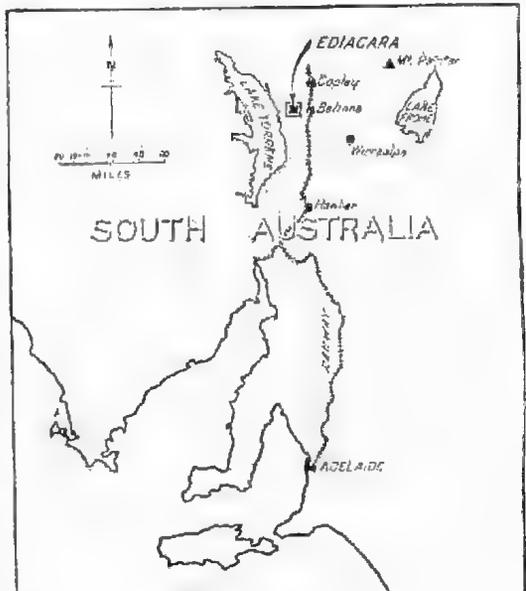
A richly fossiliferous horizon has been discovered within the massive Pound Quartzite formation which underlies the Cambrian Archaeocyathinae limestones in the Flinders Ranges, South Australia. The fossils occur as impressions on surfaces of flaggy quartzite. The five genera and species described are almost certainly all pelagic Coelenterates, and while several forms are referred to the class Scyphozoa, it is possible that one or more species may be more correctly assigned as Hydromedusae. The more problematical forms may prove to be pneumatophores or swimming bells.

INTRODUCTION

In this paper a group of fossils recently discovered in the uppermost formation of the Adelaide Series (Upper Proterozoic to Lower Cambrian) is discussed. The fossils were found on a rise approximately three hundred yards south-west of the principal south-mine workings at Ediacara, near Beltana, South Australia. They occurred as impressions in flaggy quartzite and are among the oldest direct records of animal life in the world.

If the environmental associations of the forms have been correctly interpreted there is good reason to consider all the forms pelagic and free swimming. They all appear to lack hard parts and to represent animals of very varied affinities. All are probably Coelenterates and all may be jellyfishes, although in at least two cases insufficient detail is available to make reliable comparisons with any living or fossil animals (*vis.*, *Papilionata*, *Dickinsonia* and the unnamed circular form described in association with *Beltanella*). Just possibly the latter two forms may be floats or pneumatophores of colonial coelenterates.

One form (*Ediacaria*) is referred tentatively to either of the orders Semaestomeae (Discomedusae) or Rhizostomeae of the class Scyphozoa, while another (*Beltanella*) may be referable to either of the classes Hydromedusae or Scyphozoa.



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STRATIGRAPHICAL CONSIDERATIONS

Fossil jellyfish as casts and impressions have been described from the Lower Cambrian of New York, Sweden, Russia and Bohemia, and now from Australia; from the mid-Cambrian of British Columbia and Alabama; from the Silurian of Victoria and from the Permian of Saxony; from the Jurassic of Solnhöfen, Bavaria and from the Cretaceous of Texas. The identity of some of these fossils has been questioned, and some are better referred to the Problematica. The stratigraphic range of jellyfishes is almost certainly pre-Cambrian to present.

As indicated above the fossil jellyfishes described in this paper are very probably Lower Cambrian in age. The fossil impressions were found in the "Pound" quartzite formation of the Upper Adelaide Series. This massive formation, which frequently measures several thousands of feet in thickness, immediately precedes massive Cambrian Pleospongia (= Archaeocyathinae) limestones. The impressions occurred at a horizon approximately 100 feet stratigraphically below the base of the limestone, and approximately 600 feet below the first Pleospongia remains yet located at this locality.⁽¹⁾

Generally speaking the horizon of the Pleospongia is considered to be near the top of the Lower Cambrian (David, 1927). On this assumption the present fossils would have been living in about middle Lower Cambrian time. The "Pound" quartzite in which the fossils were found is considered tentatively (Mawson, 1939) to represent the base of Cambrian sedimentation in South Australia, although there is reason to believe that the dawn of the Cambrian may eventually be taken back still further (Sprigg, 1942).

With perhaps the exception of David's (1936) Lipalian problematica, and certain annelid tracks common in several quartzites of the Adelaide Series, the new fossils represent the oldest undoubted marine animals recorded in Australia (fig. 2). They provide the first reliable indication that the Pound Quartzite is of marine origin.

MODE OF OCCURRENCE AND PRESERVATION

Considering the extremely perishable nature of jellyfishes and related soft-bodied coelenterates (many jellyfish contain 99% sea water), it is remarkable that any of them should have left traces of their existence in the fossil state. It is obvious that very special conditions of burial would be necessary for their preservation. Walcott (1898) suggests that in the case of many United States Cambrian forms the medusae probably had the habit of living on a muddy bottom in great numbers. Associated fossils suggest a shallow water environment. There appeared to be rapid burial and consolidation of the sediment, not by exposure between tides, but entirely beneath the water. In other cases, such as at Solnhöfen, Bavaria (Lower Jurassic), medusae have been found in extremely fine-grained slates.

Agassiz (1862) notes that the living *Aurelia flavida*, after the spawning period, is frequently seen in large numbers floating on the water. There has been a thickening of the tissues by an increased deposition of animal substance. The disc of the animal has become thin and almost leathery and it is more elastic (and at the same time more brittle) than before. Many of the marginal appendages

(1) It is to be noted that, contrary to popular conception, the South Australian Pleospongia are not reef builders. Their spatial distribution within the enclosing sediment simulates "coral meadows" conditions. This explains why, in this case (and in many other cases) Archaeocyathinae do not occur right from the base of the so-called Archaeocyathinae limestone. The Archaeos are usually restricted to more or less definite horizons within the limestone formation, and even in the most highly fossiliferous of these, actual fossil remains form only a relatively small portion of the rock. They are not massed remains as in modern coral reefs.

of the umbrella and oral region drop off during this period. It can be seen that in this dried out condition the medusae, when stranded on beaches and covered by sediment, offer much better chance for fossilization.

Caster (1945) notes that when *Aurelia* and other medusae are washed ashore and stranded during low tide in midsummer, they quickly dry out on the surface. "Dehydration of the aqueous jelly brings out in surface relief embedded structures, which in life would hardly be discernible, except by transparency, on the

exterior. While the upper surface is hardened, thus inhibiting dehydration, the surface in contact with the beach remains soft and often turgid as in life. Depending on the texture of the strand, the imprint made by the surface may be faithful or indistinct. The incoming tide picks up the partially embedded jellies and carries them further ashore, and occasionally turns them over to embed them again at turn of tide with the erstwhile downside up." He notes further that extraordinarily rapid solidification of the entombing matrix is not necessary, as firm jellyfish can be dug from tidal sands of today wherein they have apparently remained buried for a much longer time than tidal periodicity.

In the case of the newly discovered fossils we are dealing exclusively with buried pelagic forms. The fossils are impressions in flaggy sandstone quartzite, and the grooves of the impressions are stained with ferruginous material or possess a film of clayey material. The enclosing sediment was originally a fine-grained and well-sorted sand which had accumulated near the western margin of the vast Flinders sedimentary geosyncline. The environment of entombment was that of intertidal flats or of the strandline.

Toughening of the surface tissues of the fossil animals as described by Agassiz and Caster seems almost certainly to have occurred prior to burial, and judging from the attitude of the fossils in the field the animals were mostly preserved with their ex-umbrella surfaces uppermost.

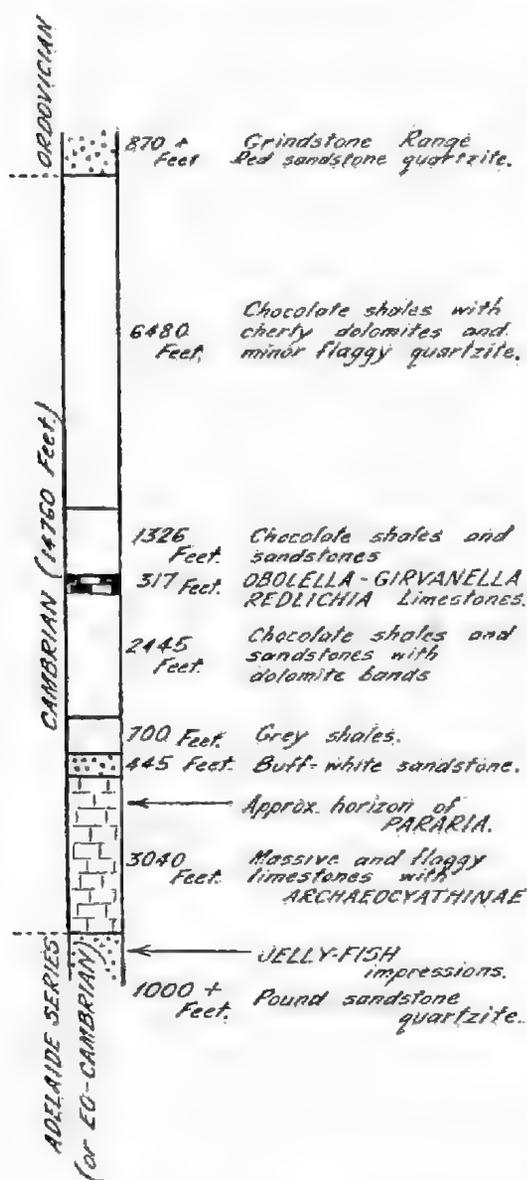


Fig. 2

Generalised Section across Cambrian and associated formations of Flinders Ranges [modified after Sir D. Mawson 1939 (2)], showing approximate horizons of known fossils.

It is noted that the fossils were all found on "free" faces of flaggy quartzite, and always on the upper surfaces of these slabs. (Beds dip at 10° to 20°). The fissility of the quartzite appears to have been controlled to some extent by the presence of clayey films, which might also have had significance in the preservation of the fossil impressions.

DESCRIPTION AND TENTATIVE CLASSIFICATION^(*) OF THE FOSSILS

Class SCYPHOZOA

Order (?) SAEMOSTOMEAE or (?) RHIZOSTOMEAE

Genus *Ediacaria* Sprigg, gen. nov.

Genotype *Ediacaria flindersi* Sprigg, gen. et sp. nov.

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

Being monotypic the new genus shows the species characters described below. Generic characters include the bell-like manubrial structure and other structures of the central disc area. Comparisons between *Ediacaria* and other most closely related genera are given below.

Ediacaria flindersi Sprigg, gen. et sp. nov.

(Pl. I, fig. 1)

Holotype: No. T.1, Tate Museum Collection, Adelaide University, South Australia.

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 delimited on inner and outer aspects by concentric grooves—one (or two) on 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.

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); and with one or two doubtful exceptions is devoid of marginal notches. A concentric groove lies approximately 4 mm. in from the perimeter of the form.

(*) Classification used in this work is based on that of Parker and Haswell 1940.

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 to the oral surface of the original animal have come to stand out in relief, and the manubrium stands out strongly. The central zone probably corresponds with the gastrovascular cavity, and external structures of the central disc region are superimposed upon it.

The sub-triangular (?) manubrial structure has been so interpreted because 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 manubrial bell 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 disposed about the centre largely contradicts this view. In life the manubrial structure would be suspended vertically from the central region. The shape of the mouth opening cannot be judged.

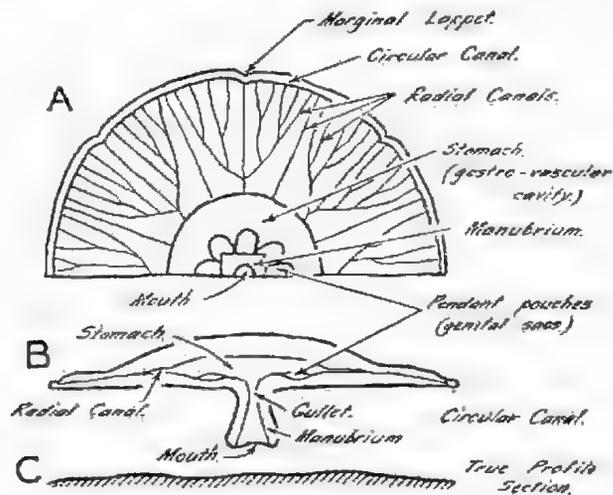


Fig. 3
Ediacaria flandersi

A, details of the subumbrella surface of the reconstructed form; B, cross section through radial canals; C, actual profile section along a diameter of the fossil.

The three pendant pouches extending radially from the base of the manubrium are possibly gastro-genital sacs in connection with radial canals. Judging from the distribution of the three sacs preserved there were probably eight of these in the original animal.

Various concentric flutings, with the exception of that adjacent the margin of the form, are referable to the circular muscles of the sub-umbrella. The epimarginal groove is probably a circular canal, in which case the narrow flange beyond it would probably be a "hood."

The well-marked radial grooves of the median zone correspond with inter-, ad-, or per-radial canals, whereas the much finer, numerous radial striations of the outer zone and to a much lesser extent of the median zone suggest more minor canals, splitting and radiating towards the circular canal. This may merely be shrinkage creasing, but in any cases such creases would tend to follow such relative weaknesses as the canal lines. The grooves are sub-parallel and tend to increase in number centrifugally, a feature which is in keeping with the canal theory.

Two marginal notches can be interpreted; these are at intervals corresponding with the separation indicated by projection to the margin of the stronger radial canals of the median zone. It is noticeable that in each case deeper radial striations continue to each notch. The annular (?) hood structure, where observed beyond one marginal notch, is indented in sympathy. 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. This would suggest that the two notches noted may be accidental invaginations of the margin consequent upon deformation during burial.

There are no indications of marginal tentacles, but in view of the coarse nature of the enclosing sediment and the probable delicate nature of such tentacles if present, it is difficult to imagine that evidence of them could have been preserved. Furthermore, experience with modern jellyfish (*Aurelia*, etc.) indicates that in many cases the marginal tentacles drop off in the senescent stages.

There appears little doubt that *Ediacaria* is a Scyphozoon. The form obviously had a flattened saucer or disc-like umbrella, and for this reason is referred to either of the orders Semaestomeae (Discomedusae) 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. In view of the nature of the preservation of the specimen this cannot be hoped for. However, it is noticeable that the manubrial structure as interpreted is relatively simple—a fact which suggests correlation with the Semaestomeae, or could perceptibly indicate an even simpler class relationship (*viz.*, Hydrozoan). The absence of marginal tentacles on the other hand is a Rhizostomid character, but in view of the difficulties already pointed out evidence such as this is primarily negative. It does seem, however, that no strong tentacles existed—a fact which would preclude membership of the order Trachymedusae of the class Trachylinae.

Detailed comparisons with other fossils is exceedingly difficult in view of the lack of knowledge of many critical features, but it is noticeable that closest (superficial) resemblance is perhaps with *Rhizostomites* and *Semaestomites* (both Haeckel) of the Upper Jurassic of Solnhöfen, 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 it is in *Ediacaria* and *Semaestomites*, and whereas the margin of *Semaestomites* is split up into 120-128 marginal lobes, such subdivision is not apparent in the other two forms.

Ediacaria (?) sp. Sprigg

(Pl. 1, fig. 2)

Specimen No. T.2.; Tate Mus. Coll., Adel. Univ., S. Aust.

Description—Impression fragmentary; original form apparently circular, but less than one-eighth of the perimeter is preserved, although the outline of the central disc region is almost complete. In all, three concentric zones can be made out.

Central Zone—Surface smooth except where badly preserved; slightly inflated; perimeter sub-circular.

Median and Outer Zones—Zones poorly differentiated; median one is smooth and of variable width. Outer zone inflated somewhat towards outer margin, and traversed by numerous sub-parallel radial grooves which fade towards either margin. Exterior margin slightly lobate with indications of two minor notches.

Discussion and Comparison—In view of the absence of structures in surface relief in the central and median zones of this fossil, it is suggested that here is a cast of the ab-oral or ex-umbrella surface of a jellyfish. The poor state of preservation of the centremost portion of the fossil form prevents complete assessment of this fact, but nevertheless there appear to be no signs of mouth or gastrointestinal structures. The centrally inflated region appears to have collapsed over the stomachs of the animal and preserved, therefore, the roughly circular outline of this region.

In the outer zone which, presumably, in the living animal was thin, the sub-parallel radial grooves are well preserved. These are very numerous and appear unbranched; they may represent radial canals or merely be shrinkage creases. Prominent radial striations continue directly to the two minor marginal notches, and there are no signs of marginal tentacles.

Tentatively the fossil is considered to be an impression of the ab-oral surface of a species of Ediacaria. As with the holotype specimen, three concentric zones can be interpreted, the outermost of which is traversed by very numerous radial striations. Indefinite notches which are separated by approximately equal intervals appear marginally in both forms. Width relations of the respective zones of the fossils agree favourably.

Class (?) SCYPHOZOA

Genus *Beltanella* Sprigg, gen. nov.

Genotype *Beltanella gilesi* Sprigg, gen. et sp. nov.

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

Being monotypic this new genus shares the species traits described below. Until more is known of the fossil, generic characters should include the octagonal arrangement of the circular (?) gonadial structures and their association with the radial canals, the presence of a well-developed delicate peripheral umbral or velar structure and the simple circular oral aperture.

Beltanella gilesi Sprigg, gen. et sp. nov.
(Pl. II, fig. 1)

Holotype: No. T.3., Tate Mus. Coll., Adel. Univ., S. Aust.

Description—Medusa impression circular. Umbrella rather flat, but falling away sharply near its outer margin. (?) Velarium 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 the centre. Centremost area depressed very slightly.

Outer Zone—Surface dominantly flat, but slopes away steeply near outer margin of umbrella. This secondary (sloping) surface has the form of a highly truncate cone whose apical angle is approximately 80 degrees. Zone characterised by the presence of circular (?) gonadial structures, approximately 10 mm. in diameter. These regular structures are arranged on either sides of the major radial canals in an octagonal pattern centrally within the zone. At least four of these can be recognised and each possesses an inner concentric groove 3-4 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 (?) paired gonadial structures but do not continue into the inner

zone. The ex-umbrella surface is slightly lobate at the edge of the flat raised portion, but below where the conical surface meets the (?) velarium the margin is smooth.

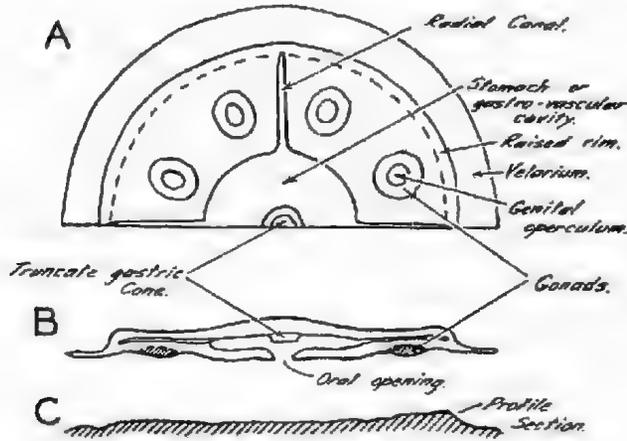


Fig. 4
Beltanella gilesi

A, details of exumbrella surface and related embedded organs; B, transverse section through restored form; C, true profile section along diameter of form.

Velarium—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 velarium respectively 18-20, 21-23 and 10-14 mm.

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

The central zone evidently corresponds with the gastrovascular cavity as at its margin it gives off paired grooves which are interpreted as interradial 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 which occurs in some jellyfish to aid in the even distribution of food to various portions of the animal's stomach.

The radial grooves of the outer zone are thought to be interradial canals, although why they should be paired is not known. 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. The central annular grooves of each gonadial structure may mark a genital operculum.

The (?) velarium or peripheral umbral jelly is remarkably well preserved considering its obvious delicateness; its contained annular undulations may indicate ring muscles.

The decision to place *Beltanella* within the Scyphozoa must be regarded only as very tentative, as the animal has many restrictive features characteristic of either certain orders of the Scyphozoa or of the Hydrozoa. For example, the simple mouth, the presence of a few unbranched radial canals and the association

of the gonads with the radial canals are Trachylinid (Hydrozoan) characters. On the other hand the flattened disc-shaped umbrella, its relatively large size, and the absence of large tentacles are more characteristic of the Scyphozoa. It appears very likely, therefore, that *Beltanella* is a member of a group, ancestral to either or both the Scyphozoa and Hydrozoa of modern times. Indeed, this is to be expected considering the great age of the fossil. The author knows of no living or fossil jellyfish with which useful comparison of the foregoing specimen can be made.

The fossil is tentatively classified with the Scyphozoa, mainly in view of the absence of the large tentacles which are typical of the Trachylinids.

On the slab of rock carrying the holotype there are at least four additional circular structures (10-23 mm. in diameter) which may represent juvenile forms. All display annular grooves, and in the largest specimen, the central portion (9 mm. in diameter) is raised relatively to the outer zone. In the latter example (which is photographed with the holotype) there is very definite evidence of a velar structure, 2 mm. wide, similar to that of *Beltanella*.

Still another possibly related form found at the same locality is the disc-like impression shown on pl. ii., fig. 2 (specimen No. T4). This external cast is almost



Fig. 5

True profile section of un-named form figured on pl. ii, fig. 2.

perfectly circular with a slightly raised rim near the external margin. The whole structure stands in relief a little above the face of the quartzite slab, and its surface is evenly convex, except in the marginal region, where it is raised somewhat; it shows no recognisable anatomical structure or ornamentation. This smooth depressed (annular) area (7-10 mm. wide) is faintly reminiscent of a velar structure. Maximum diameter is 104 mm., not including the latter structure. The impression may be that of a simple discoid jellyfish or of a hydroid float.

Class (?) HYDROZOA or (?) SCYPHOZOA

Genus *Cyclomedusa* Sprigg, gen. nov.

Genotype *Cyclomedusa davidi* Sprigg, gen. et sp. nov.

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

This genus also is monotypic, and in view of the lack of detail of most of the critical features of the form the generic characters are based tentatively on the sculpturing of the (?) ex-umbrella surface of the form.

Cyclomedusa davidi Sprigg gen. et sp. nov.

(Pl. iii, fig. 1)

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

Description—Impression circular, depressed, with concentric undulations. Central portion raised, distinctly nodular. The whole form exhibits striking radial symmetry. Surface subdivided by at least seven annular grooves. For convenience three major zones are recognised.

Inner Zone—Consists simply of the hemispherical nodular portion mentioned previously. Approximately 2.5 mm. in radial width and 1.5 mm. in height.

Median Zone—Subdivided into two annular portions of low relief, the inner of which is traversed in turn by two annular grooves, while the outer is

ornamented by very numerous radial striations about 3 mm. in length. There are approximately 16 of these grooves in each quarter. A poorly developed annular groove traverses the outer portion.

Outer Zone—Surface sculpture very similar to that of the median zone; the smooth inner portion is bounded by annular grooves and the outer is traversed by numerous poorly developed radial striations averaging 4 mm. in length. The outer margin to the zone is very poorly preserved.

Dimensions—Maximum diameter probably 50 mm. Average widths of the inner, median and outer zones along single radius 2.5, 11.0 and 11.0 mm. respectively.

Discussions and Comparisons—The surface ornamentations, which stand in strong relief, appear to be of superficial significance, but some of the annular flutings may be related to ring muscles of the subumbrella of a jellyfish. No structures which can be attributed to a body cavity or to gonads are visible.

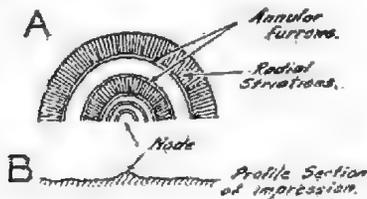


Fig. 6

Cyclamedusa davidi

A, details of the surface ornamentation of the restored form;

B, profile section along a diameter of the actual fossil.

There is no evidence of extra-marginal structures, but as noted, the marginal region of the fossil is poorly preserved.

In view of the paucity of critical detail, it is only with hesitation that the fossil is provisionally included within the Coelenterata. The form is highly problematical and possibly only represents the restricted central portion of a larger animal. It does seem certain from its regularity and complexity, however, that the form is not a pseudofossil.

Genus *Dickinsonia* Sprigg, gen. nov.

Genotype *Dickinsonia costata* Sprigg gen. et sp. nov.

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

This genus which is monotypic, exhibits the species characters described below. Animal of ovoid form, (?) inflated aborally and possesses a marginal crenulate flange. Median longitudinal furrow gives off very numerous subradial grooves to the outer (crenulate) margin of the form.

Dickinsonia costata gen. et sp. nov.

(Pl. iii, fig. 2)

Holotype: No. T.6., Tate Mus. Coll., Adel. Univ., South Australia.

Description—Impression ovoid, bilaterally symmetrical, essentially flat. Median longitudinal furrow approximately 35 mm. long, gives off 80 to 90 radiating or diverging grooves or costae (?) alternatively to the outer margin of the fossil. Margin slightly crenulate, the notches corresponding with the intersection of the radiating grooves. Well developed concentric epi-marginal sulcus marks off a marginal flange.

Dimensions—Length 68 mm.; width 60 mm. Flange width variable, from 2 to 7 mm., due to distortion.

Discussions and Comparisons—The fossil is the impression of the (?) dorsal aspect of a bilaterally symmetrical animal of very doubtful affinities. During burial the animal was flattened and compressed slightly obliquely in a manner which suggests that it was strongly convex dorsally. The animal was symmetrical across both longitudinal and transverse planes. Radiating grooves or costae may represent chitinous rods or canals, while the epimarginal groove may represent a circular canal. No gastrogenital structures or appendages are apparent.

It is exceedingly difficult to classify *Dickinsonia* on the little detail available. The author knows of no related animal with which to establish relationships, and until new specimens with more detail are found little more can be suggested than that the animal is probably a coelenterate.

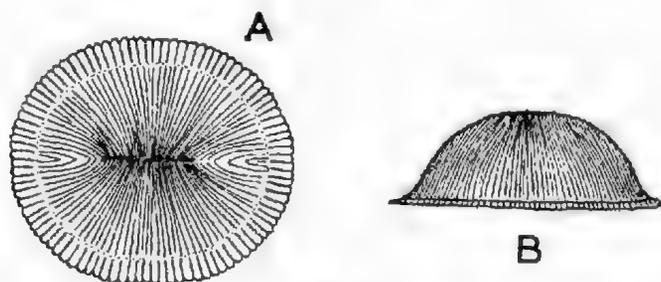


Fig. 7

Dickinsonia costata

Details of surface ornamentation of the restored form as viewed in elevation (A) and in plan (B).

There are certain superficial features in which it resembles the problematical form *Discophyllum peltatum* (Hall), but these apparent resemblances soon disappear when detailed comparisons are made. *Discophyllum* is a rounded or oval flattened form with bars which radiate from the centre of the form, and not from a longitudinal furrow as in *Dickinsonia*. Also there are fine concentric undulating lines that cross both the rays and the interspaces between them. Comparable structures do not occur in *Dickinsonia*. There is no flange structure in *Discophyllum*, nor is the external margin crenulate. The ribs fade out before the margin is reached.

(?) *Dickinsonia* sp.
(Pl. iv, fig. 1)

Specimen No. T.7., Tate Mus. Coll., Adel. Univ., South Australia.

Description—Impression fragmentary, radially costate; costae continue to the margin. Margin rounded, slightly crenulate in sympathy with the disposition of the costae. A slight bending of the costae, noticeable 7-8 mm. in from the margin of the fossil, indicates a tendency to flange formation.

Discussions and Comparisons—From the little detail available for comparison of this specimen with the foregoing holotype the major similarities are concerned with the radiating costae, which in both forms are strongly developed and continue to the somewhat crenulate margin. In the holotype specimen the costae are interrupted by a very well marked concentric sulcus, whereas in the latter specimen there is only the faintest hint of interruption of the radial costae in a similar position. None of the costae in the second specimen appear to diverge as if to unite alternatively into a central furrow as in the type form.

The correlation of this fossil with *Dickinsonia* is quite tentative and the form must be considered problematical.

Genus *Papilionata* Sprigg, gen. nov.Genotype *Papilionata eyrei* gen. et sp. nov.

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

The genus is monotypic and shares the species characters described below. Unfortunately, the generic characters must be based on the shape of the fossil and its restricted surface sculpture. The form is bilaterally symmetrical, papilionaceous with the amygdaloidal "wings" fused anteriorly. A marginal groove is present and the posterior margin of the wings is met by sub-parallel or slightly radiating grooves.

Papilionata eyrei Sprigg, gen. et sp. nov.

(Pl. iv, fig. 2)

Holotype: No. T.8., Tate Mus. Coll., Adel. Univ., South Australia.

Description—Impression bilaterally symmetrical. Left hand portion imperfectly preserved and fragmental. Complete impression papilionaceous, the "wings" being fused for approximately 30 mm. in the anterior aspect. The left hand wing is amygdaloidal in plan, curved convexly on the inner margin, and rounded and slightly lobate (posteriorly) on the lateral margin. From the posterior portion of this margin, radial grooves converge towards a central point near the inner margin, but fade out after 10 to 20 mm. The grooves are stronger and longer at the posterior extremity, and they are not visible forward of the centre of this margin. The single notch on the lateral margin may not have anatomical significance, being probably a crenulation due to the animal's assumed position of rest. The lateral margin is paralleled by a well-developed groove through which the radial costae continue uninterrupted. The groove diverges slightly from the margin at the anterior end. A similar divergence is apparent in the "reflected" wing.

Dimensions—Maximum width of complete extended form 150 mm. Maximum length and width of single wing 112 and 56 mm. respectively.

Discussions and Comparisons—The impression has been described as bilaterally symmetrical, but there is a possibility that two separate organisms may be represented, the line of "fusion" as described being a fortuitous overlap of the respective organisms. Nevertheless, the excellent "reflection" of the two portions appears to predispose of this view. The single wing impression suggests a disc-like jellyfish lying upon its margin with portion of its umbrella surface folded under.

The author knows of no similar organism with which useful comparison can be made.

ACKNOWLEDGMENTS

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Fig. 1 *Ediacaria flindersi* Sprigg
(approx. $\times 1$).

Photo by K. P. Phillips



Fig. 2 *Ediacaria* (?) *flindersi* Sprigg
Slightly less than natural size.

Photo by K. P. Phillips



Fig. 1 *Beltanella gilesi* Sprigg
Two thirds natural size.

Photo by K. P. Phillips



Fig. 2 Discoid Scyphozoan or Zooidal float (x 100)

Photo by K. P. Phillips



Fig. 1 *Dickinsonia australis* Sprigg (1841)

Photo by K. P. Phillips



Fig. 2 *Dickinsonia costata* Sprigg
Slightly larger than natural size.

Photo by K. P. Phillips

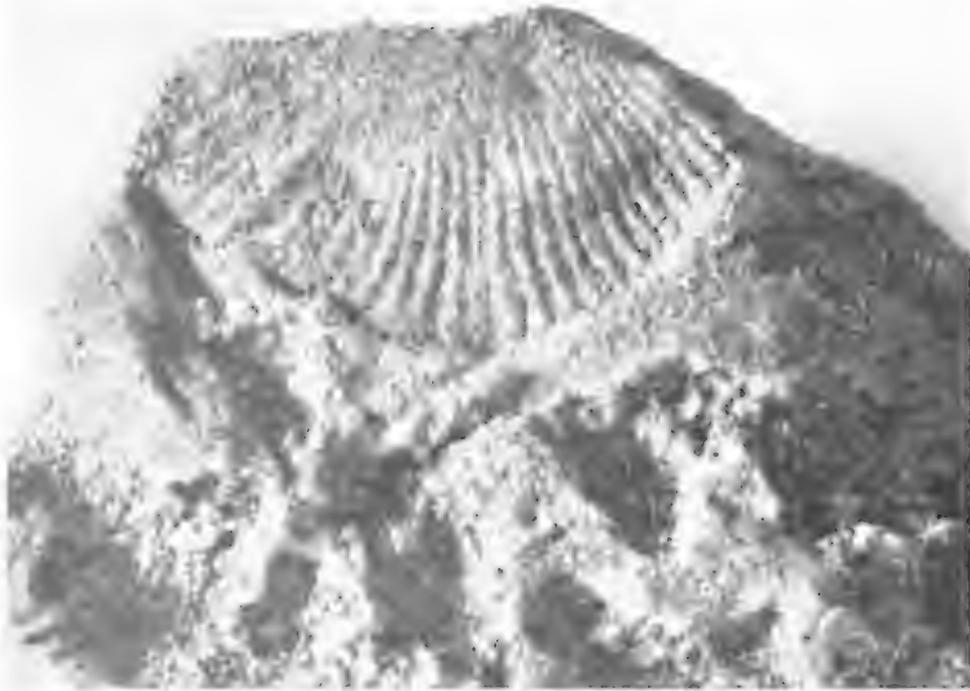


Fig. 1 *Dickinsonia* (?) sp. (approx. x 17)

Photo by K. P. Phillips



Fig. 2 *Papilionata eyrei* Sprigg
(approx. x 6).

Photo by K. P. Phillips

SOME NEW EURYMELIDS FROM AUSTRALIA AND NEW GUINEA (HOMOPTERA, JASSOIDEA)

BY J. W. EVANS

Summary

A collection of Homoptera recently sent me by Mr. D. C. Swan included representatives of eight species of Jassoids belonging to the family Eurymelidae, which he had collected in New Guinea during the war. Five of these species are described below. Of the remainder, one, *Eurymeloides nigra* Evans, is confined to New Guinea, and two, *Eurymeloides punctata* Sign. and *E. adspersa* Sign., both of which are well-known Australian species, are recorded from New Guinea for the first time. The host plants were species of *Eucalyptus* and *Melaleuca*.

SOME NEW EURYMELIDS FROM AUSTRALIA AND NEW GUINEA
(HOMOPTERA, JASSOIDEA)

By J. W. EVANS*

Communicated by D. C. Swan

[Read 7 August 1947]

A collection of Homoptera recently sent me by Mr. D. C. Swan included representatives of eight species of Jassoids belonging to the family Eurymelidae, which he had collected in New Guinea during the war. Five of these species are described below. Of the remainder, one, *Eurymeloides nigra* Evans, is confined to New Guinea, and two, *Eurymeloides punctata* Sign. and *E. adspersa* Sign., both of which are well-known Australian species, are recorded from New Guinea for the first time. The host plants were species of *Eucalyptus* and *McLaleuca*.

Of the remaining four new species of Eurymelids described below, the most distinctive is *Ipoella davisi*, which was collected in North-west Australia by the late Dr. Consett Davis, whose tragic death in 1944 was an irreparable loss to entomology in Australia.

***Eurymeloides sogerensis* sp. nov.**

Length, 5 mm. *Head*, face evenly dark brown, but for the outer margins of the lora and maxillary plates, which are cream. *Pronotum* brown mottled with pale greyish-brown. *Scutellum* dark brown. *Tegmen* dark brown, irregularly mottled with dark grey. *Thorax*, ventral surface and legs, dark brown. *Male Genitalia*, aedeagus as in fig. 1, A.

Holotype, ♂, from Sogeri, New Guinea (D. C. Swan, 5/45), in the British Museum. Paratypes in the South Australian Museum.

***Eurymeloides motuana* sp. nov.**

Length, 7 mm. *Head* dark nigger or reddish-brown mottled with yellow; ante-clypeus dark brown; lora and adjacent parts of the maxillary plates yellowish or pale brown. *Pronotum* nigger or reddish-brown mottled with ivory. *Scutellum*, the angles black, centrally dark brown with oval yellowish markings. *Tegmen* black with two irregular white, transverse fasciae and with a white marking at the distal apex of each anal vein. *Legs* brown, the bases of the spines and the proximal tarsal segment of the hind tibia, white. *Male Genitalia*, aedeagus as in fig. 1, B.

Holotype, ♂, from Port Moresby, New Guinea (D. C. Swan, 5/45), in the British Museum. Paratypes in the South Australian Museum.

***Eurymeloides nigrobrunnea* sp. nov.**

Length, 7.2 mm. *Head*, maxillary plates pale brownish-yellow; ante-clypeus lora and fronto-clypeus pale reddish-brown; vertex dark brown mottled with apricot yellow. *Pronotum* and *Scutellum* chestnut brown or brown mottled with yellow. *Tegmen* black with two white fasciae, each with a large irregular black marking, anal veins distally white. *Legs*, femora pale brown, tibiae dark brown, the bases of the spines and the proximal tarsal segment, white. *Male Genitalia*, aedeagus as in fig. 1, C.

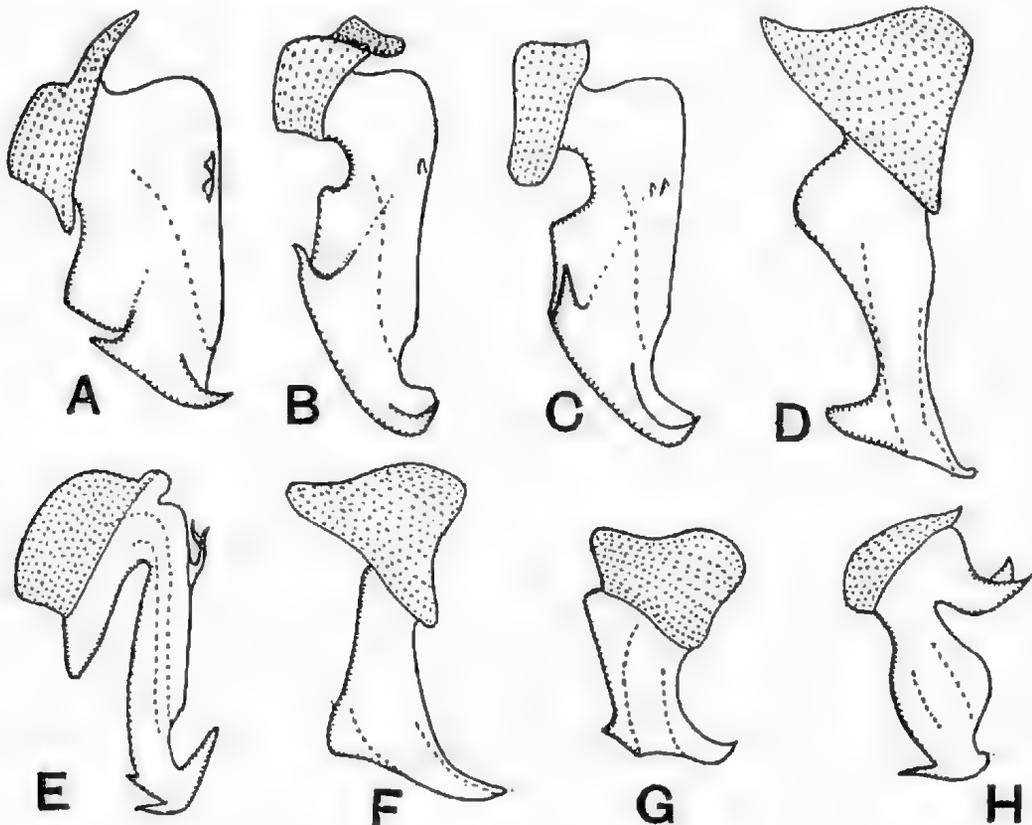
Holotype, ♂, from Port George, North-west Australia (C. Davis, 5/43), in the British Museum. Paratypes in the South Australian Museum.

* Imperial Institute of Entomology.

***Ipoides brunomaculata* sp. nov.**

Length, 5 mm. *Head*, face, but for the vertex, yellowish-ivory with a median longitudinal dark brown stripe. Vertex pale brown irregularly mottled with chestnut brown. Crown and *pronotum* pale chestnut brown mottled with yellowish-ivory. *Scutellum* deep chestnut brown with two pale semi-circular markings. *Tegmen* pale hyaline brown with irregular white markings; veins white, brown in part. *Legs* very pale brown. *Male Genitalia*, aedeagus as in fig. 1, F.

Holotype, ♂, from Port Moresby, New Guinea (D. C. Swan, 5/45), in the British Museum. Paratypes in the South Australian Museum.

***Ipoides melaleuca* sp. nov.**

Length, 5 mm. *Head*, face, maxillary plates greyish, the rest of the face pale greyish-brown evenly mottled with dark brown. Crown, *pronotum* and *scutellum*, greyish, sparsely mottled with brown. *Tegmen* very pale hyaline brown; veins brown with white bars. *Legs*, femora dark brown, tibiae pale brown. *Male Genitalia*, aedeagus as in fig. 1, G.

Holotype, ♂, from Sogeri, New Guinea (D. C. Swan, 5/45), in the British Museum. Paratypes in the South Australian Museum.

***Anipo pallescens* sp. nov.**

Length, 5.5 mm. *Head*, face, maxillary plates, lora and fronto-clypeus laterally, ivory partially suffused with apricot; ante-clypeus, the fronto-clypeus

medially and the vertex, deep coffee brown with pale oval markings. Crown and pronotum pale greyish-brown mottled laterally with dark brown. Scutellum, anterior lateral angles dark brown, the remainder pale brown. Tegmen pale hyaline brown with evenly distributed circular colourless hyaline areas. Thorax, ventral surface and legs marked with a pattern of pale and dark brown. Male Genitalia, aedeagus as in fig. 1, E.

Holotype, ♂, from Sogeri, New Guinea (D. C. Swan, 5/45), in the British Museum. Paratypes in the South Australian Museum.

***Ipoella davisii* sp. nov.**

Length, 5 mm. *Head*, face almost flat; ante-clypeus narrowly depressed anteriorly, dark brown; fronto-clypeus medially dark brown, shading to pale brown, laterally ivory; lora brown adjacent to the ante-clypeus, laterally ivory; maxillary plates ivory anterior to the antennae, dark brown beneath the eyes; vertex chestnut and very dark brown, posteriorly ivory. Crown brown with irregular dark brown markings. Pronotum buff mottled with brown. Scutellum dark brown. Tegmen hyaline, the costal margin and the apex smoky brown, the remainder dark brown with a broad proximal white fascia and white markings at the apex of the first anal vein. Some specimens have also a distal white fascia. Male Genitalia, aedeagus as in fig. 1, D.

Holotype, ♂, from Isdell River, Walcott Inlet, North-west Australia (C. Davis, 9/43 on *Ficus*), in the British Museum. Paratypes in the South Australian Museum.

***Bakeriola tasmaniensis* sp. nov.**

Length, 5 mm. *Head*, face black sparsely mottled with brown but for the outer margins of the maxillary plates, which are white and the lora, which are cream, partially suffused with pale brown. Crown of head and pronotum pale brown mottled with dark brown. Scutellum dark brown. Tegmen, clavus concolorous with the pronotum, the remainder hyaline brown with circular and irregularly shaped colourless area. Legs dark brown but for the coxae, the tarsi, and both ends of the tibiae and femora, which are pale brown. Male Genitalia, aedeagus as in fig. 1, H.

Holotype, ♂ from Risdon, Tasmania (J. W. E., 4/39), in the British Museum. Paratypes in the South Australian Museum.

***Bakeriola rubra* sp. nov.**

Length, 4.8 mm. General coloration dark brown. *Head*, face evenly convex, dark brown mottled with reddish-brown. Crown and pronotum irregularly mottled with dark brown and reddish-brown. Scutellum dark brown, mottled antero-medially with pale reddish-brown. Tegmen, hyaline dark and reddish-brown with oval white markings. Legs reddish-brown, hind tibia with three spurs and several spines.

Holotype, ♂, from Moolooka, Queensland (4/44, E. F. Riek), in the British Museum. Paratype in the South Australian Museum.

GEOLOGICAL MAP

PORTION OF HUNDREDS OF
BELALIE, YANGYA, CALTOWIE, TARCOWIE, MANNANARIE AND WHYTE
COUNTIES VICTORIA AND DALHOUSIE
SOUTH AUSTRALIA

TARCOWIE

MANNANARIE

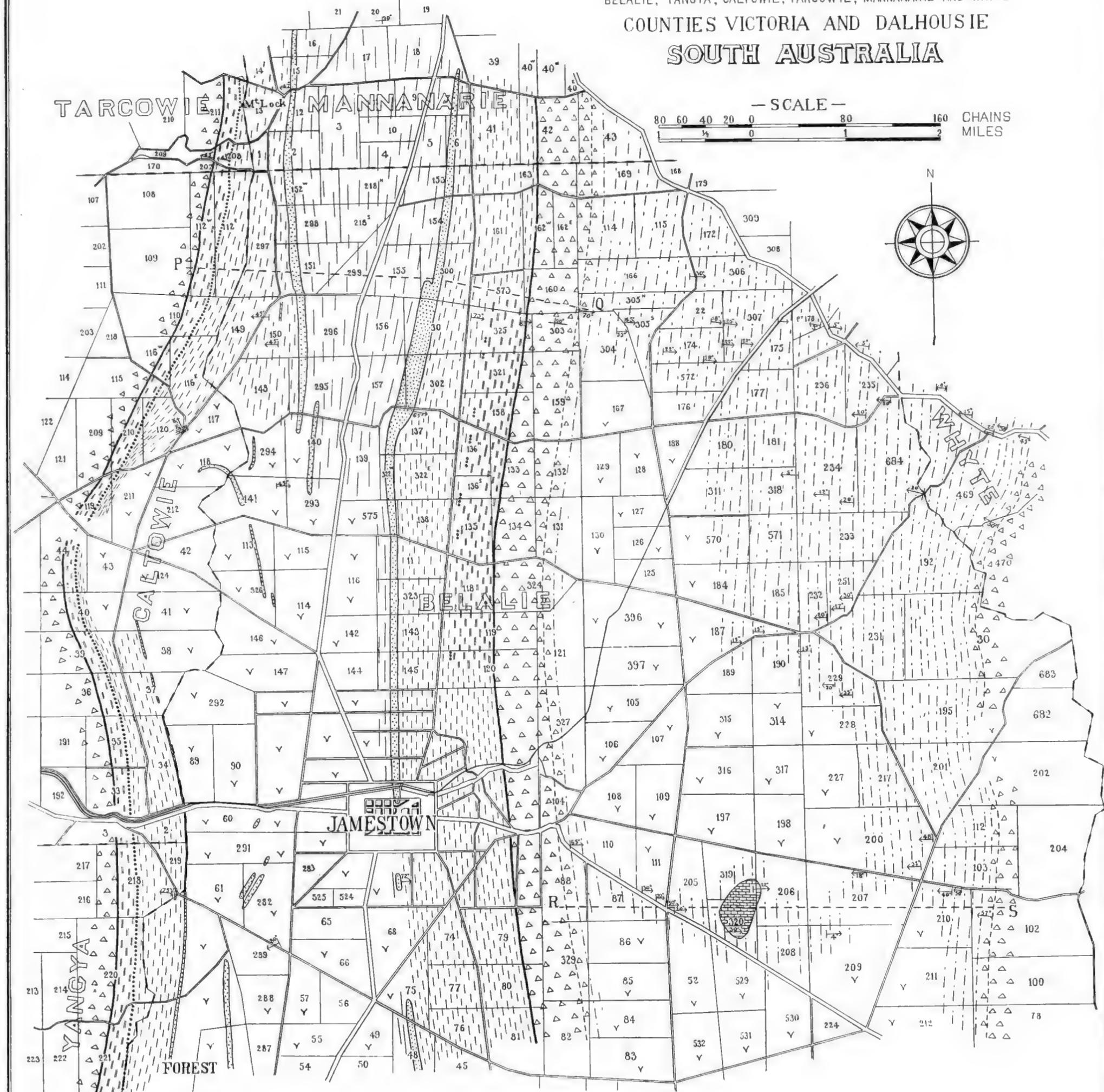
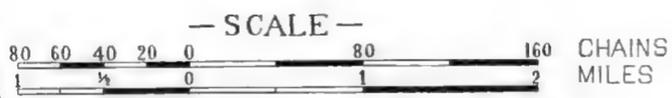
BELALIE

CALTOWIE

YANGYA

JAMESTOWN

FOREST
RESERVE



— LEGEND —

- | | | | |
|--|--|--|--|
| | J Banded Siliceous Limestones | | D Quartzite & Sandstone |
| | H Slates & Shales (Tabley Hill Series) | | C Slates & Phyllites with some Shales & thin beds of Dolomitic Limestone |
| | G Tillite Series | | B Quartzite & Sandstone |
| | X Arkose Grit in Tillite Series | | A Phyllites & Slates with some thin beds of Dolomitic Limestone |
| | F Sub-Glacial Quartzite | | Y Alluvium with no rock outcrops |
| | E Slates Phyllites & Hornfels | | |

THE MARINE ALGAE OF KANGAROO ISLAND

By J. W. EVANS

Summary

Kangaroo Island lies off the South Australian coast at the base of Gulf St. Vincent, being separated from Fleurieu Peninsula by Backstairs Passage (10 miles wide) and from Yorke Peninsula by Investigator Strait (about 26 miles wide). The Island is 90 miles long and up to 32 miles wide, narrowing to only $\frac{1}{2}$ mile wide between the American River inlet and the south coast (see fig. 1). The long axis of the island is approximately east-west; the island lies between latitude $35^{\circ} 5' S.$ and $35^{\circ} 34 \frac{1}{2}' E.$ and $138^{\circ} 8' E.$

THE MARINE ALGAE OF KANGAROO ISLAND
I. A GENERAL ACCOUNT OF THE ALGAL ECOLOGY

By H. B. S. WOMERSLEY*

PLATES IX TO XIII

[Read 7 August 1947]

INTRODUCTION

Kangaroo Island lies off the South Australian coast at the base of Gulf St. Vincent, being separated from Fleurieu Peninsula by Backstairs Passage (10 miles wide) and from Yorke Peninsula by Investigator Strait (about 26 miles wide). The Island is 90 miles long and up to 32 miles wide, narrowing to only $\frac{1}{2}$ mile wide between the American River inlet and the south coast (see fig. 1). The long axis of the island is approximately east-west; the island lies between latitude $35^{\circ} 5' S.$ and $35^{\circ} 34\frac{1}{2}' S.$ and between longitude $136^{\circ} 32' E.$ and $138^{\circ} 8' E.$

The situation of Kangaroo Island in relation to the mainland, and the shape of the island itself, result in great variation in conditions of roughness along the coast. The exposed and rough south and west coasts contrast markedly with the calmer areas of the north coast, while the American River tidal inlet forms a distinct type of habitat not found elsewhere around the island.

From the point of view of algal ecology Kangaroo Island offers a particularly satisfactory area for study, especially in illustrating the control exerted on the algal flora by the degree of wave action.

This paper is the first report on work carried out during the past four years. The aim has been, firstly, to give a general account of the intertidal algal ecology of a part of the Southern Australian coast, since there have been no previous ecological studies of this region; secondly, to obtain as comprehensive a list as possible of the species present; and thirdly, to carry out autecological studies of the more characteristic and dominant species.

In this paper it is proposed to describe the more important environmental factors for the island as a whole; to discuss the terminology found most satisfactory; and to give a preliminary general account of the broader aspects of the algal ecology. In subsequent papers the more detailed ecology of characteristic regions will be dealt with, and a census of the known species will be given. Floristic and ecological comparisons with other areas will also be left to later papers. By first presenting a general survey of the algal ecology of the whole island, it is hoped to give perspective to the later detailed descriptions of individual localities.

The localities around the island which have been studied are shown in fig. 4. Of these, Pennington Bay and American River have received most attention. It has been possible to pay only one or two short visits to the western end of the island, while the very rough nature of the country and lack of roads prevents visits to most of the intervening parts of the south and west coasts. This, and the restriction of field work to the University vacations, have limited examination of most localities other than American River and Pennington Bay to January. Seasonal changes in places other than American River and Pennington Bay are therefore unknown as yet, but the associations which occur in these places and are described in this paper are almost certainly present throughout the year.

* Department of Botany, University of Adelaide.

The areas studied at Western River and Middle River consist of the coast on either side of the river mouth. These rivers run only after heavy rain, at other times being blocked by a sand bar at the mouth. American River, however, is an extensive tidal inlet, consisting of a series of lagoons with wide tidal flats and a central channel, opening to the sea through a mouth some 250 yards wide. The amount of fresh water entering the lagoons from small creeks is negligible, except for possible local effects after heavy rain. The conditions at all "River" localities, therefore, are truly marine.

PREVIOUS MARINE ECOLOGICAL STUDIES IN AUSTRALIA

Australian phycology is based to a large extent on the work of the early European algologists, Harvey, Agardh, Sonder and others, who described collections sent to them from Australia. As a result, very little ecological information is available about the early localities from which collections were made. Harvey (1854), however, gave short notes on the Western Australian coast, and ecological information about many species in his *Phycologia Australica*.

More recently, Hedley (1915) has presented a very general survey of the New South Wales coast, and Lucas (1935) has described the algal ecology of Lord Howe Island. Pope's (1943) survey of animal and algal life on a reef near Sydney is the only work of a detailed nature, but deals primarily with the animal ecology.

The review of Chapman (1946) gives a comprehensive list of references to algal ecology studies elsewhere in the world.

PREVIOUS RECORDS FROM KANGAROO ISLAND

Previous records of marine algae from Kangaroo Island are very few. Cleland and Black (1941) listed 11 species collected from near the mouth of Sou' West River, and determined by A. H. S. Lucas. Lucas (1929), in his census, lists two species from the island, while Part I of "The Seaweeds of South Australia" records *Caulerpa hedleyi* W. v. Bossé, "dredged in some 8 fathoms off the coast." Part II of the "Seaweeds of South Australia" contains several records, all incorporated by the present author. Two short reports on the *Rivularias* and a new species of *Dasyopsis* have also been published (Womersley 1946 a and b).

The land vegetation of Kangaroo Island has received considerable attention. Tate (1883) gave the first general account of the Island, and more recently Wood (1930) has elucidated the relationships of the flora and shown a high degree of endemism, particularly in species confined to the western end. Baldwin and Crocker (1941) have described vegetation communities in the central part of the Island.

ENVIRONMENTAL CONDITIONS

1. THE COASTAL GEOLOGY

The present study has shown that while the individual type of rock has little effect on the flora, the rock topography, in that it may result in different types of habitats, may be of considerable importance in determining the algal associations of an area.

The only reasonably detailed geological map of Kangaroo Island is that of Wade (1915), which is followed in fig. 1. The backbone of the island consists of Pre-Cambrian schists and gneisses, overlain in the central part by siliceous sand and laterite. On the west coast, eastern part of the north coast, and to a lesser extent on the east coast, these rocks form magnificent cliff scenery. The coast west of Emu Bay is of later age (Post-Cambrian) (Madigan 1928).

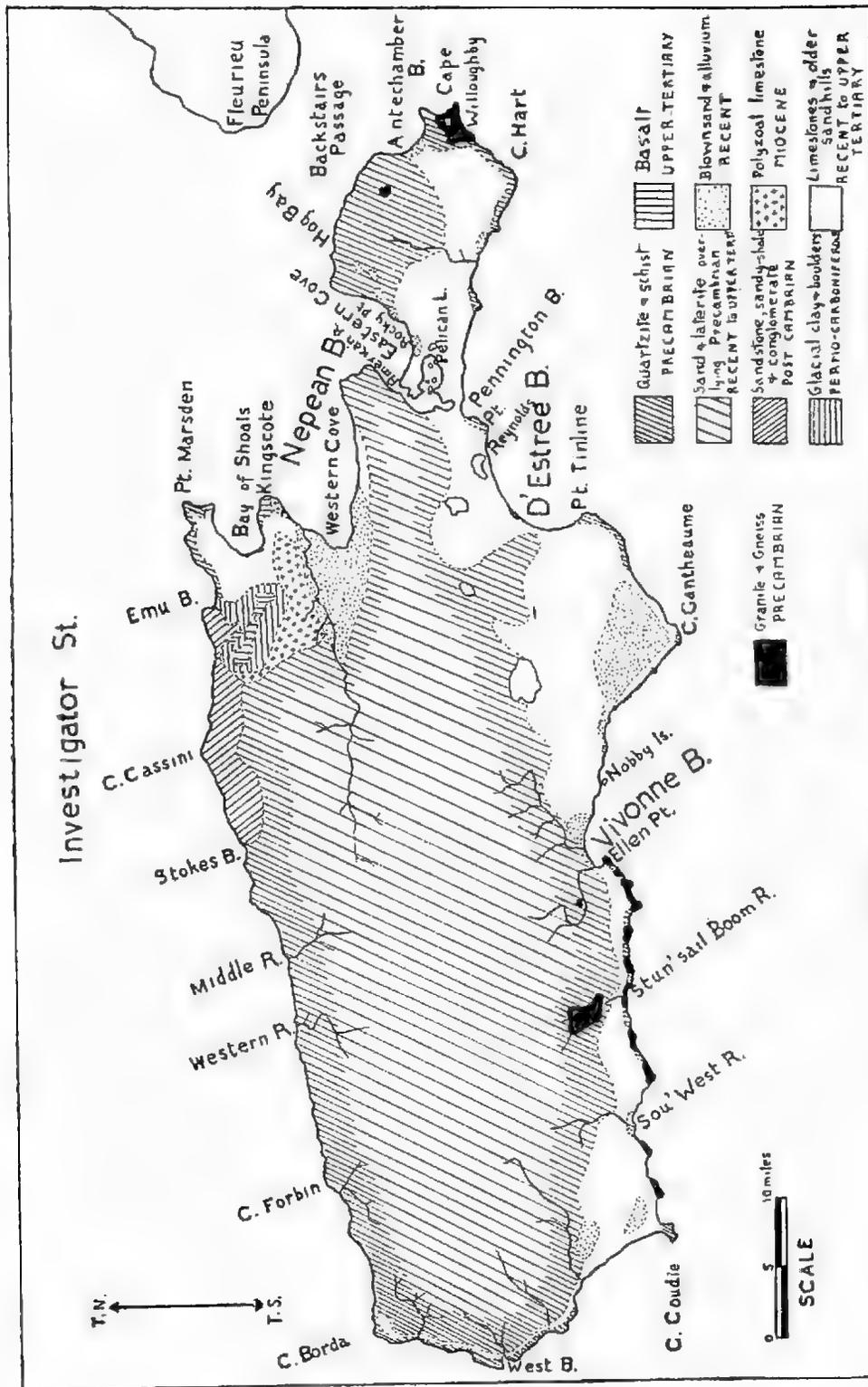


Fig. 1
Geological sketch map of Kangaroo Island. (after Wade 1915.)

The most significant geological features of the south coast of Kangaroo Island are the outcrops of ancient rocks at the capes. These outcrops do not rise to any notable height above sea level, and mostly appear at the foot of cliffs which fringe the shore. The extent of these outcrops of Pre-Cambrian rocks is shown in fig. 1. Two types of rocks, granite and quartzite or mica schists, form alternating patches along some of the coast. Between the areas of older rocks the coast consists either of sandy beaches backed by sand dunes or of sand-rock cliffs and horizontal reefs formed from older consolidated sand dunes. This rock weathers into very sharp edges and pinnacles, and by its variable hardness makes an irregular coast.

The two different types of rock found on the south coast of Kangaroo Island, *i.e.*, the flat rock platforms of consolidated sand-rock such as at Pennington Bay, and the harder more steeply sloping rocks such as seen at Cape Willoughby, west of Vivonne Bay, and Cape Coudie, result in two very different habitats for algal and animal growth, and appear to illustrate the conditions occurring along most of the south coast (*cf.*, pl. ix, fig. 3, and pl. xii, fig. 1).

Most of the American River inlet consists of extensive sandy or sandy-mud tidal flats, but in many areas, particularly in Pelican Lagoon, these stretch out from low cliffs of the same consolidated sand-rock as at Pennington Bay on the south coast.

The northern coast of the island is composed mainly of ancient rocks sloping off into 3 to 12 or more feet of water, giving a relatively small area of rock exposed at low tide.

2. DEGREE OF WAVE ACTION

The degree of roughness of any locality is of prime importance in determining the algal associations present. The south and west coasts are exposed without any protection to the Southern Ocean, and conditions are invariably rough. Heavy breakers are a constant feature of this coastline (see pl. ix, fig. 1). Passing along the north coast, from west to east, conditions become progressively calmer, owing to the shelter afforded by the mainland. Northwards from Cape Willoughby and past Hog Bay wave action is moderate, with breakers only in rough weather. American River and Pelican Lagoon, quite unlike the rest of the island, form an almost land-locked area where wave action is at a minimum.

Although wave action is of great importance as an ecological factor, its measurement in any satisfactory way seems impossible. Average values of the forces from wave action to which algae are subjected in any one locality are needed. These should be measured over short periods (when extremes may occur), as well as over monthly and yearly periods. In the absence of any such measurements it is necessary, in some cases, to use the algae themselves as an index of the conditions. This has been done in subdividing the Rocky Shore Formation into subformations, depending on the presence or absence of *Cystophora intermedia* J. Ag. This alga is dominant in the sublittoral fringe on rough rocky coasts, but is replaced by other species of *Cystophora* on calmer coasts.

3. TIDES

The tides around the Australian coast, including the main characteristics and ranges of the tides in the South Australian Gulf region, have been described briefly by R. W. Chapman (1938). The tides around Kangaroo Island are of the semi-diurnal type, with two maxima, one appreciably lower than the other, and two minima during each 24½-hour period. Fig. 2 shows the form of the spring and neap ("dodge") tides at American River.

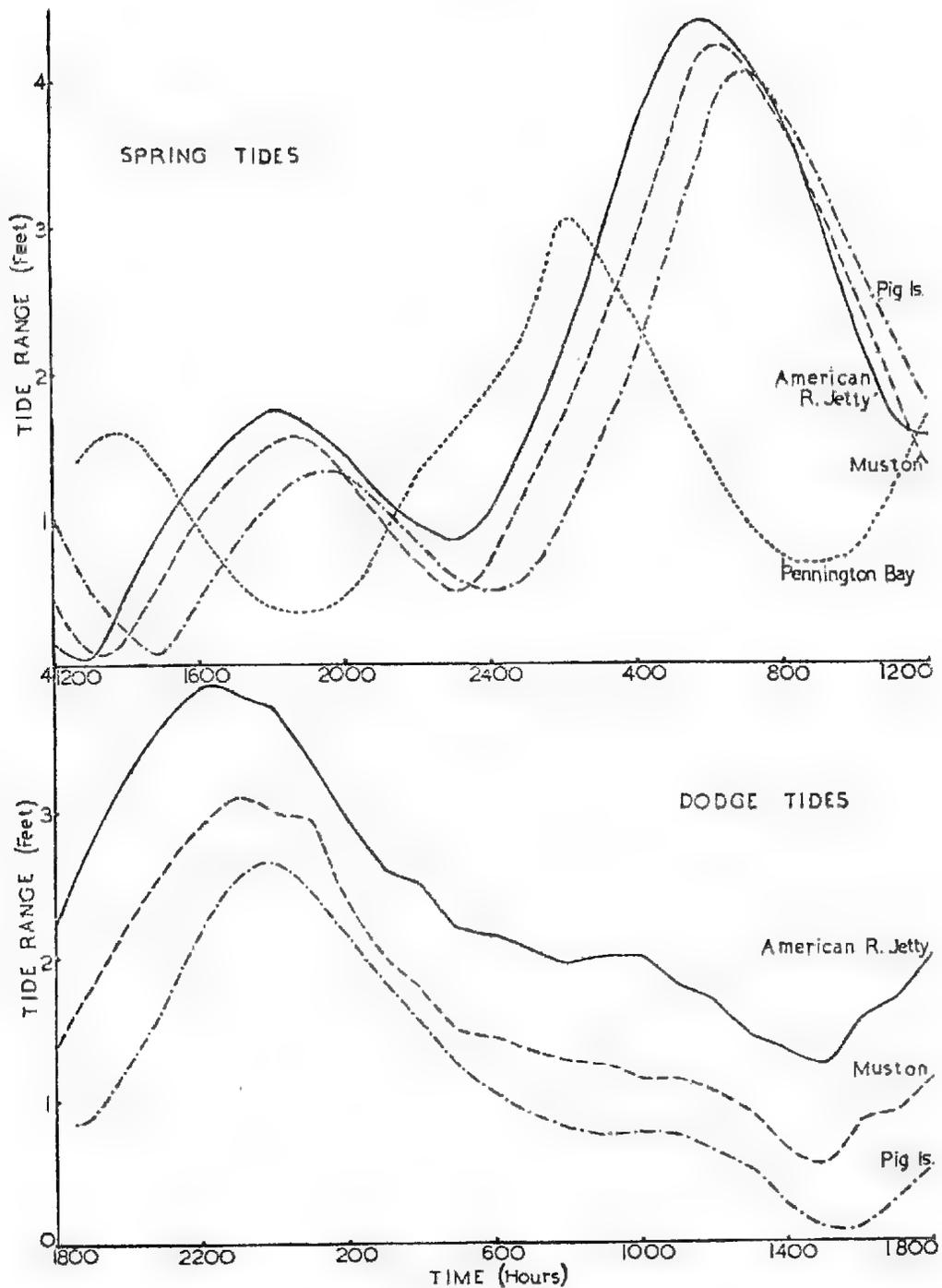


Fig. 2

Tide curves for spring and dodge tides in the American River Inlet and at Pennington Bay (spring tides only). The range of each tide curve and times of high and low water are comparable, but the heights given for each are arbitrary. The curves are derived from 24-hour surveys carried out at the American River Jetty, Muston Jetty, (3 miles south of American River Jetty), Pig Island in Pelican Lagoon, (2 miles East of Muston) and at Pennington Bay on the following dates: spring tides Jan. 10-11, 1947; dodge tides Jan. 16-17, 1947.

South Australian tides vary so greatly from place to place along the coast, both in their nature and times of high and low water, that it is necessary to obtain actual records from each locality. The tides have been analysed at comparatively few places, especially around Kangaroo Island. An automatic tide gauge recently established at Hog Bay should give most interesting results when records become available. The data given below for Kangaroo Island tides are derived from information made available by the South Australian Harbours Board and from 24-hour surveys carried out at American River and Pennington Bay. It will be evident that until accurate and more extensive tidal data are available, general limits and heights only can be given for the main algal zones.

Tidal range around Kangaroo Island is small. Along the south and west coasts the spring range is about $2\frac{1}{2}$ feet. Passing eastwards along the north coast it increases to $4\frac{1}{2}$ feet at Kingscote, just over 4 feet at American River and Hog Bay, $4\frac{1}{2}$ feet at Antechamber Bay, while a rise of 6 feet is recorded from Cape Willoughby from old data (but this is probably too high). The neap (or "dodge") tides probably have a range of about $1\frac{1}{2}$ feet on the south coast and $2\frac{1}{2}$ feet on the north. On the south and west coasts the small tidal range means that the wind and strength of the swell may exert nearly as great an effect as the tide itself, and little reliance can be placed on the tides alone.

The most notable peculiarity of South Australian tides is the "dodging" tide. This is discussed by R. W. Chapman (1924). At Port Adelaide, where the effect is most prominent, the water level may remain almost constant for 24 hours or more at the neap periods. The cause is that during the neap period the sun and the moon, together with the other tide-producing forces, exert almost equal but opposite effects, one nullifying the other. It has been suggested that the abnormally large effect of the sun is accounted for by the synchronising of the natural period of swing of the basin of water between Australia and Antarctica with the period of the tide-producing forces.

At American River (see tide curves, fig. 2) the dodge effect seems to be present, though small, at the neap period. For about 6 hours the water level remains almost stationary, before the next rise or fall commences. Along much of the north coast this period of steady water level seems to occur, but no data are available as yet apart from isolated surveys at American River.

During winter the mean sea level at Port Adelaide is from 4 inches to 6 inches higher than in summer. This applies also to Kangaroo Island, with consequently higher tides during the winter months. With heavy west to north weather during winter very high tides often occur along the north coast. This is due to Investigator Strait being about $2\frac{1}{2}$ times as wide as Backstairs Passage, with consequent building up of the water mass in the area north of Kangaroo Island under the influence of westerly weather. The higher sea level during winter is of considerable importance on the south coast, where the increase is large compared with the tidal range. The level of the horizontal rock platforms of the Pennington Bay region appears to correspond approximately with an average low neap tide level in summer. While north winds and low tides occasionally leave much of the reefs exposed in summer, with consequent drying and desiccation of the algae, this rarely, if ever, occurs in winter. Apart from allowing a heavier growth in winter, this is also one of the factors controlling seasonal changes on the reefs. Similar considerations may apply to a less extent in the American River inlet.

4. CURRENTS

The surface current flows from west to east across the Great Australian Bight, passes along both sides of Kangaroo Island and on towards Tasmania

(see "Australia Pilot," 1, 24). Eastward from the Bight the coastal current is strongest in the period May to July, with an average rate of 7 miles per day off the coast between Kangaroo Island and Cape Northumberland. During February to April and August to October it is weaker, averaging 3 miles per day, while from November to January it averages less than 2 miles per day. The currents in Backstairs Passage are largely tidal, reaching a speed of $2\frac{1}{2}$ knots.

5. TEMPERATURES

Observations taken around the coast of the island give the following results for sea temperature (Table I). No data from other sources are available, but the figures agree well with the temperature isotherms given by Sverdrup et al (1942).

TABLE I
Sea Temperatures around the Coast of Kangaroo Island

South coast—Summer (Jan.)	-	-	inshore 19-20° C., offshore probably 18° C.
Winter (early June)	-	-	inshore 16° C.
(late July)	-	-	inshore 13.5° C.
(Sept.)	-	-	inshore 14° C.
North coast—Summer (Jan.)	-	-	inshore 20-21° C., offshore 19-20° C.
Winter (June)	-	-	inshore 11-13° C., depending on depth and air temperature; offshore 13-14° C.

From this table it is evident that the yearly range of sea temperature on the south coast is small, being about 4° C. offshore and 5 to 6° C. on reefs. The range is greater on the north coast and depends greatly on the depth of water and degree of roughness, since the calmer water is affected much more by air temperatures. On the tidal flats at American River temperatures as high as 32° C. have been recorded during summer in 6" - 12" of water, and as low as 10° C. in winter. Algae on the flats must be able to withstand a far greater range in temperature than south coast forms. In isolated rock pools at Vivonne Bay and along the north coast temperatures of up to 30 - 34° C. are frequent in summer.

AIR TEMPERATURES

The climate of Kangaroo Island is fairly uniform. Some data for Kingscote are given in Table II. The humidity figures probably give little indication of the humidity near algae exposed at low tide. Air temperatures are of greatest importance when a hot day (sometimes 35 - 38° C. in summer) coincides with a low tide. Under such conditions algae on the Pennington Bay reefs may be almost or quite exposed for several hours and considerable damage may result.

TABLE II
Air Temperature and Humidity Data for Kingscote
(From data made available by the South Australian Weather Bureau)

All readings were taken at 50 feet above sea level, over a period of 17 years.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Déc.	Yearly Av.
Mean Max. Temp. °C.	22.3	22.7	21.4	19.3	17.7	14.9	14.2	14.5	15.8	17.8	19.8	21.4	18.4
Mean Min. Temp. °C.	14.5	15.6	14.2	12.5	11.0	9.6	8.7	8.5	9.3	10.5	12.1	13.8	11.7
Mean Rel. Humidity	70	74	75	76	80	83	82	80	79	75	72	72	76

6. SALINITY

Chlorinity of sea water on the south and north coasts is within the range 19.6 - 19.9‰ (salinity 35.4 - 35.9‰). North coast values are usually slightly higher than those from the south coast. At Pelican Lagoon chlorinity in summer reaches 20.5‰ (salinity 37.0‰), while in isolated rock pools (some with a heavy growth of *Enteromorpha*) summer chlorinity figures of 24.0‰ have been obtained. After three days of heavy rain (January 1946) chlorinity on the tidal flats at American River decreased to 17‰; such conditions, however, are very exceptional.

Normal sea salinity around Kangaroo Island is high compared with other regions (e.g., 34.9‰ salinity near Sydney (Pope 1943)).

7. PHOSPHATE AND NITRATE

Estimations of these two major nutrients are as yet too few in number for any general conclusions to be reached. It appears, however, that nitrate is often extremely low (less than 1 part per 10⁹), while phosphate is rather variable. Phosphate figures of 14 and 23 p.p. 10⁹ have been obtained from the south coast, and values between 2 and 60 pp. 10⁹ from the American River inlet. Isolated high figures obtained at American River are probably due to the large bird population.

8. ALKALINITY

The pH of water (by colorimetric methods) at Pennington Bay is about 8.2 - 8.3, while at Pelican Lagoon figures of 8.1 have been obtained.

9. DISSOLVED OXYGEN

The constantly boisterous seas on the south and west coasts result in water supersaturated with oxygen. The water on reefs at Pennington Bay is usually about 110% saturated with oxygen. Oxygen figures in shallow water at the American River inlet in summer show high supersaturation during the day (120 - 150%, rarely as high as 250%), dropping to 50 - 70% saturation at night (an extreme of 10% saturation has been recorded). Such large ranges are due to the heavy growth of algae in the calm shallow water. For the most part it is unlikely that oxygen content of the water is of importance in the algal ecology. The Winkler method was used in all estimations.

10. LIGHT

No attempt has been made to measure light intensities at different depths, but correlation of shaded littoral areas with communities of sub-littoral algae has been observed at Pennington Bay and Vivonne Bay. On the south coast, with constantly broken water, light penetration will be less than in calmer waters off the north coast. At American River the large amount of silt carried in the tidal current reduces light penetration and may influence algal distribution.

TERMINOLOGY

At the present stage there is little uniformity in nomenclature used in marine algal ecology. Chapman (1946) reviews opinions expressed about terminology, and advocates adoption of the terms used in land ecology. However, land ecologists are far from agreement on their terminology, and until many more marine ecological studies in different parts of the world have been carried out, uniform and satisfactory meanings of the terms cannot be expected. This applies particularly to the Australian coasts. As in the past, each worker must use the terminology which best suits his locality and his own concepts.

The definitions adopted here have been found satisfactory in describing the algal vegetation of the Kangaroo Island coasts. Only further studies in other regions of the Southern Australian coast will show to what extent the concepts need to be modified, and their usage at present makes no pretension to be final.

ASSOCIATION AND COMMUNITY

The concept of an association is fundamental to all ecological work, yet many different meanings have been applied to the term. The association is used here in the sense of a grouping of organisms distinct in species composition and facies from another grouping. It is composed of a dominant or dominants usually accompanied by other species whose presence is determined by responses to factors similar to those influencing the dominants (see Rees 1935). This concept is to some extent subjective, but experience shows that most associations are objective entities. Studies over a long stretch of coast are usually necessary before the associations present can be determined. Intensive work on small areas often results in variations of one basic association being considered as separate associations. On the other hand, an association may be scattered in its occurrence and cover areas of only a few square feet of rock, yet may be typical of that particular habitat, and pure and well defined in its occurrence. This is especially true of irregular and dissected coastlines.

When associations occur during certain periods of the year only, they are classed as "seasonal associations."

The term "community" is commonly used with the same meaning as association, but often in a more general sense. It is applied in this and following papers when the status of the algal grouping has not been satisfactorily established.

FORMATIONS

Apart from classifying the associations in their zones (see later), the only other grouping used is the formation. This is applied to the principal types of marine vegetation, much as it was used by Cotton (1912) for Clare Island and Rees (1935) for Lough Ine. Cotton's formations were based on the substrate and environment for algal growth, and comprised the following:

1. Rocky shore Formation.
2. Sand and Sandy-mud Formation.
3. Salt-marsh Formation.

He also distinguished:

4. Vegetation of river mouths.
5. Vegetation of brackish bays.

Of these, the Rocky Coast ("Shore" of Cotton) and Sand and Sandy-mud Formations are found around Kangaroo Island, and they are real and natural entities. Rees' formations are based to a larger extent than Cotton's on the degree of wave action, but this is nearly always closely associated with the nature of the coast, and there is little difference between the formations of Rees and Cotton. The distribution of algae around Kangaroo Island shows that the degree of wave action is the most important environmental factor, as was emphasised by Rees.

Use of the substrate and environment as criteria for "formation" is criticised by Chapman (1946, p. 658), who advocates following the practice of naming land plant formations on the dominant species. However, Tansley (1940), to whom Chapman refers, describes Salt-marsh and Sand-dune Formations, and the naming of formations on the type of plant, while conveying at the same time something of the nature of the environment, is common in land ecology (*e.g.*, mallee,

savannah woodland, forest formations). Naming of the formation on the dominant plant or animal species is quite impracticable in many cases, such as with the Sand and Sandy-mud Formation.

In any case the formation is an abstraction. Of the four chief characteristics of an association, *viz.*, floristic composition, life-form, structure and habitat, Tansley uses two only (life-form and structure) as a basis for uniting associations into formations. It is just as logical to use either habitat or floristic composition as a criterion for such higher grouping (Crocker and Wood 1947).

Some algal formations in Tansley's sense can be readily determined by life form, *e.g.*, a blue-green formation and coralline-mat formation. On Kangaroo Island these formations are formed essentially of a single association, each delimited by definite environmental conditions, with the former occurring above the latter. It is evident that when the distinctive zones of algae around a coastline have very different life-forms, one zone must be chosen on which to base any classification; around Kangaroo Island this is the upper sub-littoral zone. To regard each zone as a distinct formation is clearly not justified.

It is well not to lose sight of the fundamental principle underlying the existence of communities, namely, that certain species live together in a particular situation because they have been selected by that environment, *i.e.*, all of the species have the same habitat requirements for growth. This gives the basis for defining associations.

Within any one tidal zone, different associations may occur depending upon local variations. These associations often have similar life forms, and possess unity in the fact that they have certain habitat requirements in common. Such "habitat zones" are realities and are the natural units of higher grade than the association.

In practice tide level, degree of exposure to wave action and nature of the substratum are the chief habitat factors. Using the latter two criteria a large unit (formation) is obtained; depending on the degree of wave action, the formation may be divided into sub-formations; and by using tide levels zonation is obtained.

Using habitat factors as criteria does present us with realities common in all parts of the world, and in this lies a real hope of achieving some degree of uniformity in marine ecological nomenclature. The formations of Cotton and Rees, or a combination of them, would be of world-wide occurrence, and subdivisions could well express the characteristic algal groups of the geographical regions.

ZONATION

The occurrence of marine algae in distinct zones between and often below tide levels is a distinctive feature of rocky coasts, though more prominent where the tidal range is large. The tidal range around Kangaroo Island is small (between 2 and 4½ feet), but zonation is always present and often marked.

In delimiting the zones around Kangaroo Island absence of accurate tidal data is a limiting factor. Until such data become available, the position of the zones of algae in relation to tide levels can be given only approximately, and what appear to be critical levels only from subjective observations. Thus the two main littoral associations of rocky coasts are referred to as being in the "upper littoral" and "lower littoral," but the relation of these to tide levels cannot be given. The upper littoral zone of blue-green algae probably does not extend to high water mark of spring tides, except when influenced by splash effects.

As long as the occurrence of algae and animals on the shore is referred to as "zonation"—a word which is far too well established to be dropped—there

seems no justification for replacing the term "zone" by "belt," as is advocated by Chapman.

It has been possible to relate the algal zones to measurements of tide levels only in the American River inlet. Here the stationary low water level of dodge tides appears to be of most importance, marking the separation of the *Hormosira* zone from a zone of red algae (*Hypnea* - *Centroceras* - *Spyridia*) which is nearly always covered. This level is very little higher than the low water level of neap tides (see graphs, fig. 2). On the south coast the low water mark of neap or dodge tides in summer appears to correspond closely with the surface level of the flat rock-platforms, and this marks a distinctive change in the algal flora. The higher mean sea level in winter may cause an elevation of the littoral flora, but the lower summer level will be the limiting factor at least for the more permanent algae.

The littoral zone is therefore considered as ranging from the stationary low of dodge tides, or the low water mark of neap tides to the upper limit of the algal vegetation. Accurate fixation of this level will have to await detailed tidal information.

The term "supralittoral" is often applied to the zone above high water level of spring tides. Alternative names are the "splash" or "spray" zones. Cotton (1912) has given good reasons for rejecting this term, and investigations around Kangaroo Island support the view that algal vegetation above actual high water level is simply an upward extension of the upper littoral algae under the influence of shade and wave-splash. One exception to this lies in the occurrence of *Prasiola* during winter at Pennington Bay and on Shag Rock in Pelican Lagoon, well above the area splashed by waves. This alga is subject to fine blown spray, but is as much terrestrial as marine. In both localities it occurs only where penguin and shag excrement is present. The lichen *Lichina* may occur in small patches in and above the splash area, and the mollusc *Melaraphe unifasciata* extends many feet above high water mark. Apart from these associations the term supralittoral is of little use in describing the algal ecology of Kangaroo Island.

Below the littoral is the sublittoral, which extends down to the limit of algal vegetation. The upper limit of the sublittoral, particularly on exposed rocky coasts, bears a distinctive algal flora, and this area, between low water mark of neap tides and extreme low water of spring tides, has been termed the "sublittoral fringe" by Stephenson (1939). The sublittoral fringe on rough coasts is exposed during the suck back between waves at low tide, and the short but frequent periods of exposure to air are probably of importance in determining the algal flora present. On the south and west coasts of the island this zone is dominated by *Cystophora intermedia*, which is strictly confined to the region exposed between waves at low tide. On calmer rocky coasts other species of *Cystophora* are dominant, but these extend to 6 or more feet below low water. At American River also the flora just below low water is not so distinctive, and is better referred to as "upper sublittoral." The sublittoral fringe must be regarded simply as a useful division of the sublittoral in certain areas, such as the rough coasts of Kangaroo Island.

A GENERAL ACCOUNT OF THE ALGAL ECOLOGY

This account is of a general nature only. While it is derived from the study of localities illustrating most of the coast and appears at the present stage well founded, it makes no pretensions to be final, and modification may be necessary as other coastal areas are visited. Descriptions of the typical localities will be given in later papers.

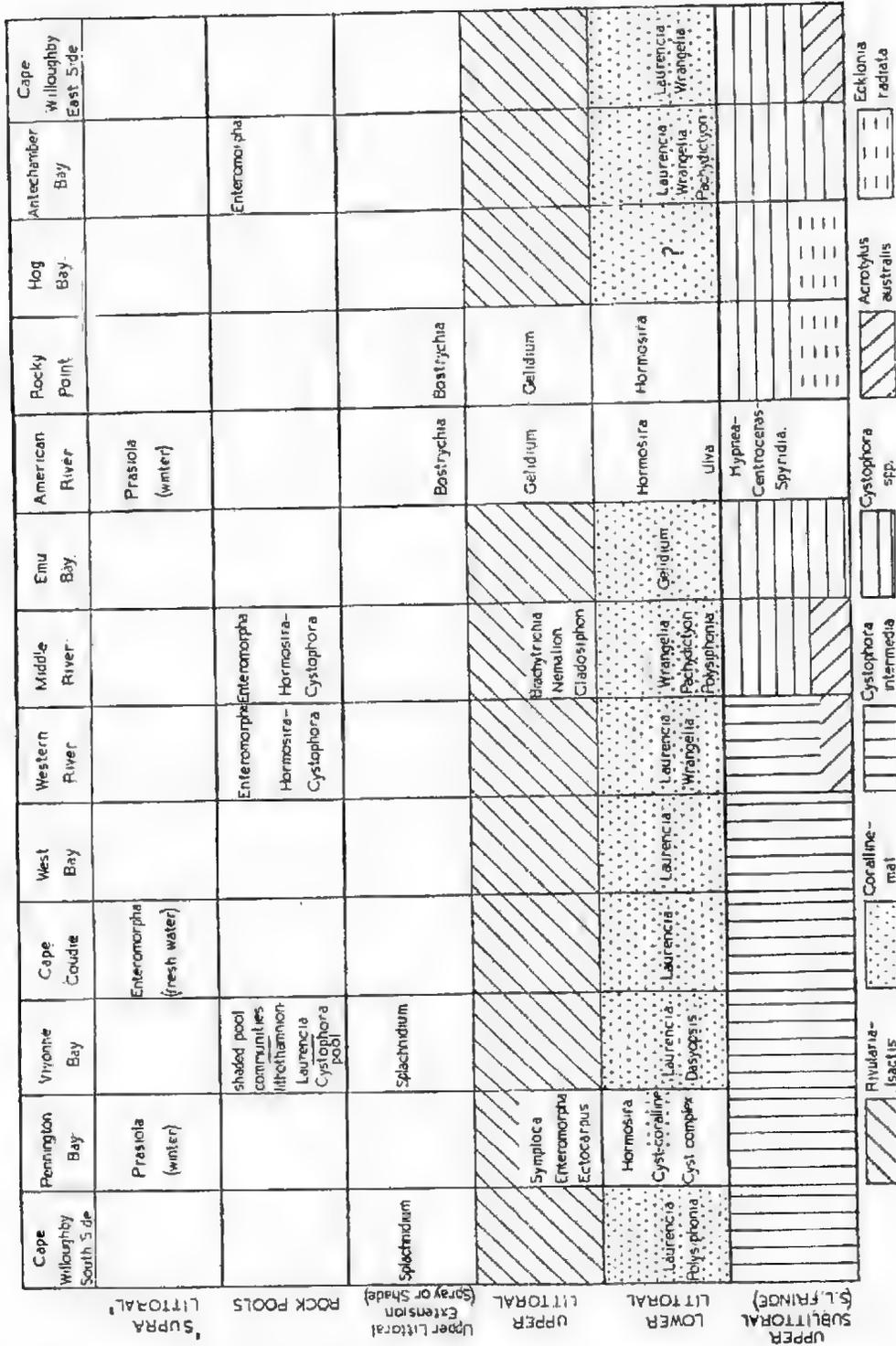


Fig. 3

The basic algal zonation at the localities studied around the coast of Kangaroo Island. Shading or dotting symbolises the main associations, but in the lower littoral zone the most prominent accompanying species are shown superimposed on the coralline-mat association. The *Prasiola* association at Pennington Bay and American River is found only where penguins or shags inhabit the coast.

Fig. 3 shows the basic zonation at the localities studied. Two main regions are clearly defined:

- (1) The American River tidal inlet where species of *Cystophora* (or other large brown algae) are almost completely absent from the upper sublittoral zone. *Hormosira banksii* Dene., *Gelidium pusillum* (Stackh.) Le Jol and *Bostrychia simpliciuscula* Harv. dominate the basic littoral zones from lower to upper littoral.
- (2) The rest of the coast of the island where species of *Cystophora* (or *Ecklonia radiata* (Turn.) J. Ag.) are dominant in the upper sublittoral zone. Coralline-mat and blue-green algae here form the two characteristic zones of the littoral.

Hence, depending on the presence or absence of species of *Cystophora*, the coast may be divided into two formations named from their characteristic habitat, the "Sand or Sandy-mud (Flat) Formation" (American River inlet) and the "Rocky Coast Formation" (see fig. 4). The naming of these formations on the habitat has been discussed under "Terminology."

The chief differences between the two formations are:

- (1) *The difference in species composition.* Species common to both formations are rare, and if common they usually differ greatly in relative abundance. The *Gelidium pusillum* association, well developed and prominent in Pelican Lagoon, is present, but poorly developed at Pennington Bay, and fragments may be found elsewhere along the coast. *Hormosira banksii* forms well-developed associations in both formations, but the ecological forms in each are very distinct (see pl. B, fig. 4, and pl. E, fig. 4). In number of species the Rocky Coast Formation is much richer than the Sand and Sandy-mud Flat Formation, while the size of the algae is usually greater in the former.
- (2) *Methods of attachment.* A wide, expanded, holdfast disc is characteristic of all the larger algae in the Rocky Coast Formation. In rough places this disc is extremely strong. Other methods of attachment are found in the littoral zone; viz., ramifying and densely matted attaching filaments of the coralline mat association, and the gelatinous adhesive thalli of the blue-green association of the upper littoral.

In the American River inlet the expanded holdfast disc is rarely found, and the adhesive thalli of blue-green algae are almost completely absent from the upper littoral. The chief mode of attachment is by rhizoidal filaments (a notable exception being *Hormosira*). Attachment of filaments by means of a basal cell or cells occurs in both formations.

- (3) *The growth substratum.* On rocky coasts the vast majority of algae grow on rock, while a few occur as epiphytes where the growth is dense. Many epiphytes can grow equally well on rock or on other algae, but a few are limited to particular hosts (e.g., *Nothelia* on *Hormosira*).

At American River most of the tidal flats are colonised by the marine Angiosperms *Posidonia australis* Hook. and *Zostera muelleri* Lrmisch, and these bear a profusion of epiphytic algae. Apart from *Bostrychia*, *Gelidium* and *Porphyra*, which occur on rock in the upper littoral, and to some extent *Hormosira*, all others are either epiphytes or grow on shells and small stones in the sand and mud. No macroscopic algae are able to grow directly in or on the sand or mud, although they may often be partly buried in mud; growth in sand or mud is, however, characteristic of the marine Angiosperms.

In discussing the Rocky Coast Formation, no account is taken of stretches of sandy beach between rocky sections of the coast. Rees considered such areas as a separate subformation, but devoid of algae. No macroscopic forms are found on such beaches, and wherever rocks occur the typical algae of the Rocky Coast Formation are found.

Within the Rocky Coast Formation conditions of roughness vary from very rough to moderately calm, and the coast may be divided on the presence or absence of *Cystophora intermedia*. This brown alga is found only in conditions of fairly strong to very strong wave action, and never occurs on calm coasts. It grows best under the constant action of heavy breakers, and has by far the strongest thallus for its thickness of any Kangaroo Island alga. *Cystophora intermedia* is dominant in the sublittoral fringe zone from Cape Willoughby along the south and west coasts, and along the north coast to between Western River and Middle River, where it is replaced by other species of *Cystophora*,

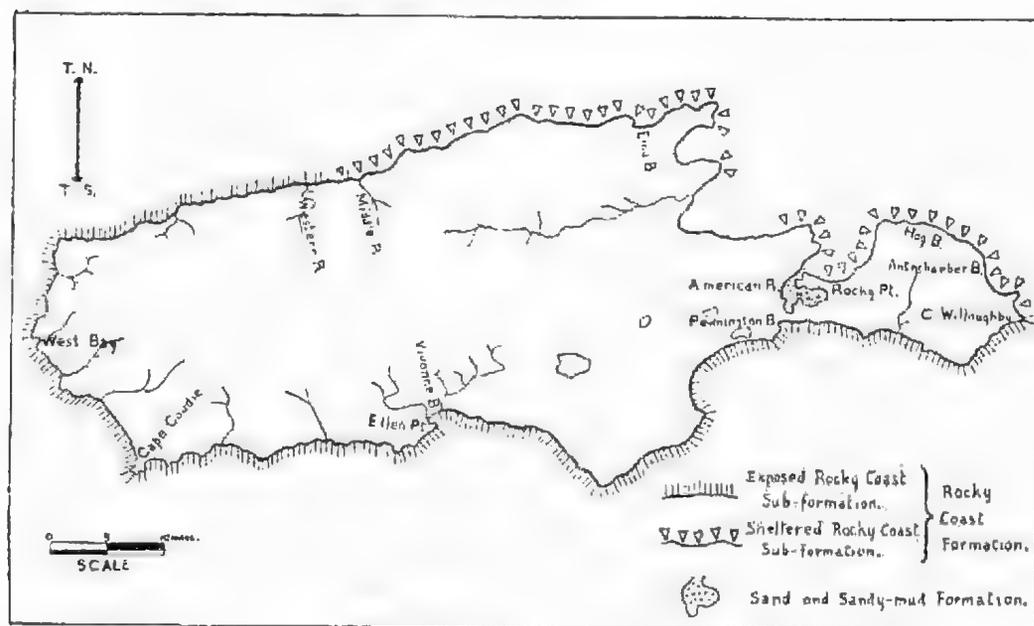


Fig. 4

The Algal Formations and Subformations around the Kangaroo Island coast. Areas in the Bay of Shoals and Western Cove not yet studied are left unclassified. Only the localities actually examined are shown on the map.

On the north coast between Cape Willoughby and Middle River (excepting the American River inlet) other species of *Cystophora* (*C. subfarcinata* (Mert.) J. Ag., *C. siliquosa* J. Ag., and others) or *Ecklonia radiata*, and in some places the red alga *Acrotylus australis* J. Ag., are dominant in the upper sublittoral zone. These species require constant water movement, but sudden rough weather will remove many plants from the rock. The outer edge of the Pennington Bay rock platforms is very rough, with calmer conditions nearer in and at the rear of the reefs, where *Cystophora subfarcinata* and *C. siliquosa* are very common. Along the whole south coast, however, *C. intermedia* is dominant in the sublittoral fringe, and although fairly common, the species characteristic of more sheltered coasts occur only where conditions are locally less rough.

The Rocky Coast Formation is therefore divided as follows (see fig. 4):

- (1) **THE EXPOSED ROCKY COAST SUBFORMATION:** from Cape Willoughby along the south, west and north coasts to between Western River and Middle River. The area is characterised by the presence of *Cystophora intermedia* in the sublittoral fringe.
- (2) **THE SHELTERED ROCKY COAST SUBFORMATION:** found along the north coast between Cape Willoughby and Middle River, excluding the American River inlet. Characterised by other species of *Cystophora*, *Ecklonia radiata*, and in some areas *Acrotylus australis*, in the upper sublittoral. *Sargassum* spp. may also occur in some areas.

Cotton found it necessary to divide his Rocky Shore Formation into Exposed and Sheltered Series. This appears to correspond closely as far as environment and status go with the two subformations of the Rocky Coast Formation on Kangaroo Island.

Although referred to as "sheltered," the degree of shelter in this subformation is very much less than in the Sand and Sandy-mud Formation. The latter is developed mainly in almost land-locked areas, whereas the Rocky Coast Formation is always found on open coasts.

Within the exposed Rocky Coast Formation two distinctive types of habitat occur, dependent on the geology of the coast (see "Coastal Geology," under "Environment"). These are the horizontal sand rock reefs, actually wave cut platforms, occurring along much of the south coast (pl. ix, fig. 3), and the steeply sloping rocky areas occupying the rest of the coast (pl. xii, fig. 1). A brief description of the main associations in these two areas is given below, but detailed reports will be left till later papers.

A. THE ROCKY COAST FORMATION

I. THE EXPOSED ROCKY COAST SUBFORMATION

(a) The Pennington Bay Rock Platforms

The type of horizontal wave-cut platform (pl. ix, fig. 3) found at Pennington Bay occurs along much of the south coast of Kangaroo Island (see fig. 1). The reefs which have been studied in detail at Pennington Bay are probably representative of this type of algal habitat, and a detailed account will be given in another paper. The following are the main associations found in the Pennington Bay area:

(1) THE LITTORAL ZONE:

REAR LITTORAL ASSOCIATIONS—These occur on the vertical or sloping rock backing the reefs, usually at a higher elevation than the reef itself. The associations are exposed at low tide, but washed or splashed continuously at medium and high tides.

1. *Rivularia firma* association (pl. x, fig. 2). This alga favours areas where wave splash is moderate or else there is constantly running water. For further notes see Womersley (1946 a).
2. *Symploca hydnoides* association: forming scattered patches in shaded hollows of vertical or sloping rocks.
3. *Gelidium pusillum* association: common, but usually poorly developed.
4. *Enteromorpha* association: forming bright green, usually pure areas on sloping well-washed rock.
5. *Ectocarpus confervoides* and *Pylaiella* seasonal associations. These form brown mats and tufts on well-washed sloping rock, *Ectocarpus* occurring during winter and *Pylaiella* mainly in summer.

LITTORAL ASSOCIATIONS (on the flat reef surface).

6. The *Cystophora* complex. Four species of *Cystophora*, *C. subfarcinata*, *C. siliquosa*, *C. unifera* (Ag.) J. Ag. and *C. brownii* (Turn.) J. Ag., together with *Sargassum muriculatum* J. Ag., form a complex of associations on the flat reef surface, always where they are submerged. Each species may form a pure association or occur mixed with one or more of the others, depending on the depth of water at low tide (pl. x, fig. 1). This complex covers the larger part of the reef surface.
7. *Hormosira banksii* association. This is a well-marked association on slightly higher and therefore more exposed parts of the flat reef surface. On higher areas it is pure and dense (pl. ix, fig. 4, and pl. x, fig. 4); in other places it may become mixed with species of *Cystophora*. *Nothcia anomala* Bail. et Harv. is always found growing from the conceptacles.
8. *Cystophyllum muricatum* association. A pure area of this alga occurs in well-washed, relatively calm, and rather sandy parts of the main reef.
9. *Laurencia heteroclada* association. This occurs in fairly rough places, where it forms a dense mat of stunted plants.
10. *Cystophora*-coralline association. A distinctive association found on the rougher parts of the reefs, consisting of *Corallina cuvieri* Lamour. on rock and *Jania fastigiata* Harv. on species of *Cystophora*; a dense and rich association.

(2) THE SUBLITTORAL FRINGE

11. *Cystophora intermedia* association. This brown alga dominates the outer edges of the reefs in the roughest conditions. It is an extremely rich association of small, often stunted species (over 50 have been recorded from an area of a few square yards), completely covering the rock (pl. ix, fig. 2).

The sublittoral assemblage will not be dealt with here, but it is very similar to that listed for Vivonne Bay (see p. 244). The coast at Pennington Bay is very rich in number of species; over an area of $\frac{1}{2}$ mile more than 220 species have been recorded, and many more, no doubt, remain to be found.

(b) Steeply Sloping Coasts

Three main zones, each comprising one association and in certain localities others, occur in the intertidal areas of the more steeply sloping parts of the south and west coasts. Heavy wave splash or regular passage of breakers up sloping rocks results in considerable upward extension of these zones.

1. RIVULARIA-ISACTIS ASSOCIATION of the upper littoral.

This association is composed of *Rivularia firma* Womersley, *R. atra* Roth. and *Isactis plana* (Harv.) Thuret, all forming scattered, dark blue-green gelatinous thalli on otherwise bare rock. In some areas they are very well developed (especially *R. firma*), in other places they are almost absent. Degree of wave action is the determining factor, but the association is often poorly developed where least expected.

2. CORALLINE-MAT ASSOCIATION.

The lower littoral, between the blue-green algae and the sub-littoral fringe, usually consists of a dense mat of stunted *Jania fastigiata* and/or *Corallina* (probably *C. cuvieri*) (pl. xi, fig. 4). This mat is 1-3 cm. in thickness, pinkish-white in colour, and forms a continuous covering on much of the rock. Where breakers run well up sloping rocks it may reach a height of 5 or 6 feet. At Vivonne Bay

(on the south side of Ellen Point), *Dasyopsis clavigera* Womersley, and a small stout *Laurencia* are prominent amongst the corallines. This *Jania-Dasyopsis-Laurencia* variant is probably general in many areas of the south and west coasts, but rather than being a distinct association it consists of the addition of the latter two algae to the basic coralline-mat association.

3. CYSTOPHORA INTERMEDIA ASSOCIATION of the sublittoral fringing.

This brown alga forms a striking sublittoral fringe zone on sloping rocks of the south, west and north-western coasts of Kangaroo Island. The upper edge of the association is often very sharply limited, as shown in pl. xi, fig. 2, the zone appearing as a dark band stretching along vertical rock at Cape Willoughby. In situations where waves pass along the rock, rather than breaking against it, the coralline-mat and blue-green zones may be poorly developed, but the sharpness of the upper limit to *Cystophora intermedia* can be seen from pl. x, fig. 3. Where waves break heavily on rocks the upper edge is less well defined, and the coralline-mat often merges with *Cystophora intermedia* (pl. xi, fig. 4).

The dark-brown pinnate fronds of *Cystophora intermedia* reach a length of 40 to 45 cm. The stems are extremely strong, and only very rarely are fronds found cast up. A common epiphyte is *Corynophloea cystophorae* J. Ag.

THE SUBLITTORAL.

Study of the sublittoral flora is restricted to the algae cast up but not known to occur in the intertidal area. The following list includes the commonest forms of the sublittoral assemblage of the south coast, but comprises only a small fraction of the total.

CHLOROPHYCEAE—*Caulerpa harveyi* F. v. M.; *C. obscura* Sonder; *C. vesiculifera* Harvey; *Codium galeatum* J. Ag.; *C. mammosum* Harvey; *C. pomoides* J. Ag.

PHAEOPHYCEAE—*Phloeocaulon spectabile* Reinke; *Dictyota latifolia* J. Ag.; *Zonaria turneriana* J. Ag.; *Sporochnus scoparius* Harvey; *S. comosus* C. Ag.; *Bellotia eriophorum* Harv.; *Encyorthalia cliftoni* Harvey; *Perithalia inermis* (R. Br.) J. Ag.; *Ecklonia radiata* (Turn.) J. Ag.; *Scytothalia dorycarpa* (Turn.) Grev.; *Sierococcus axillaris* Greville; *Scaberia agardii* Grev.; *Myriodesma quercifolium* (Bory) J. Ag.; *Carpoglossum confluens* (R. Br.) Kütz.; *Cystophora monilifera* J. Ag.; *C. dumosa* J. Ag.; *C. retorta* (Mert.) J. Ag.; *C. racemosa* Harv.; *C. platylobium* (Mert.) J. Ag.; *C. spartioides* (Turn.) J. Ag.; *C. siliquosa* J. Ag.; *C. paniculata* (Turn.) J. Ag.; *Sargassum varians* Sonder; *S. sonderi* J. Ag.; *S. trichophyllum* J. Ag.; *S. cristatum* J. Ag.

RHODOPHYCEAE—*Asparagopsis armata* Harvey; *Mychodea compressa* Harvey; *Hypnea episcopalis* H. & H.; *Delisea elegans* C. Ag.; *Phacelocarpus tubillardieri* J. Ag.; *Plocamium nidificum* (Harv.) J. Ag.; *P. preissianum* Sonder; *P. costatum* (J. Ag.) H. & H.; *Hymenocladia polymorpha* (Harv.) J. Ag.; *Antithamnion mucronatum* (J. Ag.) De Toni; *Monospora elongata* (Harv.) De Toni; *Ceramium puberulum* Sonder; *Lasiolithalia formosa* (Harv.) De Toni; *Spongoclonium* sp.; *Spyridia opposita* Harv.; *Sarcomenia dasyoides* Harv.; *Nitophyllum curdieanum* Harv.; *Amanasia pinnatifida* Harvey; *Lenormandia spectabilis* Sonder; *Osmundaria prolifera* Lamour.; *Thuretia quercifolia* Dene.

OTHER COMMUNITIES OF STEEPLY SLOPING COASTS

An *Enteromorpha* association occurs on rock well above normal wave-splash at Cape Coudie. It is dependent on the presence of fresh water percolating

through the upper limestone stratum and running down over the harder ancient rocks forming the base of the cliffs. The species has not been determined, but it occurs in dense, pure masses on otherwise bare rock. *Enteromorpha* associations dependent on the presence of fresh water have been recorded by numerous other authors (see Cotton 1912).

A *Splachnidium rugosum* association is found in the upper littoral at Cape Willoughby, usually at a higher level than the blue-green zone. The Cape is composed of granite boulders, and where waves break heavily, leaving the rock exposed between waves, *Splachnidium* forms a pure association of short, tufted plants (see pl. xi, fig. 3).

At Vivonne Bay, on gneissic rock, *Splachnidium rugosum* (L.) Grev. is often common on wave-splashed rock, but may merge with *Rivularia firma*. *Helminthoru tumens* J. Ag. and *Polysiphonia desyoides* Zan. are also characteristic of this region during January.

On other types of rock *Splachnidium* is very rare. If further studies show that it is restricted to granite or gneissic rock, this will be one of the very few cases known from Kangaroo Island of the type of rock influencing algal distribution.

A marked feature of the south side of Ellen Point, Vivonne Bay, is the occurrence of at least five species of lithothamnium. Elsewhere on the island they are rare. Two distinct species (generic determination has not yet been possible) form pure but localised communities in the littoral zone in what are apparently rather specialised habitats. They grow as crustose thalli forming small irregular branches.

The coast at Ellen Point consists of fossiliferous calcareous limestone overlying the hard gneissic base. Wearing back of the softer limestone has resulted in many rock pools, from very small to over 20 yards across, being left in the harder base (pl. xi, fig. 1). Most of these pools are subject to wave influx only at high tide, and during summer their water temperature is considerably higher than that of the sea (up to 28° C. when sea temperature is 18° C.).

Some of these pools bear distinctive algal communities; others, where conditions are apparently too severe, are devoid of growth.

One pool, shown in the foreground in pl. xi, fig. 1, contains a *Laurencia*—lithothamnium community. The lithothamnium forms scattered, irregular pinkish masses (to 10 cm. across and 3 cm. thick), while *Laurencia heteroclada* Harv. grows on the rock or the lithothamnium and is heavily epiphytised by *Ceramium minutum* Suhr. and *Polysiphonia abscissa* Harv.

In the rear pool of the two shown in pl. xi, fig. 1, the end shaded by the cliff bears a community of red algae which are normally sublittoral forms. *Dictyomenia tridens* Grev. and *Bornetia* sp. are the commonest, while in another shaded area of the same pool *Lyngbya majuscula* (Dillw.) Harv. forms a pure community in January. The effect of continual shade is evident in both cases.

In another pool, at a lower level and subject to wave influx except at low tide, species of *Cystophora* are dominant. One corner, however, is shaded by overhanging rock, and here *Ecklonia radiata*, *Scytothalia dorycarpa*, *Myriodesma latifolia* Harv. var. *duriuscula* J. Ag. (with epiphytic *Sphaecularia tribuloides* Menegh.), and *Gelidium australe* J. Ag. are prominent. All these are normally upper sublittoral forms.

In some of the pools minor communities of *Bryopsis plumosa* (Huds.) C. Ag., *Bryopsis baculifera* J. Ag.; *Derbesia* sp., two lithothamnium, and two species of coral occur. This assemblage shows more relationship to the flora of tropical waters, and is almost certainly due to the higher temperatures maintained in these pools during summer.

To deal adequately with the complex nature of the littoral zone at Ellen Point requires detailed mapping of the greatly dissected coastline. The variation in minor habitats is almost without limit, and similar complex areas probably occur along other parts of the south coast. However, the basic zonation of blue-green, coralline-mat and *Cystophora intermedia* zones is found on all rocks directly exposed to the sea.

II. THE SHELTERED ROCKY COAST SUBFORMATION

Wave action on the coast included under this subformation is from moderate to slight (see pl. xii, fig. 2 and 4). In fine weather waves gently lap the shore, while breakers a few feet high occur in rough weather. Some degree of water movement is always present, whereas in the American River inlet conditions are more often than not a dead calm on the tidal flats.

Littoral zonation is basically similar to that on exposed coasts, comprising blue-green and coralline-mat associations.

1. THE UPPER LITTORAL ZONE OF BLUE-GREEN ALGAE.

On the eastern end of the island, and at Middle River, *Rivularia firma* is dominant, accompanied by *Rivularia atra*, *Isactis plana* and sometimes *Symploca hydroides* Kutz. In calmer areas *R. firma* disappears and *R. atra* and *Isactis* become dominant. From Middle River to Stokes Bay (and probably further east) *Brachytrichia quoyi* (Ag.) B. & F. is prominent in January.

In some places where wave-splash is absent this blue-green zone may be very inconspicuous. The gelatinous thalli occur scattered singly or in patches on otherwise bare rock. No other algae normally occur in this area of the upper littoral. Blue-green algae are absent at Rocky Point, where the substrate is consolidated sand rock and the littoral zonation is closely allied to that found in Pelican Lagoon.

A community of *Nemalion helminthoides* (Velley) Batt. occurs on rocks on the east side of the beach at Middle River, in the mid-littoral, while on the west side of the beach *Cladosiphon filum* (Harv.) Kylin is common below the blue-green zone.

2. CORALLINE-MAT ASSOCIATION.

This is usually well developed in the lower littoral, often forming a closed community with a well-defined upper edge (see pl. xii, fig. 4, at Emu Bay). *Jania fastigiata* and fragments of *Corallina* are the main constituents, but *Dasyopsis clavigera* and the *Laurrciu* of the south coast association are absent. *Gelidium pusillum* is often, in calmer localities, an integral part of the mat, while other species commonly present are: *Wrangelia plumosa* Harv., *Pachydictyon paniculatum* J. Ag., *Zonaria turneriana* J. Ag., *Amphiroa charoides* Lamour, *Laurencia heteroclada* Harv., *Ceramium minutum* and *Polysiphonia* spp.

At Rocky Point *Gelidium pusillum* has become completely dominant, with only fragments of coralline left amongst the *Hormosira* association at a lower level. Above this is a zone of *Bostrychia*, similar but often better defined than in Pelican Lagoon.

3. THE UPPER SUBLITTORAL ZONE.

This region, on sheltered rocky coasts, is characterised by the dominance of fairly large brown algae, forming several associations in different localities.

Cystophora association.

Three species, *C. subfarcinata*, *C. polycystidia* Aresch., *C. siliquosa*, and to a lesser extent *C. spartioides*, extend from low water mark to a depth of 6 or 8 feet. They may reach a length of 1½ metres, and at low tide in some localities

the fronds float at or below water surface, giving the zone a distinctive appearance.

C. subfarcinata is found throughout the subformation, but in calmer areas (e.g., Rocky Point) forms numerous vesicles and is more branched. *C. siliquosa* and *C. spartioides* are restricted to slightly rougher parts, while *C. polycystidia* becomes dominant in calmer regions. In shallow water and locally calm places *Cystophyllum muricatum* forms a distinct community.

Although *C. polycystidia* is characteristic of the north coast of Kangaroo Island, it does occur in locally sheltered places on the south coast.

On the east side of Ballast Head (north of American River) *Sargassum* sp. dominates the upper sublittoral.

Ecklonia radiata association.

At Hog Bay and Rocky Point, where wave action is slight, *Ecklonia radiata* forms a distinct sublittoral fringe, accompanied by some *C. subfarcinata*. Under locally suitable conditions elsewhere around the island it may be found; at Cape Coudie a protected channel bears a dense fringe of *Ecklonia*.

Acrotylus australis association.

At Middle River and the east side of Cape Willoughby dense and pure patches of the red alga *Acrotylus australis* occur in the upper sublittoral. The dark brown dichotomous fronds, from 10 to 20 cm. high, completely cover the rock, forming a distinct association. At both localities conditions of wave action are very similar, and the general algal ecology is almost identical. *Caulerpa brownii* Endl. often forms dense bright green mats within a few feet of low water mark.

The following species are commonly cast up within the Sheltered Rocky Coast Subformation: *Codium spongiosum* Harv., *C. pomoides*, *Cladostephus verticillatus* (Lightf.) Ag., *Halopteris pseudospicata* Sauv., *Sargassum* sp. (small stunted plants), *Cystophora botryocystis* Sonder, *C. grevillei* (Ag.) J. Ag., *C. monilifera* J. Ag., *Amphiroa charoides*, *Dictymania harveyana* Sonder, *Laurencia* sp.

In Eastern Cove, and probably in Western Cove, at least four distinct associations occur in deep water,

- (1) *Posidonia australis*, known as the "sea grass" or "tape weed," forms extensive meadows on a sandy bottom in from 1 to 6 or 7 fathoms of water.
- (2) *Scaberia agardhii* Grev. occurs on a rocky bottom in from $\frac{1}{2}$ to 3 or even 5 fathoms below low water.
- (3) *Cystophora monilifera* occurs in from 1 to 7 fathoms.
- (4) *Chiracanthia arborea* (Harv.) Falk. forms dense masses, especially in winter, in 1 to $2\frac{1}{2}$ fathoms.

The shore in the Bay of Shoals and Western Cove is sandy and muddy, with few rocky areas. Tidal flats, however, are not formed to any extent. This type of habitat is intermediate between the Sheltered Rocky Coast Subformation and the Sand or Sandy-mud Formation, with closer affinities to the latter. Until the area has been more thoroughly investigated, no classification will be attempted.

Along the shore of the Bay of Shoals *Zostera muelleri* is common, and amongst it, on old shells, occurs the green alga *Acetabularia peniculus* R. Br. (probably a winter form). In deeper water *Posidonia australis* is dominant.

ROCK POOL ASSOCIATIONS.

At Western River and Middle River rock pools are a feature of the coast. They are mostly small, from 1 to 10 feet across and to 2 or 3 feet deep. During summer the temperature in smaller pools (containing *Enteromorpha*) reaches

35° C. The conditions in any pool depend on its size, height above sea level, and general situation; the environment of smaller pools during summer is extreme in both temperature and salinity conditions. Two types of pools occur:

(1) ENTEROMORPHA POOL ASSOCIATION.

This association occurs in the smaller and higher pools where conditions are extreme and very variable. *E. linguata* J. Ag. and *E. intestinalis* (L.) Link. form a dense fringe around the edge. In summer exposure on the water surface often kills and bleaches the upper plants. The toleration these algae have for high temperatures is shown by their active oxygen liberation under temperatures of 30-35° C.

(2) HORMOSIRA - CYSTOPHORA POOL ASSOCIATION.

In larger and lower pools, where waves enter more frequently and temperatures are therefore lower, *Hormosira banksii* forms a dense fringe around the edge, at or just below water level (see pl. xii, fig. 3), while *Cystophora subfarinata*, *C. polycystidia*, *C. siliquosa*, *C. browni*, and often *Cystophyllum muricatum* and *Sargassum* sp. grow on the lower sides and bottom.

In many pools along the north coast, particularly those with a sandy bottom, the only algal growth consists of small mats of *Gelidium pusillum* and fragments of *Corallina* and *Jania*.

B. THE SAND AND SANDY-MUD FORMATION

The American River tidal inlet comprises several large lagoons with wide tidal flats and a central channel, opening into Eastern Cove through a narrow neck. Conditions are very calm, particularly on the tidal flats where large beds of *Posidonia* and other weed tend to minimise wave action.

Tidal range is just over 4 feet, decreasing only 2" or 3" from American River to Pelican Lagoon (see fig. 2). The fast scouring currents during spring tides, together with the sandy bottom, prevent algal growth in the channel proper. The temperature range on the flats is large, for at low tide less than a foot, and often only 1" or 2" of water covers the algae. Winter temperatures reach as low as 10° C., summer up to 32° C. on the flats.

In Pelican Lagoon the tidal flats usually extend out from low cliffs of calcareous sand-rock (similar to the coast at Pennington Bay) (pl. xiii, fig. 2), but sandy beaches are frequent, especially between Muston and American River jetty. South of Muston samphire swamps cover several miles of the shore.

An important characteristic of this formation is the large quantity of moveable sand and mud. The fast tidal currents carry suspended mud, which algae on the flats must be able to tolerate. The characteristic colour of Rhodophyceae at American River is a dirty brown, very different from the red of clean water forms at Pennington Bay.

The basic zonation in Pelican Lagoon is shown in fig. 5. Where a sandy beach occurs, *Hormosira* or *Zostera* comprise the upper zone. Over most of the flats the area colonised by *Hormosira*, *Zostera* and *Posidonia* is much greater than shown in the figure, but the sequence of zones and their positions in relation to tide levels applies generally. Microscopic algae, particularly diatoms, are usually present as epiphytes on the larger algae, but identification has not been attempted.

On Shag Rock (a small island at the entrance of Pelican Lagoon), and probably elsewhere where shag colonies occur, a filamentous form of *Prasiola* covers rocks affected by the bird droppings. This appears to be a winter association only, occurring several feet above high tide level.

LITTORAL ASSOCIATIONS

1. BOSTRYCHIA AND GELIDIUM ASSOCIATIONS.

These two associations will be considered together, as they occur in very similar habitats and sometimes become mixed. At Rocky Point, however, each association forms a distinct zone, the *Gelidium* below the *Bostrychia*. Both algae form dark reddish-brown dense mats, up to 1 cm. thick, covering the rock from about mid to just below high water level of spring tides. They are restricted to shaded areas of rock (see pl. xiii, fig. 2, and fig. 5). With continual shade, the mats retain sufficient water during the periods of exposure. Rock not shaded in this zone is usually bare of macroscopic algae.

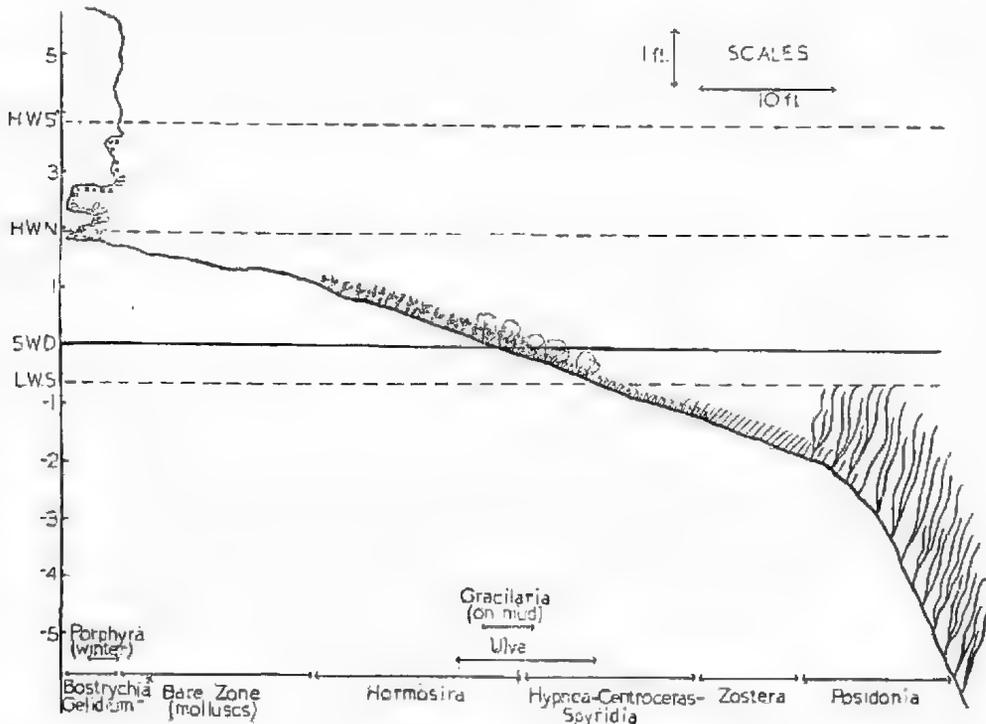


Fig. 5

Typical algal zonation on Pig Island, Pelican Lagoon. The relation of each zone to tide levels is approximately true; but in many areas the tidal flats are much wider and the *Hormosira*, *Zostera* and *Posidonia* associations occupy far greater areas than indicated. H.W.S., high water springs; L.W.S., low water springs; H.W.N., high water neaps; S.W.D., stationary water dodges.

As a general rule, *Gelidium pusillum* covers lower and more exposed rock than *Bostrychia* (*B. simpliciuscula*, with some *B. mixta* H. & H.). The roof and sides of small wave-cut caves are the most suitable habitat for *Bostrychia*.

During winter a community of *Porphyra umbilicalis* (L.) J. Ag. occurs in the lower *Gelidium* zone, but on more exposed rocks. The red-purple fronds reach a length of only 8 to 12 cm., and lie as flat sheets on the rock at low tide.

From the base of the low cliffs to the start of the *Hormosira* association (a distance of up to 20 yards) is a zone bare of macroscopic algal growth. The area is left quite dry and fully exposed to the sun at low tide. Such conditions are too severe for any alga, but the molluscs *Bembicium melanostoma* and *Modiolus areolatus* are common.

2. HORMOSIRA ASSOCIATION.

Hormosira banksii forms an extensive and conspicuous association in the low littoral, from about 1 foot above the dodge low to an inch or two below. Each plant grows either on the rock, or, if the substrate is sandy or muddy, on the partially buried bivalve *Brachyodontes erosus*. The spherical water containing receptacles of *Hormosira* enable it to grow where it is always exposed at low tide (pl. xiii, fig. 4).

The form of *Hormosira banksii* at American River is *labillardieri* Harv. It differs from the south coast form in being more branched, and having larger and more spherical vesicles. In both localities it grows only where it is exposed for a period each day; this exposure must in some way be essential to the growth of the alga.

During winter *Ectocarpus confervoides* (Roth.) Le Jol. is a common epiphyte on *Hormosira* at American River.

3. ULVA ASSOCIATION.

Ulva lactuca is always prominent at about low tide level, in the lower *Hormosira* and upper *Hypnea* - *Centroceras* - *Spyridia* associations. On the flats north of the American River jetty it forms a green band along the shore, superimposed on the *Zostera* association. In other areas it frequently becomes dominant to form a distinct association.

Forms of *Enteromorpha prolifera* J. Ag., *E. clostrata* Roth. and *E. bulbosa* Kütz. are common in the lower littoral and upper sublittoral, sometimes forming communities.

SUBLITTORAL ASSOCIATIONS

4. HYPNEA - CENTRO CERAS - SPYRIDIA ASSOCIATION.

This association extends from about low dodge level to 1 foot or slightly more below. The dominant algae are brown-coloured Rhodophyceae, and where dense give the zone an even brown appearance. *Hypnea musciformis* (Wulf.) Lamour., *Centroceras clavulatum* Ag. and *Spyridia biannulata* J. Ag. occur in varying but often about equal proportions. They are all slender forms, rarely more than 25 cm. long, and are just exposed at very low tides. In some places *Gracilaria confervoides* (L.) Grev. is common; on muddy patches around the small islands in Pelican Lagoon it forms dense but localised communities. The base of each plant is buried in mud but actually attached to a mollusc.

Other algae occur in the lower part of this association, and in somewhat deeper water. The distinctive feature, however, is the virtual absence of any species of *Cystophora* or other large brown alga. (The one exception is *Sargassum biforme*, which occasionally grows on rock on the sides of the channel where there is more water movement, but rarely in the upper sublittoral.) The commonest species are: *Caulerpa remotifolia* Sonder; *C. simpliciuscula*; *Codium muelleri* Kütz., a lithothamnion forming spherical nodules to 5 cm. across; *Corallina* sp. (hemispherical tufts 20 cm. across), and more rarely *Cystophyllum muricatum*.

5. ZOSTERA MUELLERI ASSOCIATION.

Zostera muelleri forms a pure and dense association over large areas of the tidal flats (pl. xiii, fig. 3), from low water level to 2 feet below, in some places to as much as 6 feet below. This angiosperm spreads almost entirely by means of runners which anchor the plant in the mud and produce narrow leaves (to 25 cm. long). It seems to prefer a muddy substratum. Epiphytes on the leaves are common (pl. xiii, fig. 3), especially *Centroceras clavulatum*,

Cladophora ceratina Kütz., *Ceramium* sp., and *Rivularia polyotis* (Ag.) B. & N. Amongst the *Zostera*, on small sandy patches, *Chondria dasyphila* (Grev.) C. Ag., *Spyridia biannulata*, *Polysiphonia patersonis* Sonder and *Graciliaria confervoides* occur. Very rarely plants of *Cystophyllum muricatum* and *Cystophora cephalornithus* (Lab.) J. Ag. may be found.

6. POSIDONIA AUSTRALIS ASSOCIATION.

Posidonia australis colonises deeper parts of the tidal flats and the channel edges, from 1 to 10 feet below extreme low water, with occasional plants to 14 feet. In Eastern Cove it extends to about 7 fathoms. The long strap-like leaves have a distinctive appearance as they just reach the water surface on the flats at low tide.

The association is dense and pure, but the rough leaves bear a wealth of epiphytes. On small pieces of leaf 10 species are often present. The most important ones are: *Rivularia polyotis*, *Ectocarpus* sp., *Asperococcus bullosus* Lamour., *Colpomenia sinuosa* (Roth.) D. & Sol., *Jania micrarthrodia* Lamour., *Centroceras clavulatum*, *Ceramium puberulum*, *Spyridia biannulata*, *Polysiphonia succulenta* Harv., *P. fuscescens* Harv., *P. darvayae* Reinb. Many of these attain their maximum development during winter months.

7. HALOPHILA OVALIS ASSOCIATION.

Another marine angiosperm, *Halophila ovalis* (R. Br.) Hook. forms dense patches between 2 and 12 feet below low water. The ovate leaves, produced from runners, reach a height of 15 cm., but epiphytic growth on them is much less than on the *Zostera* or *Posidonia*.

The three marine angiosperms all spread largely by runners. This ensures for the most part a pure association, but in shallow water all three have been observed growing together.

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The author is indebted to Professor J. G. Wood for advice during the progress of this work and criticism of the manuscript.

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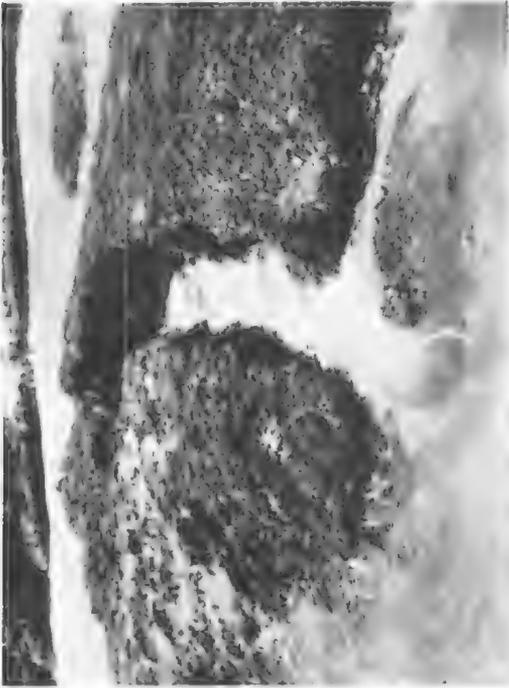


Fig. 2 Rocks off the eastern edge of the main reef at Pennington Bay, exposed between waves at low tide. On these rocks the very dense sub-littoral fringe association, dominated by *Cystophora intermedia*, is developed.



Fig. 4 The *Hormosira banksii* association at Pennington Bay. Slightly higher areas of rock on the reefs are densely covered with *Hormosira*, as is shown in the photo.



Fig. 1 Conditions at Pennington Bay on the South Coast of the Island with a heavy swell. The large breaker is 8-10 feet high. The figures are about half-way out on one of the rock-platform reefs.



Fig. 3 Typical rock-platform reefs at Pennington Bay exposed during low tide on a calm day.

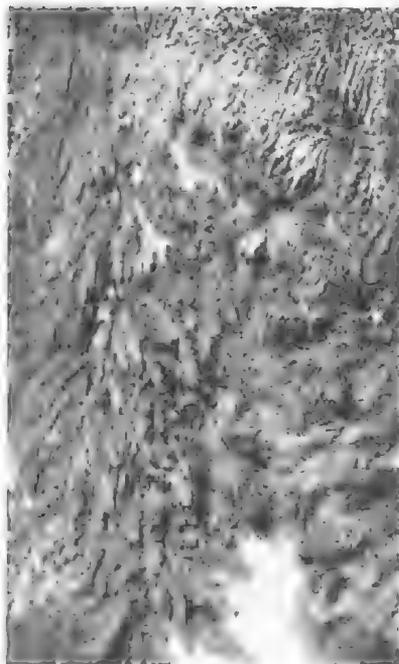


FIG. 1. The mixed *Penningtonia* and *Hormosira* association on higher rock in the right, with *Penningtonia* fringing the side of a small pool (upper in the photo) and *C. striata* on fringing the other (left) side.

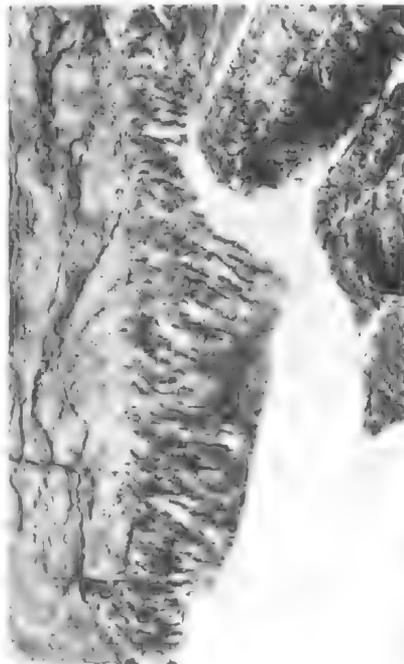


FIG. 3. The sub-littoral fringe association of *C. striata* and *intermedia* on the south side of Ellen Point, Vivienne Bay. Here the upper edge of the association is sharply limited, due partly to waves passing along the rock rather than breaking against it, but for some reason the combination association is almost absent here.

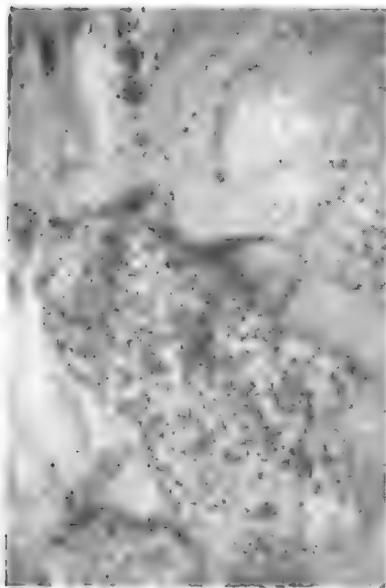


FIG. 2. *Algalia frondosa* rocks at the rear of the main Reef at Pennington Bay, during winter. The hemispherical lobes of *Algalia frondosa* are usually more scattered than shown here.



FIG. 4. Close up view of the *Hormosira boeckii* association at Pennington Bay. The *Hormosira* here is pure and dense, with a few epiphytes.



Fig. 2 The coast on the south side of Cape Willoughby. The dark band of *Cystophora intermedia*, with a sharply limited upper edge, is shown passing along the rock just above the water level. The photograph was taken between waves at low tide.



Fig. 4 The coralline-mat association in the lower littoral at Cape Willoughby. In very rough places *Cystophora intermedia* spreads into the dense mat of corallines (mainly *Jania*), as is shown here.



Fig. 1 Rock pools on the south side of Ellen Point, Vivonne Bay. The pool in the foreground contains a community of *Laurencia heteroclada* and a lithothamnion; in the rear pool localised communities occur in shaded areas. Waves enter these pools only at high tide.



Fig. 3 *Splachnidium ruosum* occurring as short tufted plants on granite rocks in the upper littoral at Cape Willoughby.



Fig. 1. The coast on the south side of Ellen Point, Vivonne Bay, looking west. This type of coast is typical of the south coast of Kangaroo Island where Precambrian rocks occur.

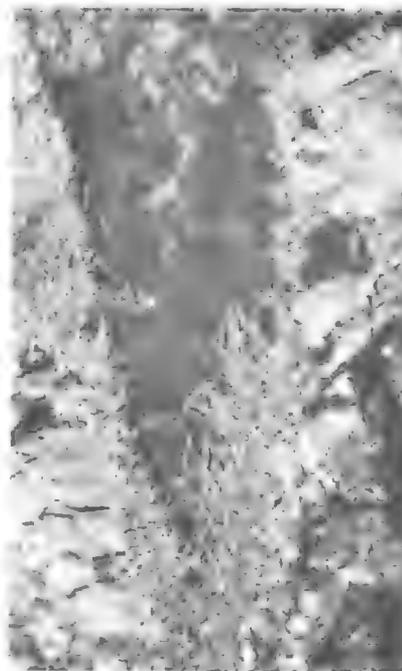


Fig. 3. *Halimeda laticornis* fringing a pool at Middle River. Below the water surface species of *Cystodinium* occur, forming the *Halimeda-Cystodinium* faunal association.



Fig. 2. The coast east of Middle River. Such conditions are typical of this area of coast on a calm day.

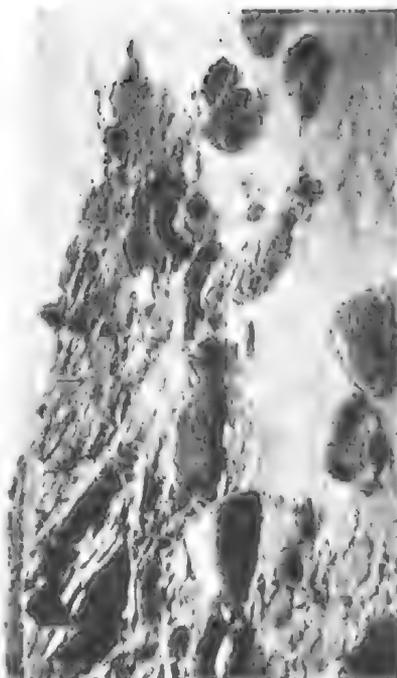


Fig. 4. The coast just west of the jetty at Emu Bay. Rocks in the lower littoral are covered with the coralline mat association, the upper rocks of which is indicated by the arrow.

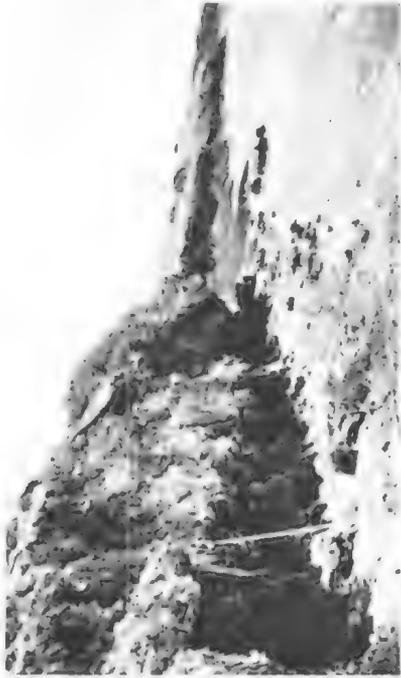


Fig. 2 The coast at Pig Island in Pelican Lagoon. In the shaded region of undercut rock, associations of *Bostrychia* and *Gelidium pusillum* occur, while the flat area exposed to the sun and not under water is bare of algae. The tide is just covering the *Hormosira* association.

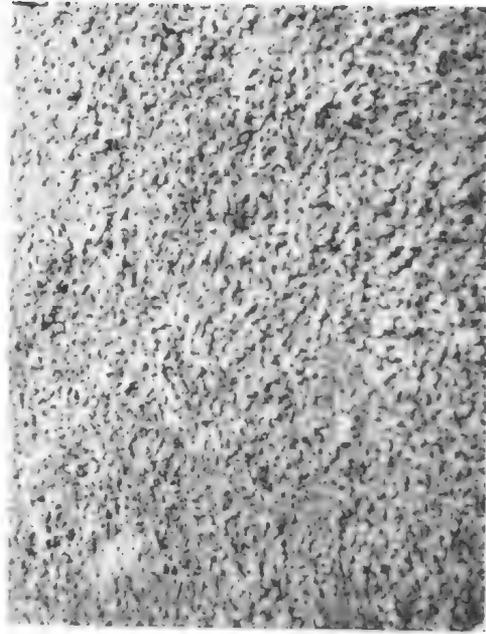


Fig. 4 Close up view of the *Hormosira* association at American River, showing its dense nature. Note the difference in form between the *Hormosira* shown here and that shown in Plate X, figure 4 (at Pennington Bay).



Wide tidal flats on the east side of the American River Inlet, colonised during low tide. The channel can be seen on the far right. Most of the area shown is colonised by *Posidonia*, with some *Zostera* and *Ulva* also.

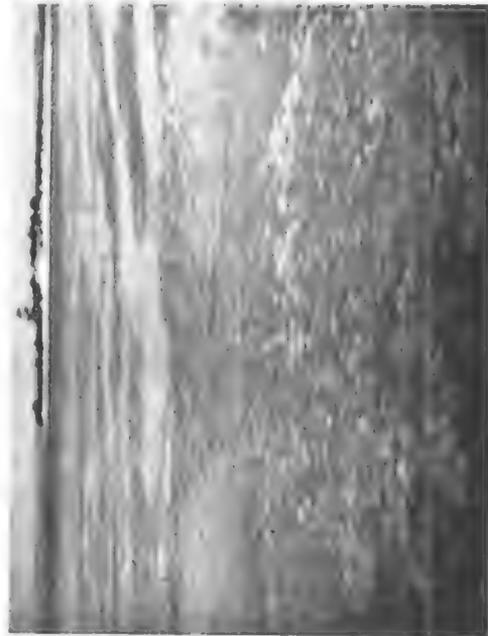


Fig. 3 Tidal flats near the American River Jetty, colonised by *Zostera* and showing masses of epiphytes floating on the surface during low tide (summer).

PYTHIUM DEBARYANUM AND RELATED SPECIES IN SOUTH AUSTRALIA

By L. C. P. KERLING

Summary

During an investigation of pre-emergence rotting of peas at the Waite Institute it was evident that infections of seedlings by *Pythium* spp. were important. It was not known what species were concerned, and the writer undertook to investigate this problem during a brief sojourn in Adelaide.

**PYTHIUM DEBARYANUM AND RELATED SPECIES
IN SOUTH AUSTRALIA**

L. C. P. KERLING *

Communicated by D. B. Adam

[Read 11 September 1947]

MATERIALS

During an investigation of pre-emergence rotting of peas at the Waite Institute it was evident that infections of seedlings by *Pythium* spp. were important. It was not known what species were concerned, and the writer undertook to investigate this problem during a brief sojourn in Adelaide.

Available for study were six isolations of *Pythium* from pea seedlings which had been grown in a red-brown earth at the Waite Institute, two from potatoes affected by "leak" disease and one from a tomato seedling. The isolations had been made by Mr. N. T. Flentje.

The various isolates were grown on potato-dextrose, oatmeal, cornmeal and water agars, respectively, as used by Middleton (1943), and on carrot agar as described by Johann (1928) and Schulz (1942). Since carrot agar, which has been autoclaved, was said to be unfavourable for oospore production (Schulz), it was sterilised by steaming it twice at 95° C. However, oospore reproduction was secured quite readily on the autoclaved media. The cultures studied were derived after a series of transfers from the edges of 24-26 hour old colonies, and each time the inoculum piece contained about half-a-dozen hyphal tips. Attempts were made to use single hyphal tips, but only in one case which is mentioned later was this successful. The use of single zoospores was precluded because their production was never observed. In all cases germination took place by means of a germ tube. The observation of oogonial and antheridial characters was facilitated by using cultures grown on a drop of potato agar in a small moisture chamber made from a glass ring and cover slip.

The diameters of the reproductive organs provide important criteria for differentiating species of *Pythium*, and it is desirable to measure large numbers of these structures to ascertain their range and mean value. It was found that diameters of oogonia and oospores were less variable than those of the sporangia, and that counts of 100-300 revealed that they followed a normal frequency distribution. It is appropriate then to describe the variability of means in terms of their standard errors calculated in the usual way. The sporangia, however, were much more variable in size and shape and only limits in size observed are described.

RESULTS

It was evident that the isolates could be referred to *Pythium debaryanum* Hesse or closely related species.

The genus *Pythium* has been treated systematically at least six times and has been the subject of several monographs. The isolates made locally have been referred to the species mentioned below and are reviewed in the light of recent descriptions and figures of Drechsler (1946), Matthews (1931), Sideris (1932), Van Luyk (1934, and especially, that of Middleton (1943).

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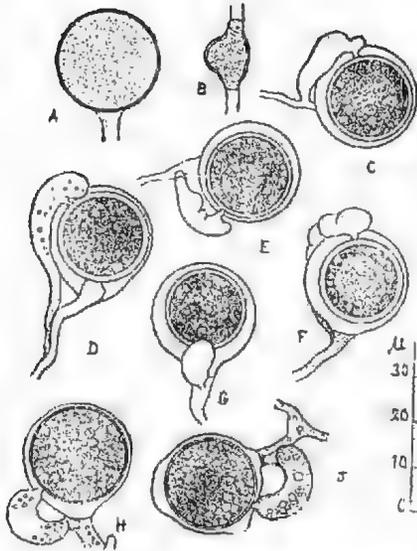


Fig. 1 *Pythium debaryanum* Hesse
 A-D—Sporangia; E, Empty monoclinal antheridium; F, Dichlous antheridium; G, Oogonium penetrated by monoclinal and dichlous antheridia.

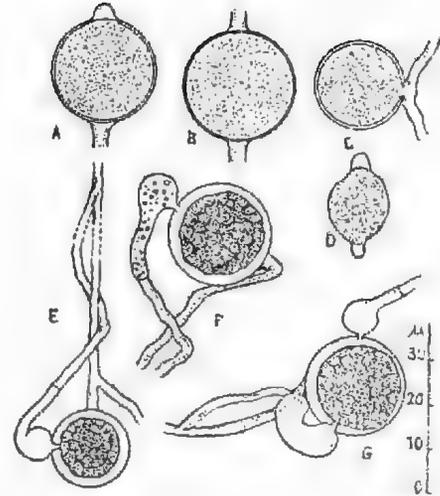


Fig. 2 *Pythium ultimum* Trow
 A-B—Sporangia; C-J: Oogonia and cospores each with one monoclinal antheridium.

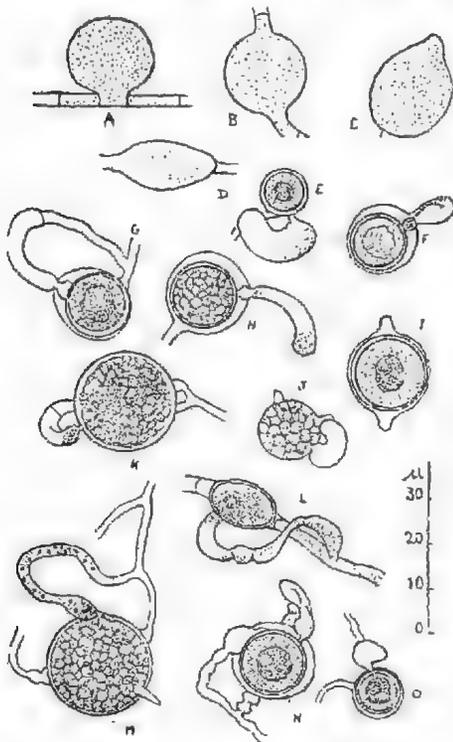


Fig. 3 *Pythium polymorphum* Sideris
 A-D—Sporangia; E, F, G, H, I, Antheridium after fertilization; J, Intercalary oogonium; K, L, M, N, Young oogonia with one antheridium. Antheridial stalk typically curved; N, Two antheridia to one oogonium.

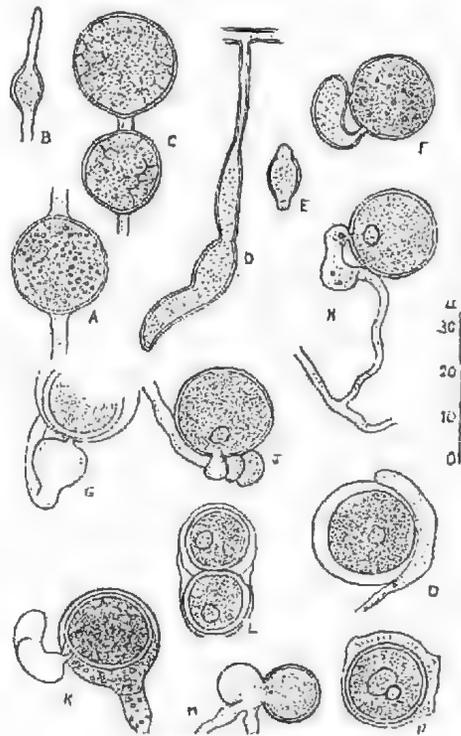


Fig. 4 *Pythium vexans* de Bary
 A-C—Sporangia; D, Mycelial body; E, Germinating sporangium; F, Allantoid antheridium and young oogonium; G, H, I, J, K, L, M, N, O, Variations in antheridial shape; L, oogonium with two cospores; N, Aplerotic oogonium; K, Germinating oospore with empty antheridium; M, Germinating sporangium.

Pythium debaryanum Hesse

Hyphae 2.5-11 μ , usually 4-5 μ in diameter; sporangia spherical to oval terminal or intercalary, sometimes in chains ranging from 9-41 μ in diameter and germinating by germ tubes; oogonia smooth, spherical, terminal, 14-29 μ , means 20.7-23.1 μ in diameter. Antheridia one or more per oogonium generally declinous but sometimes monoclinal when they arise some distance, 40-280 μ , below the oogonium. Antheridia stalked, crooked-necked with the terminal portion oblong, spherical or clavate and 5-11 μ in diameter, apex obtuse or narrow, tapering gradually to the oogonial wall to which it is more or less applied. Oospores smooth, aplerotic, 11-25 μ , averaging 17.4-19.9 μ in diameter, with a thick wall. Parasitic on *Pisum sativum* and *Solanum tuberosum* (see fig. 1).

The above description covers four of the isolates from peas and one from a potato affected by "leak." It agrees generally with those given by other authors, and at this point only the sizes of oogonia and oospores described above call for comment. If those quoted are compared with those of various authorities [Butler (1913), Braun (1925), Sideris (1932), Van Luyk (1934), Middleton (1943)], it is seen that the range of means we found is somewhat less than that described in the literature. Actually, statistical analysis reveals that the means for both oogonia and oospores in our different isolates may be significantly different. For example, the mean diameters of oogonia and oospores of isolate 5 from peas were 20.7 $\mu \pm 0.09$ and 17.4 $\mu \pm 0.18$ μ respectively, whereas corresponding measurements for isolate 2 (also referred to *Pythium debaryanum*), were 23.1 $\mu \pm 0.19$ and 19. $\mu \pm 0.22$ respectively. However, it is possible to arrange the isolates we classify as *Pythium debaryanum* in such a way that differences between successive pairs are not significant. The differences in means may indicate the existence of strains, but they offer little warranty for specific segregation.

Pythium ultimum Trow.

Hyphae 3-9 μ , usually 4-5 μ in diameter with frequent irregular mycelial bodies; Sporangia terminal or intercalary, 7-25 μ diameter, germinating by germ tube; Oogonia smooth, terminal rarely intercalary, spherical 18-26 μ average 22.3 $\mu \pm 0.09$ borne on laterals 15-90 μ long. Antheridia one per oogonium, monoclinal and arising from immediately below the oogonium (hypogynous) (fig. 2 C-J). Antheridium tube-like, swollen, curved with apex tapering towards oogonial wall, 5-8 $\mu \times 11-23$ μ . Oospores aplerotic, single spherical 12-23 average 18.3 $\mu \pm 0.09$ in diameter, thick walled. Isolated from *Solanum tuberosum*.

Middleton (1943), in concurring with Drechsler (1927) for the maintenance of *Pythium ultimum* as a distinct species, points out that its typically monoclinal swollen antheridia, which originate close to the oogonium, and curve sharply upwards to make a narrow apical contact with the basal portion of the oogonium, distinguish it from *Pythium debaryanum*. These features were characteristic of the isolate described and figured here. However, in another isolate, one from peas (Isolate 1) at least two types of antheridial structure occurred in the one culture. One or more declinous, long stalked, crook-necked antheridia typical of *Pythium debaryanum* occurred in the same culture as monoclinal, stalkless hypogynous antheridia characteristic of *Pythium ultimum*. There were also many gradations (fig. 2).

Middleton, while he refers to the infrequent occurrence of declinous antheridia in *Pythium ultimum* says that "they are not distinctive enough to be utilized in the identification of the species." On the other hand, Van Luyk (1934), with others, doubts whether such differences between the antheridial characters as are mentioned above are sufficient to segregate the two species. He considers that *Pythium debaryanum*, among its different strains, exhibits differences of the type described; a view with which the writer concurs.

Pythium polymorphon Sideris

Hyphae 3-7 μ in diameter. Sporangia spherical, subspherical terminal or intercalary 7-33 μ in diameter and germinating by germ tube. Oogonia spherical, terminal or intercalary, smooth but sometimes with one or more papillae (fig. 3, J. M.) 9-25 μ av. 16.2 $\mu \pm 0.22$ in diameter. Antheridia 1-2 per oogonium monoclinal, antheridial stalk typically falcate or sigmoid or with curved antheridial cell (fig. 3, K. L. M). Antheridial cell not greatly swollen and with a long fertilization tube, 8-20 μ long \times 5-7 μ wide. After fertilization the apical portion is divided from the base by a narrow ring at junction with oogonial wall (fig. 3, F. G. H.). Swollen declinous antheridia also occur but mostly in association with the smaller oogonia (fig. 3, J. E. O.). Oospores aplerotic, 7-23 μ , av. 13.4 ± 0.27 in diameter with somewhat thickened wall. Isolated from *Pisum sativum*.

The characteristic feature of this fungus is the shape of the antheridial branch, which may be curved like the letter C or double curved like the letter S. In our isolate the origin of the antheridial stalk was always monoclinal, arising some distance from the oogonium and generally curving in a wide bow to meet the oogonial wall in the way illustrated by Sideris.

The swollen declinous antheridia applying to the smaller oogonia described above suggested the possible presence of more than one strain in our culture. However, it was possible to secure growth from a single hyphal tip of this isolate and the culture derived behaved in the way already described.

The isolate we describe is slightly different from *P. polymorphon* described by Middleton and appears to be the first record of the association of this fungus with *Pisum sativum*. Previous records associate *P. polymorphon* with *Ananas comosus* in Hawaii and *Nicotiana Tabacum* in the United States.

Pythium vexans De Bary

Hyphae 2-7 μ in diameter with irregular mycelial bodies associated (fig. 4, D). Sporangia terminal or intercalary, spherical to oval 10-26 μ in diameter and germinating by germ tubes (fig. 4, M). Oogonia spherical terminal, 15-26 μ av. 21.7 $\mu \pm 0.10$ in diameter. Antheridia 1-2 per oogonium, declinous. Antheridial cell very variable in shape (fig. 4, G. H. J. O.). In some cases, cylindrical and hardly curved or swollen, in others slightly swollen or so swollen that the shape is nearly spherical. The antheridial cell or its stalk may be so curved that application to the oogonial wall is narrow. In profile it may appear bell-shaped, and in another plane as an allantoid or disc-like structure covering the oogonium (fig. 4, G. O.). The cylindrical antheridia are 11-18 μ long by 7-11 μ wide, the spherical 7-9 μ in diameter. Oospores smooth, aplerotic, 13-24 μ av. 18.8 $\mu \pm 0.11$ in diameter and with a thick brown wall. Isolated from *Lycopersicon esculentum*.

Middleton states that "*Pythium vexans* is readily distinguished from its congeners possessing aplerotic oospores by its typically monoclinal, stalked antheridium which arises in close proximity to the oogonium and by the clavate antheridial cell with the apex bell-shaped and broadly applied, sometimes fused with the oogonial cell."

In respect to the origin of the antheridia Middleton says that they are rarely declinous, but Drechsler (1946 b), who cultivated *Pythium complectens* Braun, and like Middleton considers the name a synonym of *Pythium vexans*, remarks that "frequently the mycelial connection between the oogonial stalk and antheridial branch is too remote to be traced for certainty amid the confusion of ramifying hyphae." Thus the apparently declinous character of antheridia in our isolate is not, in itself, sufficient to distinguish it from *Pythium vexans*. Antheridial shape in our isolate was very variable. It is true that in certain aspects, trumpet-shaped structures flaring out at the region of attachment, as described by Braund, bell-

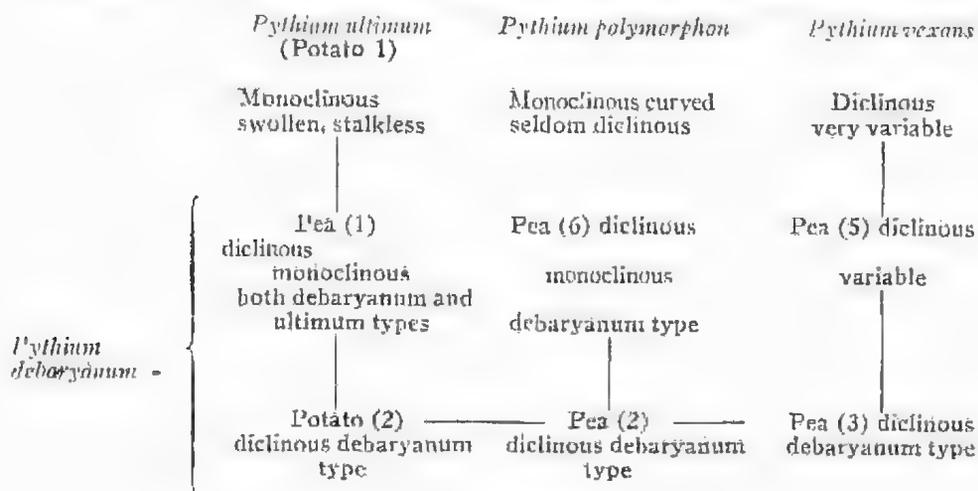
shaped apices as mentioned by Middleton, and the bilobate and biramous male cells, figured by Drechsler, were observed, but the antheridial cells were by no means uniformly of these shapes.

However, there is another feature in which our isolate resembled descriptions of *Pythium vexans*. According to Middleton the germination of oospores of *Pythium* is not common; it occurs more readily in *Pythium vexans*, a fact also noted by Butler (1907) and Drechsler (1946). The oospores of our isolate germinated fairly readily to produce sessile sporangia which in turn produced a germ tube (fig. 4, K). The sporangia, when they germinate first, produce a vesicle into which the contents of the sporangia passed. The vesicles then developed a germ tube.

GENERAL DISCUSSION

Middleton considers that the origin and morphology of the antheridia afford valuable criteria for specific identification. Our isolates, because of close resemblance in other respects, have had to be looked at particularly in respect to antheridial characters, but we found these to be rather more variable than Middleton's descriptions might suggest. In one case (isolate 5) differently shaped antheridia were even found on one branch. (See also the discussion under *Pythium ultimum*.) Although we have distinguished our isolates in the terms discussed above, we should bear in mind the advice of Buisman (1927) not to define species too strictly: "It is not at all easy to determine if a special isolation belongs to the well-known *Pythium debaryanum* or not." It is clear, too, that in view of the methods of reproduction concerned and the obvious chances of hybridization, intermediate forms might be expected.

In view of the foregoing remarks, the following scheme of relationship of the isolates examined is suggested, remarks refer to salient antheridial features:—



SUMMARY

The morphology of nine isolates of *Pythium* spp. grown in pure culture on various media have been studied. Four isolates from infected pea seedlings and one from a potato affected by "leak" disease were identified as *Pythium debaryanum* Hesse. A fifth isolate from peas was identified as *Pythium polymorphon* Sideris. A second isolate from potato with "leak" was identified as *Pythium ultimum* Trow and an isolate from a diseased tomato seedling as *Pythium vexans* De Bary.

All these species have a number of characters in common; spheroidal sporangia and smooth aplerotic oospores, and are considered to be closely related to one another, and this is discussed.

ACKNOWLEDGMENTS

I wish to express my thanks to Professor J. A. Prescott, Director of the Waite Agricultural Research Institute, for affording me facilities and the hospitality of the Institute during a three months' visit as a guest. I am also very grateful to Mr. D. B. Adam of the same Institute, who suggested the problem and gave a great deal of assistance in preparing this manuscript. Thanks are also due to other members of the Institute staff, especially those in the Department of Plant Pathology who helped in many ways.

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THE ADELAIDE SERIES AS DEVELOPED ALONG THE WESTERN MARGIN OF THE FLINDERS RANGES

By D. MAWSON

Summary

The sediments now to be considered constitute a very thick series of formations of late Precambrian age. Though varied somewhat in nature and in mass from their counterparts in the type area, they are the northward continuation of Howchin's Adelaide Series of the vicinity of Adelaide. Deposition took place in a great geosynclinal trough.

**THE ADELAIDE SERIES AS DEVELOPED ALONG THE
WESTERN MARGIN OF THE FLINDERS RANGES**

By D. MAWSON*

[Read 9 October 1947]

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The sediments now to be considered constitute a very thick series of formations of late Precambrian age. Though varied somewhat in nature and in mass

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from their counterparts in the type area, they are the northward continuation of Howchin's Adelaide Series of the vicinity of Adelaide. Deposition took place in a great geosynclinal trough.

I. THE GEOSYNCLINAL BASIN OF ACCUMULATION

The geological record evidenced in the Mount Lofty and Flinders Ranges clearly demonstrates the existence in later Precambrian and early Cambrian times of a geosynclinal depression extending from south to north for a distance of several hundred miles, then turning to north-west through the region of the Willouran Range on to the Amadeus Strait region *via* the Mount Denmu-Mount Margaret Range and the Everard Ranges. In Central Australia it appears to have been mainly located between the great belt of basal conglomerate represented by Ayers Rock and Mount Olga on the south and the MacDonnell Ranges on the north. From there it may have extended in the north-west to the region of the "Desert Basin" and the Kimberley Ranges.

On the western margin of this great orogenic feature was an ancient massif constituting the Early Precambrian land area which has received the palaeogeographic name of Yilgarnia (Cotton 1930). From the denudation of Yilgarnia there came much, probably most, of the detrital material contributing to the sediments of that progressively subsiding geosynclinal trough.

The eastern margin of the basin is not so clearly defined, for there is still some uncertainty as to the age of the rocks of the more metamorphosed terrain of the eastern flanks of the Mount Lofty Ranges. Further north, where the sediments of the geosynclinal depression are easily recognisable, they, for the most part, pass beneath the Tertiary formations of the Murravian Gulf and the Mesozoic succession occupying the basin of the one-time Lake Walloon. Only in the Barrier Ranges of western New South Wales and in the neighbouring region of north-eastern South Australia and possibly also the north-east tip of the Flinders Ranges can we clearly demonstrate the existence of Precambrian land on the eastern side of this Late Precambrian depression. This is Bryan's (1932) "Eastern Massif" and Andrews' (1937) "Willyamia."

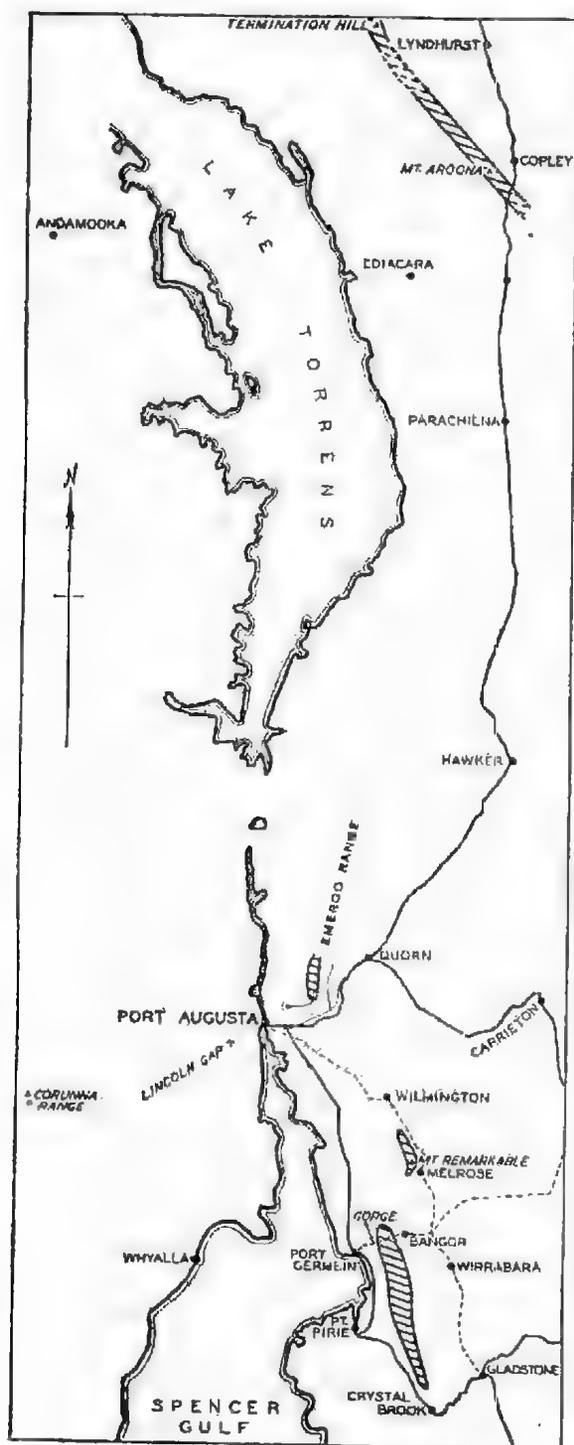
In the northern Flinders Ranges, the swing of the bedded sediments around to the west and north-west appears to have been due to the existence of a more stable crustal block to the north and north-east. This is definitely so still farther north, in the region of the MacDonnell Ranges.

II. INVESTIGATION OF THE ACCUMULATED SEDIMENTS

GENERAL REMARKS

Returning now to the region which we have studied in considerable detail, that between the ancient land masses Yilgarnia and Willyamia. During the past 40 years I have had many opportunities of examining these ancient geosynclinal sediments in selected areas in the region occupied by the Flinders Ranges and eastward to the Barrier Ranges. Measurements have disclosed that in the centre of the basin the total thickness of such deposits is immense (Mawson 1942). In the marginal regions, some at least of the very numerous formations represented thin out or are absent. Already much relating to the thickness and distribution of the sediments of the deeper parts of the trough has appeared in a series of contributions submitted by me to this Society, but there still remains to be published extended observations on the glacial and fluvioglacial succession of the central portion of the basin. Thus far, I have dealt with the types of sediments represented and their respective thickness. Their petrographic

characters have been only very cursorily touched upon, a detailed account of such having been purposely withheld until the final review when the varying phases of sedimentation can be comprehensively dealt with.



Locality Plan

Concerning the corresponding sediments represented in the eastern region bordering the Willyama massif, I have as yet published (mainly D. M. 1912) only very limited detail, reserving most of the results of work in that region for consideration in relation to the sedimentation of the geosynclinal basin as a whole. In that region the extensive survey conducted under Andrews (1922) has added greatly to the knowledge of that area, though principally relating to the Willyama series itself.

Notable contributions relating to areas of the central and western belts have been furnished by Howchin and by members of the South Australian Mines Department, including, more especially, Dickinson (1942), Jack (1914, 1922), and Segnit (1929 and 1939).

Further south, in the Adelaide region, Howchin has in the past been the chief investigator of the stratigraphical succession, but more recently Madigan (1927), Hossfeld (1935), Barnes and Kleeman (1934), Segnit (1937) and Sprigg have published important contributions to this subject. The latter, who as a student, assisted me on occasions in field work conducted in the Flinders Ranges, undertook and has now completed a check of Howchin's original work in the vicinity of Adelaide. He has published (1942 and 1946) an account of the various formations constituting Howchin's Adelaide Series as occurring in the type locality, including thickness and general distribution in that area.

PROTEROZOIC SEDIMENTS EXPOSED TO THE WEST OF COPLEY

When examining an important occurrence of magnesite near Copley which is located towards the western side of the great geosynclinal trough, I was struck by the regularity of the sedimentary formations and freedom from faulting. Accordingly, a traverse of some 16,000 feet of these beds was made extending upwards from an immensely thick arenaceous formation to somewhat above a glacial horizon, correctly regarded as equivalent to the Sturtian Precambrian glacial horizon near Adelaide. This belt of sediments, which dips steeply to the east, was found to extend for miles along the strike without a break. From Mount Aroona it was traced for a few miles to the south-east, crossing to the east of the main north road to Copley; to the north-west it extends for more than 20 miles from Mount Aroona, passing through Myrtle Springs Station and on to the neighbourhood of Termination Hill. There major faulting and shattering abruptly dislocates the formation.

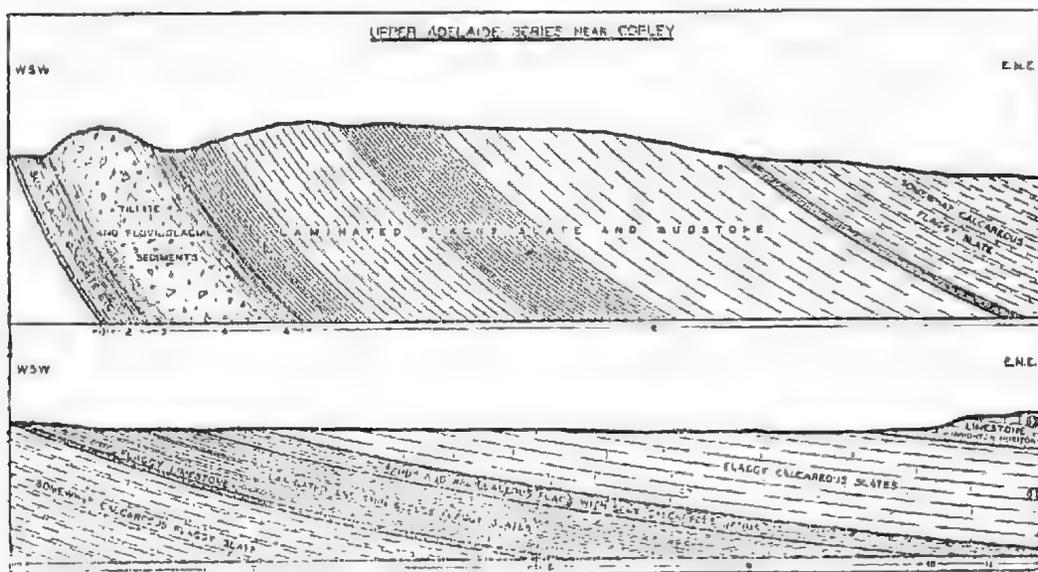


Fig. 2

A detailed section of the lower members of the succession has already been published (Mawson 1941). A further geological section is now submitted as fig. 2 herewith. This carries the sequence from the glacial stage to the Brighton Limestone horizon. The cross-section illustrated refers to observations made in a location situated some two miles northward along the strike, from that of the earlier traverse. In the locality indicated beds higher in the sequence than exposed on the former line of section are available for study.

It should be mentioned that the suggested hidden fault at the eastern end of the earlier published section almost certainly does not exist. There the out-cropping Precambrian rocks cease and the low-lying open country beyond is occupied by the Leigh Creek Triassic basin. According to earlier reports relating to this coalfield area the Triassic strata occupy a trough-faulted belt. Recently, however, a survey of the area made by officers of the S.A. Mines Department has shown that the Mesozoic rocks occupy basin-shaped, but not faulted, depressions in the older formations.

TABULATED SEQUENCE, AS DISPLAYED IN FIG. 2, OF STRATA FROM THE
GLACIAL HORIZON TO THAT OF THE BRIGHTON LIMESTONE

Pre-Glacial Sediments

- 1 32 ft. of Dolomite: strike N. 20° W. (true), dip 55° easterly.
- 2 158 ft. mainly shales.
 - (a) Flaggy calcareous shales Thickness 104 ft.
 - (b) Yellow dolomitic shale, strike N. 30° W, dip 60° easterly. Thickness 33 ft.
 - (c) A sandstone band. Thickness 15 inches.
 - (d) Sandy shale. Thickness 20 ft.

Glacial and Fluvio-glacial Sediments
(cf. items 32 to 36 of the 1941 section.)

- 3 116 ft. of Fluvio-glacial muds and siltstone.
 - (a) Sandy fluvio-glacial grit with erratics up to 5 inches diameter. Thickness 10 ft.
 - (b) Argillaceous siltstone. Thickness 48 ft.
 - (c) Fluvio-glacial mud (with gravel bands). Thickness 13 ft.
 - (d) Fluvio-glacial mud of coarser texture and with occasional erratics. Thickness 8 ft.
 - (e) Laminated silt with a little grit: strike N. 35° W, dip 64° easterly. Thickness 11 ft.
 - (f) Fluvio-glacial muds. Thickness 26 ft.
- 4 299 ft. of Tillite.
- 5 143 ft. of Laminated Fluvio-glacial series.
 - (a) Laminated shale with occasional erratics: strike N. 42° W, dip 46° easterly. Thickness 80 ft.
 - (b) Laminated shale with erratics up to 6 inches diameter. Thickness 5 ft.
 - (c) Finely laminated fluvio-glacial mud and thin bands of grit. Thickness 58 ft.

Post-Glacial Sediments

- 6 2,016 ft. of laminated flaggy shales, etc.
 - (a) Laminated shales. Thickness 110 ft.
 - (b) Laminated shale with some calcareous bands. Thickness 30 ft.
 - (c) Laminated shales. Thickness 106 ft.
 - (d) Flaggy shales; N. 35° W, dip 45° to the east. Thickness 567 ft.
 - (e) Faintly laminated fissile shales; dip 40° to the east. Thickness 307 ft.
 - (f) Slaty mudstone. Thickness 53 ft.
 - (g) Flaggy slate; strike N. 35° W, average dip 35° to the east. Thickness 843 ft.
- 7 724 ft. of somewhat calcareous flaggy slates.
 - (a) Flaggy calcareous slate in beds a few feet in thickness interbedded with slates. Total thickness 43 ft.
 - (b) Flaggy, faintly laminated, slightly calcareous slates; dip 29° to the east. Thickness 681 ft.
- 8 14 ft. of flaggy limestone.
- 9 248 ft. of slates.
 - (a) Laminated flaggy slate. Thickness 100 ft.
 - (b) Thin-bedded flaggy slate; dip 15° to east. Thickness 148 ft.
- 10 2½ ft. of Impure Limestone.
- 11 94 ft. of slate and sandy argillaceous flags.
 - (a) Slate; dip 15° to the east. Thickness 62 ft.
 - (b) Sandy argillaceous flags with some calcareous bands. Thickness 32 ft.
- 12 500 ft. of flaggy calcareous slates; dip falling off from 10° to 5° toward the east.
- 13 Massive limestone dipping at a very low angle. This is the Brighton Limestone horizon.

From item (3) to item (12) inclusive, representing all sediments from the base of the Sturtian glacial formation to the base of the Brighton Limestone amounts to 4,176 feet.

THE STRATIGRAPHICAL EQUIVALENCE OF THE MOUNT AROONA QUARTZITE WITH THE ALDgate SANDSTONE

The succession of strata as exposed to the west of Copley (Mawson 1941) exhibits sufficient correspondency with that below the Sturtian Tillite horizon in the neighbourhood of Adelaide, as established by Howchin, to indicate equivalence in time of these respective series of beds. In the neighbourhood of Adelaide, below the Sturtian Tillite, in descending order are laminated shales and minor quartzites, then shales with many intercalations of dolomite (Beaumont Dolomites) more argillites, some phyllitic in places, and then the Mount Lofty or "Thick" quartzite.

As this is broadly the succession at Copley the Mount Aroona quartzite was accepted (Mawson 1941) as the equivalent of Howchin's Thick Quartzite. This decision was based on the fact that at Copley there is no outstandingly thick quartzite in the series other than that of Mount Aroona; also at that time there was a grave doubt as to the accuracy of Howchin's succession below his "Thick Quartzite."

It will be recalled that Howchin, on account of faulting and structural complications, was not able, in the region between Mount Lofty and Aldgate, to satisfactorily relate the outcrops of the lower members of his succession. He finally relied for sequence in that part of his series upon the succession which he established in the Torrens Gorge area, which is a region greatly affected by faulting and structural complications.

Later work (Barnes and Kleeman 1934 and Mawson 1939 and 1946) had cast some doubt upon the relations, as established by Howchin, of the Torrens Gorge succession below the Thick Quartzite. The suggestion made was that Howchin's beds below the Thick Quartzite, as interpreted from the Torrens Gorge outcrops, might represent a duplication by faulting of his Upper Phyllites and Dolomites. The probability that such is the case was favoured at the time of publication of the Copley section (D. M. 1941).

Since then, Sprigg (1946) has completed his reconnaissance of the Adelaide Series in the neighbourhood of Adelaide, and though not entirely satisfied with the evidence, owing to faulting and displacements in the Torrens Gorge area, he concludes that the Upper and Lower Torrens Dolomite formations (Howchin's Upper and Lower Torrens Limestones) sequentially follow above a basal ilmenitic sandstone and below the Thick Quartzite.

Howchin recorded that his Upper Torrens "Limestone" (actually dolomite) had associated with it bands and nodules of chert. Now Sprigg has found magnesite associated with this Upper Torrens Dolomite. As both these chert and magnesite are peculiarities of the main dolomite series near Copley, it is now evident that the dolomite-magnesite series above the Mount Aroona quartzite should be correlated with the Torrens Gorge Dolomites, which latter are now accepted (Sprigg 1946) with confidence as stratigraphically below the Thick Quartzite. Thus it is that Mr. Sprigg (1946, p. 328) has indicated that the Mount Aroona Quartzite "may prove to be the equivalent of the basal ilmenitic sandstone in Howchin's type area, while Howchin's Thick Quartzite would probably be contemporaneous with one or more minor quartzites in Mawson's Magnesite series of the Flinders Ranges."

I agree with this suggestion, a conclusion consequent on Sprigg's proof that the Torrens Gorge dolomites are a separate and earlier magnesiteiferous series distinct from the Beaumont Dolomites (Howchin's Blue Metal Limestone). Evidently, the Mount Arona quartzite corresponds to the Aldgate sandstone; that is, with the basal member of Howchin's Adelaide Series. Howchin regarded the Aldgate ilmenitic sandstone as of about 200 feet in thickness. Sprigg finds that, in the Aldgate area the first 100 feet of the Adelaide Series is ilmenitic sandstone, and that while the relations are not quite clear this appears to be followed by upwards of 2,000 feet of alternating sandstones and gritty and sandy slates, all of which are located below the horizon of the Lower Torrens Dolomite.

PROTEROZOIC SEDIMENTS OF THE NEIGHBOURHOOD OF QUORN

GENERAL REMARKS

Subsequent to my examination of the Copley area, an important occurrence of magnesite was reported in the neighbourhood of Mundalloo Creek, west of Quorn, situated about 130 miles in a nearly due south direction from the former locality (see fig. 1). This has proved to be a repetition of the formation at Copley, though containing less dolomite and magnesite. Here the general sequence of formations is the same as at Copley, but here the upward range exposed is greater. An unbroken succession extends from a great basal rudaceous and arenaceous formation, equivalent to the Mount Arona quartzite of the Copley area, up to and through the basal sandstone (Pound Sandstone) of the Cambrian. There is thus exposed a complete succession corresponding to the Adelaide Series.

Howchin (1928) recorded some of the geological features of the neighbourhood of Quorn with special reference to the tillite, but he did not recognise the magnesite formation, nor did he locate the remarkable development of quartzite and conglomerate which constitutes the basal member of the Proterozoic sequence in that area. More recently, Segnit (1939) completed a geological map of some 34 square miles of that area, but missed recording the existence of magnesite and mistook the enormously thick basal quartzite of the Proterozoic sequence for the Pound Sandstone-Quartzite which is some 13,000 feet stratigraphically above it.

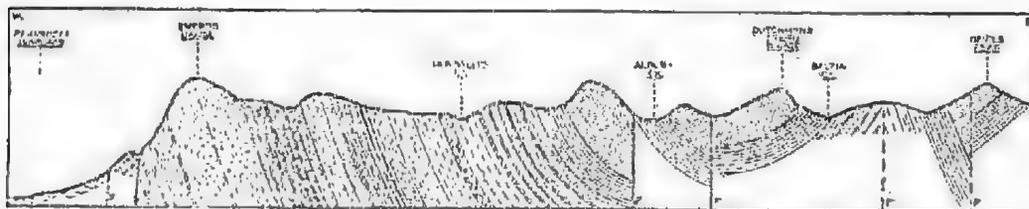


Fig. 3

Here again, as in the case of his map of the Mount Scott - Mount Arona area near Copley, Segnit (1939) mistook the thick basal quartzite of the Proterozoic for that far above in the sequence ushering in Lower-Cambrian fossiliferous formations. His interpretation necessitated the incorporation in his map of a grand strike-fault along the face of the quartzite on its eastern side. We found no evidence of such a major fault, though small displacements do occur and would be expected at the contact of so great a mass of quartzite with the less competent overlying argillaceous beds, where orogenic forces on a grand scale have thrown the sedimentary formations into a series of folds.

Elsewhere in his map, Mr. Segnit unconsciously introduces faults to reconcile, it seems to me, the observed outcrops with a preconceived conception of the sequence. Unquestionably, there are a number of large scale faults in that area. A notable strike fault passes through the quartzite belt of the Devil's Peak as mentioned by Howchin (1928) and illustrated by Segnit (1939); another trends along the valley between the Devil's Peak and the Dutchman's Stern Range; another throws down the country to the west of the great basal quartzite, shearing it in places. Other apparent lines of faulting are indicated in the diagram herewith. Minor faults and displacements are, of course, numerous, as would be expected in a region at one time (late Cambrian?) subjected to an alpine orogeny and subsequently, after peneplanation, recreated once again as a range of mountains (late Tertiary) of the nature of block uplifts.

SECTION FROM DEVIL'S PEAK WESTWARD TO THE LAKE TORRENS SUNKLAND

The general relation of the strata in this area is illustrated in fig. 3 herewith, which is a section from the Port Augusta-Lake Torrens Sunkland across the Ranges to the Devil's Peak. We have found that the field distribution of outcrops of the various formations is fundamentally dependent on the development of a system of pitching folds. The structures thus developed are modified by some major and frequent minor faults.

A typical anticlinal fold is that to be observed at Pichi-Richi Pass in the neighbourhood of the Devil's Peak. There the great Cambrian quartzite (Pound Formation) of the Dutchman's Stern Range descends again to the east as the Devil's Peak. The intervening valley region of Pichi-Richi Pass is occupied by sequentially underlying sub-Cambrian beds which, however, are sliced by a strike-fault along the crown of the anticline with considerable downthrow on the east side of this fault. Another strike-fault on a considerable scale slices the quartzite of the Devil's Peak mass as illustrated in fig. 3. The quartzite mass of the Devil's Peak is truncated to the north by a fault cutting diagonally across the strike, while to the south it can be traced looping around on a course somewhat checkered by faulting, but eventually joins up with the southern extension of the somewhat attenuated Dutchman's Stern Range. What is important is that outcrops of the Pound Quartzite (Segnit's D7 formation) shown on Segnit's map as appearing in the Pichi-Richi Pass region between its outcrop in the Dutchman's Stern Range and its repeat in Devil's Peak are not portions of the Pound Quartzite proper but are underlying greywackes, arkoses and shales separated sequentially from the former by a thick formation of chocolate shale.

In this region the sequence of beds from the basal conglomerate of the Proterozoic formation to the basal Cambrian quartzite is well illustrated in a straight run of beds on the western side of the Ranges. There is there a minimum of disturbance by faulting, a feature strikingly indicated in Segnit's (1939) coloured plan of the locality. As already stated, however, we do not agree with him where he introduces a strike-fault on a grand scale along the upper limit of the basal quartzite. The latter we have found to be equivalent of the quartzite of Mount Aroona in the Copley area.

THE PROTEROZOIC SUCCESSION IN THE NEIGHBOURHOOD OF MUNDALLO CREEK

The succession of beds in this locality is graphically represented in fig. 4 herewith. Descriptive details of the individual formations are given below. Neither the absolute bottom of the great basal conglomerate-quartzite formation nor the nature of the pre-existing (underlying) rocks is demonstrable in this area owing to major block faulting of Tertiary times responsible for downthrow of a wide belt of country (Port Augusta Lake Torrens sunkland) lying to the west of the Emeroo Range. This problem is discussed later.

TABULAR STATEMENT OF THE PROTEROZOIC SUCCESSION AT MUNDALLIO CREEK

The Proterozoic succession of strata occurring in the neighbourhood of Mundallio Creek, Southern Flinders Ranges. The beds are numbered in upward sequence from the lowest exposed beds. True bearings given in all cases. The sequence is graphically displayed as fig. 4.

	Feet
1 Basal beds of coarse water-laid conglomerate occurring in an alternating succession with finer arenaceous sediments. Pebbles met with up to 6" in diameter, mainly constituted of liver-coloured quartzite, but some appear to be Gawler Range porphyry. Dip 55° E, strike N. 6° E. Near the upper limit of this section is a sandstone with marked ilmenitic banding but free from pebbles. Strike N. 4° W, dip 55° E. The base of this section was not observed but the total thickness measured is - - -	800
2 Bands of ilmenite-bearing quartzite alternating with conglomerate, each component band being about 3 ft. thick. Strike N. 4° W, and dip 70° E.	62
3 Alternations of sandstone with reddish argillaceous partings each of the latter ranging from 2 to 3 feet thick. Dip 70°.	270
4 Quartzite without any shale partings and with only faint traces of bedding laminations. All but near the base is notably white and hard. The dip ranges from just about 70° below to near 80° at the top limit. The strike swings around locally at the upper limit to N. 4° W.	490
5 A belt of sandstone somewhat reddened in part and with traces of minor shearing.	96
6 Quartzite of a generally uniform character with dip to the east between 72° and 65°. Strike N. 14° W, below to N. true in the upper beds.	1,276
7 Quartzite, hard below and less resistant above. Average dip 70°	1,294
The Emeroo Range basal rudaceous and arenaceous sediments: - - -	Total, 4,288
8 Soft sandstone in part argillaceous. Outcrops deficient. Dip 72° to the eastward	262
9 (a) Sandy shale, Dip 70°.	144
(b) Grey dolomitic mudstone	87
(c) Flaggy sandstone and marly micaceous shale	42
(d) Sandy Marl	87
(e) Grey marly shale. Strike N. true, Dip 73° E.	70
Sandy to marly transitional beds: - - -	Total, 692
10 (a) Two very narrow seams of nodular magnesite embedded in marl	11
(b) Poor outcrop, but apparently marl and marly shale with some narrow seams of magnesite.	42
(c) Shales below with thin dolomitic bands above: then sandy marl to marly shale with thin dolomitic bands above.	54
(d) Hard dolomite.	8
(e) Marly Shale.	39
(f) Bands of dolomite and thin-bedded marly shales.	219
	373
11 (a) Marly shales with several magnesite bands. Dip 70°	17
(b) Banded dolomite with irregular seams of chert and magnesite passing above to alternating beds of shale and dolomite. Magnesite mine workings are located in this section.	329
Marly series with dolomite and magnesite: - - -	Total, 719
12 Arenaceous beds enter the succession, becoming dominant over the dolomitic shales at the top of this section where there appears a band of flinty quartzite exhibiting contorted bedding	286
13 (a) Laminated sandstone becoming more massive above.	139
(b) Carbonate laminations appear in the sandstone and it finally passes	

	into a calcareous sandstone (carbonate cement). - - - -	122	
	(c) No outcrops; probably soft calcareous sandstone. - - - -	115	376
14	(a) Sandstone which in part has a dolomite cement and occasional fragments of dolomite embedded in it. - - - -	82	
	(b) An association of marly sandstone and sandy marl, strike N. true dip 63° E. - - - -	212	
	(c) Marl - - - -	61	
	(d) Laminated shale. - - - -	78	
	(e) Hard quartzite, strike N. 4° W, dip 65° E. - - - -	64	497
15	(a) Marly shale. - - - -	67	
	(b) Sandy dolomite. - - - -	15	
	(c) Sandy shale with occasional narrow seams of dolomite. - - - -	71	
	(d) Strongly laminated (varve-like) shales. - - - -	40	
	(e) Sandstone with some marly base. Certain beds are more marly. - - - -	40	233
	Sandstone and shale, much of it dolomitic and marly: - - - -	Total,	1,392
16	Laminated shales. - - - -		362
	Laminated Shale: - - - -	Total,	362
17	(a) True tillite (quite unsorted) containing erratics, also fragments of chert and dolomite of the underlying series. With the tillite are some intercalated bands of morainic mud. - - - -	62	
	(b) Finer grained, fluvio-glacial beds more firmly cemented and resistant in the upper section. - - - -	200	
	(c) Irregular sand intercalations (each a few yards across) ramifying through the more regularly distributed fluvio-glacial sediments. - - - -	13	
	(d) Sandy tillite passing upwards into typical tillite for a few yards in thickness then reverting to fluvio-glacial sediments. - - - -	25	300
18	(a) Fluvio-glacial, well laminated slates. - - - -	539	
	(b) Slate (rock-flour type) poorly laminated. Strike N. true, dip 60° E. - - - -	167	706
	Series of Glacial and Glacigene sediments: - - - -	Total,	1,006
19	(a) Somewhat softer slates. - - - -	557	
	(b) Laminated (Tapley Hill type) slates; somewhat flinty. Strike N. 6° E., dip 65°. - - - -	101	658
	Laminated slates - - - -	Total,	658
20	(a) Slates somewhat calcareous, followed by a belt 54 ft. thick of argillaceous limestone in which are reddish bands and pellet markings not unlike the "hieroglyphic" structure recorded elsewhere in post-glacial calcareous strata of the S. Austr. Proterozoic record. - - - -	96	
	(b) Strongly calcareous edgewise pellet conglomerate. - - - -	9	
	(c) Slates. Strike N. 6° E, dip 75° E. - - - -	159	264
	Calcareous slates and argillaceous limestones: - - - -	Total,	264
21	Slates which weather reddish on outcrop though grey at a depth. Stains of copper carbonate observed in bedding planes at several points along the outcrop. This section becomes more arenaceous in its topmost limits and there weather reddish brown. - - - -		677
22	Shales and sandy shales with interbedded sandstones (brownish outcrop). Strike N. 6° E. Dip 75° E. - - - -		913
	Slates with limited arenaceous intercalations: - - - -	Total,	1,590
23	Reddish sandstones and some interbedded shale formations. - - - -		1,057
24	Soft purple shale. - - - -		1,072
	Purple series of sandstones and shale: - - - -	Total,	2,129
	Total Proterozoic Formation represented, - - - -		13,100
	BASAL CAMBRIAN FORMATION		
25	Reddish to purple sandstone. - - - -		251
	Massive sandstone and quartzite. - - - -		1,832
	Massive sandstone and quartzite (Pound Formation): - - - -	Total,	2,083

A comparison of the formations as developed in this Mundallio Creek section with their equivalents in the Copley section demonstrates the fact that in the former area, except in the case of the basal beds, the geosynclinal Proterozoic sediments are not nearly so strongly developed as in the latter locality. The explanation appears to be that the Mundallio Creek area was nearer to the old Precambrian shore-line, where the subsiding basin was less responsive to isostatic loading. Further eastward, in the Carrieton - Oraparinna belt, the total thickness of the corresponding series of beds is notably greater even than in the region of Copley.

REVIEW OF FORMATIONS

THE EMEROO RANGE BASAL RUDACEOUS AND ARENACEOUS FORMATION

On the line of section across the Emeroo Range (fig. 4) a thickness of about 4,288 feet of quartzite and conglomerates are traversed, of which the lower 800 feet is mainly conglomerate. Judging by the coarseness of the conglomerate, it is likely that the actual base of the formation is not far below the base of the exposure.

In the case of the Mount Aroona Range quartzite of the Copley area, we found near Myrtle Springs Head Station some small pebbles appearing in the quartzite at the lowest exposed outcropping horizon. There, as in the Emeroo Range, the further downward extension cannot be observed owing to a major down-throw of the region to the west.

The thick rudaceous basal section, so well exposed in the Emeroo Range, is composed of grit bands and pebble beds of varying thickness. At some horizons boulders of 6 inches diameter are not uncommon, but generally speaking such a size is exceptional. Pebbles of white quartzite and of liver-coloured quartzite are commonest, but schist and lumps of ilmenite are not uncommon ingredients. Some brown pebbles resembled the felsitic base of the Gawler Range porphyry, but none such were observed to carry porphyritic feldspars.

Towards its upper limit, this basal rudaceous section of the formation passes through a stage of alternating beds, each several feet thick, respectively of conglomerate and of pebble-free ilmenitic sandstone. Then follows a short run of similar alternations of ilmenitic quartzites and red shale. Thereafter follows the main mass of the formation, which is quartzite and arkose.

A petrological peculiarity, distinctive of a certain horizon in this quartzite, is that of a very obvious banding, due to recurring deposition of clear water-sorted quartz grains of larger size than usual along bedding planes. This banded quartzite has usually a faint to a somewhat stronger tinge of pink; it also may be spotted with white specks of kaolinized feldspar. This latter feature is also strongly developed at some other horizons, where in many cases the original bedding planes are not evident.

The sand grains of the early stages of deposition of this enormously thick formation are generally coarser and more arkosic than in the case of later contributions. In this section microcline is the most abundant mineral, apart from quartz. A pink to brown colouration is usually noticeable in this lower zone.

The quartzite of the middle region of the formation, where it is apparently most resistant to weathering and consequently stands out as the highest ridge of the range is whiter, more finely grained and not noticeably arkosic.

THE DOLOMITE - MAGNESITE SERIES

In the Mundallio Creek locality this series is developed on a more limited scale than in the Copley area, where strata of dolomite and magnesite (Mawson

1941) are scattered at intervals throughout the entire sequence between the thick basal arenaceous belt of Mount Aroona and the glacial series above, a total thickness of sediments of about 7,000 feet. The outcrop of these beds extends unbroken both to the south-east and to the north-west from Mount Aroona for a considerable distance.

Beyond Mount Parry, some 5 miles to the north, this formation is still well exposed at the surface. There the strata dip very steeply—nearly vertical—to the north-east. Thereabouts the main magnesite-bearing section of the beds occupies a surface width of 3,000 feet; included therein are a number of seams of magnesite, with a total thickness of not less than about 50 feet. The most westerly magnesite outcrop is of the very coarse nodular variety; there is there a bed of 7 feet in thickness separated from a second bed 2 feet in thickness by a thin parting. Another concentration of beds of magnesite occurs near the upper limit of the eastern side of the formation.

Details of the original area near Mount Aroona have already been recorded (Mawson 1941), but since that date much exploratory mining work by costeanis and pits has been done on a width of 100 yards, selected where richest in magnesite. The result of opening up the outcrop has been to expose more magnesite bands than were reckoned to exist when we measured up the original section. A very large tonnage of a good grade of magnesite is now exposed.

The magnesium-rich sediments were obviously laid down in shallow, saline, land basins. The magnesite is of sedimentary origin as a primary or pencon-temporaneous sediment. Many of the magnesite beds are composed of nearly pure magnesite, containing extremely little calcium. Occasional beds reach a purity of 98% $MgCO_3$. We now know this magnesium-rich formation to be very widespread in South Australia. It is most strongly developed in the more westerly areas, especially discussed in this paper. Nevertheless, important beds also appear in the more central region of the geosynclinal basin, such as the neighbourhood of Balcanoona (where magnesite rock composed of uniform pellets was originally described by Fred. Chapman as *Mawsonella*), Johnburgh and Robertstown. Sprigg (1946) has recorded pellet magnesite near Adelaide, where it is associated with the Upper Torrens Dolomites in what is apparently this same stratigraphical horizon.

The most remarkable feature of this magnesite is that it usually occurs in a peculiar nodular form. A study of this structure has convincingly shown that the nodules are original pellets laid down in beds as in the case of clay pellet formations. This appears to have been a development from magnesite sludge, which had evidently accumulated in the first instance as thin laminae of almost pure magnesite, eventually to be fragmented and re-accumulated as pellet beds.

SEDIMENTS OF GLACIAL AND FLUVIOGLACIAL ORIGIN

In sequence above the Dolomite-Magnesite series comes a variable thickness of glaciogene beds. These comprise depositions of true tillite, bedded fluvio-glacial mudstones with or without embedded erratics and some interglacial bedded arenaceous and argillaceous sediments, which are on occasions typically varved.

The variability in thickness of these glaciogene beds in the area now under consideration is considerable. In the section near Copley 608 feet of obviously glaciogene beds were met with, but at Mundallio Creek there was found a total thickness of 1,006 feet. Further south, near Crystal Brook, the section published by Howchin (1928) shows a thickness of 1,240 feet. Further towards the centre of the basin the thickness increases considerably. However, it is not only

that the total thickness varies between wide limits within the State of South Australia, but what is still more interesting is that the records preserved in different localities within the State vary considerably in regard to the number of glacial culminations evidenced. In some localities the glaciogene beds embody only one deposit of true tillite, whereas in other places there are 2, and even 3, major horizons of tillite. These are separated by fluvial and fluvio-glacial sediments, presumably of interglacial periods.

One factor in the irregularity of deposition from place to place is due to the fact that, over large areas of South Australia, and adjoining territory, the Sturtian Ice-Cap—for Ice-Cap it must have been—actually rested for a long period of its existence upon the rocks that underlie its glaciogene depositions. In these areas, as the ice finally receded, a mantle of greater or less thickness of glacial and fluvio-glacial debris was spread over the glacially eroded surface of the pre-existing formations. In other areas deposition took place in deep water.

The old highland areas existing during that glacial epoch, such as in the neighbourhood of Olary, the Barrier Ranges, Eyre Peninsula and in the vicinity of Mount Painter were all ice-capped and shed glacial debris into the sinking geosynclinal area. Even portion of the latter carried a capping of ice, so that earlier sediments of the Adelaide Series were in some areas considerably eroded by the ice sheet before the glacial deposits were eventually laid down over their ice-eroded surface.

During the past 40 years the author has made extensive field observations of evidence bearing on problems concerning this period of glaciation in Australia. The broader findings are as just mentioned, but further elaboration is reserved for a more detailed account in preparation.

LAMINATED (TAPLEY HILL) POST-GLACIAL FORMATION

Following stratigraphically above such beds of unquestionable glaciogene origin there is always a thick formation of shale, or its slate equivalent, constituted of thin laminae which are not true varves, but the author is convinced do represent a modified type of seasonal deposition. This conclusion was reached long ago and voiced before the geological section of the Australian Association for the Advancement of Science at its meeting in Adelaide in January, 1907. Since then further convincing proof has been accumulated, and is being dealt with in the compilation already mentioned.

The ribbon slates of this horizon in Howchin's Adelaide Series have long been distinguished as the Tapley Hill Slates or shales as the case may be. In the main, they represent rock flour washed out from the glaciated land during the waning phase of the glacial period.

In its upward extension the Tapley Hill formation includes more and more calcareous contributions. Eventually, in the upward sequence, some beds appear of the composition of argillaceous limestone, to be quickly followed by a greater or less thickness of purer limestones of the Brighton Limestone horizon.

At Mundallio Creek this section of sediments amounts to only about 650 feet in thickness, but in the vicinity of Copley it is much greater, namely, 3,598 feet. This is evidence that the neighbourhood of Copley was situated further from the old shore line.

(2) Not to be confused with the Aronka Range, which is part of the main Flinders Ranges and extends north from Wilpena Pound.

THE BRIGHTON LIMESTONE HORIZON

The limestones and associated argillaceous beds of this horizon are comparatively shallow water depositions, for bands of intraformational chip and pellet breccias appear in this portion of the sequence. The purer limestone formations frequently exhibit good evidence of their biostromic character.

At Mundallio Creek the main limestone formation of this horizon does not exceed 54 feet in thickness. At Copley it is thicker.

ARGILLACEOUS AND ARENACEOUS SEDIMENTS ABOVE THE BRIGHTON LIMESTONE HORIZONS

At Mundallio Creek, as elsewhere in the State, the sediments of this section are mainly of a reddish tinge of colour, often chocolate to purple.

At Mundallio Creek the measured thickness amounts to only about 2,130 feet. According to Segnit (1939) these beds are much thicker than we found them to be. We have found a vastly greater thickness further to the east in the deeper portions of the basin. No complete section of this portion of the sequence is available for measurement at Copley, but to the south-west of Copley such beds are exposed on a major scale between Mount Scott and Mount Deception. Thus again supporting the contention that Copley is further east from the old shore line than is Quorn.

THE POUND QUARTZITE (CAMBRIAN)

As the outcrops met with in the Quorn area are faulted and considerably eroded, our determination of the thickness of this formation as met with there is subject to some revision, but it is believed to be approximately correct. Our figure is about 2,000 feet. We cannot agree with Segnit's 739 feet (1939). Also, we are sure that Howchin's figure of 800 feet for this quartzite as estimated by him at Devil's Peak does not correspond to the true thickness in the Quorn area. The fact is that Devil's Peak represents only a badly faulted and sheared fragment of the Pound Formation.

In the neighbourhood of Copley this horizon is developed in great strength upwards of 2,000 feet in the Mount Scott Range.

At some 25 miles to the south-west of Copley, Sprigg (1947) made an important discovery of fossils in a sandstone below the Archaeocyathinae limestone. This sandstone appears to belong to the Pound Formation, and the discovery lends added support to the contention that the latter is Cambrian. More recently we have visited the locality of this fossil find and have been able to collect additional specimens both of Sprigg's medusa-like forms and of a plant-like impression.

OUTCROPS OF THE BASAL QUARTZITE ELSEWHERE IN THE SOUTH FLINDERS RANGES

In the South Flinders Ranges there has come under our notice two other areas occupied by outcrops of this same quartzite, basal to the sedimentary succession of the Late Proterozoic geosynclinal basin. One is that traversed by the Port Germein Gorge road, and the other constitutes the main mass of Mount Remarkable. The geographical situation of the three areas mentioned in the South Flinders Ranges and of the Mount Aroona belt further north is illustrated in fig. 1.

THE GREAT QUARTZITE OF PORT GERMEIN GORGE

The Port Germein Gorge road cuts across this quartzite at the northern end of a north-south directed and northward pitching anticline. The conformable

dolomite-magnesite series follows normally around the anticlinal structure; additional proof that this great quartzite is stratigraphically below the magnesite series as at Mundalliu Creek and at Copley and not just blocks of Pound Quartzite faulted into their present position. A portion of The Dolomite-Magnesite formation, trending in a general north-south direction, is to be seen in the bank of the Gorge Creek at the western entrance to the Gorge. Just a little farther to the west is located the Tertiary fault scarp of the Range; this effectively drops the Precambrian formations out of sight beneath the plain.

Proceeding eastward through the Gorge where the highway is hewn through a great thickness of quartzite, a further re-appearance of that of the Emeroo Range quartzite, the strike is observed to swing around from south-north on the west side through west-east in the centre region to roughly north-south on the east side where the road emerges from the quartzite. A little further on the magnesite series, having followed around the margin of the quartzite, again makes its appearance: here it is being worked by the Broken Hill Proprietary Company. Still further on to the east, across the strike, and just beyond the locality Bangor, the Sturtian Tillite comes into view.

Returning to the dolomite formation, it extends south along the eastern flank of the great quartzite anticline through the Wirrabara Forest and Beetaloo Waterworks Reserve towards Crystal Brook. In that vicinity also the tillite has been recorded (Howchin 1929). On its western side and along its southern end the great quartzite is truncated by major faults of Kosciuskan orogeny.

THE MASSIVE QUARTZITE OF MOUNT REMARKABLE

Howchin (1916) was struck with the great thickness of the imposing ridge of quartzite which constitutes Mount Remarkable. He suggested many possible ways of accounting for the great thickness; with none of which, however, was he satisfied. He had not conceived the existence in South Australia of a single quartzite formation of such magnitude. On its eastern side the country is thrown down by a great fault, again apparently of the Kosciuskan epoch. On its western side there appears to be some faulting also, but from the overlying Sturtian Tillite horizon there appears to be a regular upward succession to the west, culminating in a large development of another major quartzite formation which, judging by its broader features, appears to be the Pound Quartzite. In its relation to associated beds, there seems to be no doubt that the quartzite of Mount Remarkable is yet another outcrop of the great basal formation under consideration.

THE MOUNT AROONA-EMEROO RANGE QUARTZITE AS DISTINCT FROM THE POUND QUARTZITE

Investigation of the several areas in the western Flinders Ranges discussed in preceding pages leaves no doubt that in that region, stratigraphically situated considerably below the record of the Sturtian glaciation, and immediately below an extensive series of beds peculiarly rich in dolomite and magnesite, there exists, as the basal member of a very notable section of later Proterozoic sediments, an extraordinarily thick development of quartzite, which is arkosic in part and subject to a great development of coarse conglomerate at its base. In the Emeroo Range the lower section of this remarkable formation is exposed to view and is observed to exhibit a brown to chocolate appearance. There, sandwiched between some of the rudaceous and arenaceous beds are chocolate to purple shales as bands up to several feet in thickness.

The massiveness of this formation is apt to cause it to be confused with the other extraordinarily thick arenaceous formation of that region—the Pound

Quartzite. The confusion is increased owing to the existence of purple shales and sandstone at the base of the latter as well as being found in association with the former. Fossils have never been observed in the older formation, but in the Pound Quartzite worm burrows are not infrequent. Recently Sprigg (1947) has made a very important additional fossil find.

TRANSGRESSIONAL PROTEROZOIC SEDIMENTS LOCATED TO THE WEST OF THE LAKE TORRENS SUNKLAND

THE TENT HILL FORMATION

Segnit (1939) has referred to the horizon of the Pound Quartzite, that extensive development of sandstones and associated conglomerates widely spread over the neighbouring region on the western side of the Port Augusta-Lake Torrens Sunkland. To the earlier geologists who have discussed the geology of the region west of Port Augusta, the age of this arenaceous formation has been an intriguing problem. The formation is usually met with in the form of widely scattered mesas and buttes, obviously remnants of a former grand development. The descriptive term, Tent Hill Formation, has long been applied to it. This term came into common usage from the resemblance in profile of some of the outliers or residual hills of the formation to that of a marquee tent.

In the absence of fossils it has been the custom in the earlier records of the Geological Survey Department to doubtfully refer the Tent Hill Formation to the Ordovician. In the more southerly portion of the region, Dr. Jack (1914) has referred to several outcrops which may be considered as representing phases of this formation, including conglomerates and quartzites of the Corunna Range near Iron Knob, the quartzite of the Blue Range in the Hundred of Verran, the Moonaby Range conglomerate.

In this same general area, Segnit (1939) refers to this horizon the extensive plateau formation in the neighbourhood of Lincoln Gap, and the rocks of the Corunna Range, Mount Laura, Mount Whyalla, Mount Young and Hummock Hill. All are referred by him, as earlier mentioned, to the Pound Quartzite which is his D7 formation, which, by the way, is considered by him to be the topmost horizon of the Precambrian.

The formations under consideration in all these localities are conglomerates and quartzites, usually flat-bedded or but little inclined, not obviously metamorphosed and with no indubitable signs of great antiquity. All repose with evident unconformity upon highly metamorphosed sediments and granites. Fig. 5 is a section illustrating the relation of the Tent Hill formation of the western plateau region to the block-uplifted folded rocks of the South Flinders Ranges.



Fig. 5

THE CORUNNA RANGE RUBACIOUS AND ARENACEOUS FORMATION

We have examined in some detail an example of this formation as occurring in the Corunna Range, located north of and within several miles of Iron Knob township. This locality is well illustrated in pl. xiv.

In the neighbourhood of the reservoir at Corunna Range, the beds strike N. 35° W. and dip to the north-east. At the base of the series the dip is as steep as 30°, but rapidly diminishes in the upper beds to the east. Actually the Range is the remnant of a synclinal basin, for on its eastern side the dip is reversed, directed at low angles to the west.

At the base are red arenaceous and argillaceous beds; then follows a remarkable development of conglomerate with some bands of quartz grit. A lower 100 feet thick of greyish, medium-coarse, arkosic grit is followed in vertical succession by a whiter phase containing larger pebbles. Passing upwards another 100 feet an extremely coarse conglomerate is encountered. Here masses of the rock are composed of boulders of 4 inches to 6 inches diameter; occasional boulders were met up to 15 inches long. Current-bedding is evidenced.

Most of the boulders are of milky quartz, while occasionally are met examples of quartzite rich in hematite of a kind exactly resembling the quartzite of the Iron Monarch Hill. Red jasper pebbles up to 10 inches diameter are of frequent occurrence. Several examples of quartz-muscovite-schist and banded jaspilites were met with. Occasional pebbles of typical Gawler Range porphyry were encountered. At some horizons there appear in the fine base of the conglomerate spangles and grains of pure hematite.

No evidence was forthcoming to indicate that these boulder beds were in any way associated with glaciation. The total thickness of this formation as exposed in the Corunna Range is said by Segnit (1939) to be at least 350 feet.

Dr. Jack (1922) was the first to record finding in this conglomerate pebbles of feldspar-porphry indistinguishable from that of the Gawler Ranges (lying to the west), also of ferruginous jaspilite and hematite similar to the formation at Iron Knob and Iron Monarch (located a few miles to the south). Jack states that at about 11 miles north-north-west of the Monarch is the easternmost exposure of the great feldspar-porphry mass that forms the Gawler Ranges. Also relevant to our investigation is Edwards' (1936) record that pebbles of the ancient Middleback terrain are found in the conglomerate of the Moonah Range.

Thus it is quite clear, from this evidence alone, that the Tent Hill Formation is younger than either the Gawler Range Porphyry or the Iron Knob terrain.

EQUIVALENCE OF THE CORUNNA RANGE FORMATION WITH THAT OF THE EMERON RANGE

The latest evidence bearing upon the question of age is our discovery that the lower 800 feet at least of the Emoron Range formation is composed of conglomerates, quartzites and red shales, petrologically similar to counterparts in the Corunna Range. No such association has been found in any outcrops of the Pound Formation. Further, the range is strikingly similar to that of the conglomerates of the Corunna Range, so similar that this fact alone is most convincing as to the identity of these two.

It thus becomes clear, as already recorded (Mawson 1946), that the Flinders Ranges east of Port Augusta (see pl. xv, fig. 2) represent the crumbled sediments of the Late Proterozoic to Cambrian geosynclinal basin, while the Tent Hill Formation to the west of Port Augusta (see pl. xv, fig. 1) represents shallow water sediments of the early stages of marine transgression over the coastal fringe of Yilgarnia, and corresponds to the basal formation of the Adelaide Series.

A further important deduction that arises is that we can now fix the age of the Gawler Range Porphyry as pre-dating the base of the Adelaide Series. It may be tentatively regarded as a product of the period of Algonian revolution (U.S.A. nomenclature).

CORRELATION WITH SEDIMENTS OF THE MOUNT LOFTY RANGES

While the succession on the western side of the basin in the region of the Flinders Ranges can now, with a high degree of confidence, be correlated with

that in the neighbourhood of Adelaide, the relation between the sediments dipping to the east on the eastern side of the Mount Lofty Ranges and those of the Adelaide Series as established on the west side of the Range and in the Flinders Ranges is not so evident.

Howchin held that the sediments on the east side of the Mount Lofty Ranges which dip consistently to the east and become successively more metamorphosed as they progress in that direction are the same beds as constitute the series, the sequence of which he had established on the western slopes; the succession being repeated on the eastern side of the Barossian core of the Range. For instance, he regarded the Grey Spur conglomerate, which unconformably overlies Barossian gneisses and faces east, as the Base of the Adelaide Series and equivalent to the Aldgate sandstone.

We have since traced the Grey Spur conglomerate to Blackfellows Creek, near Mount Magnificent. Accordingly, on Howchin's reckoning, the Blackfellows Creek conglomerate and the overlying Mount Magnificent Series of beds should be the basal member of the Adelaide Series. However, as already stated (Mawson 1939), the marble in that series is almost free from magnesia, and is therefore unlikely to be the counterpart of the richly magnesian dolomites of the lower Adelaide Series as developed on the neighbouring western side of the Ranges.

Consequently it is obvious that, before Howchin's views regarding a repetition of the Adelaide Series on the east side of the range can be accepted without further question, a thorough-going investigation must be made. Hossfeld (1935) holds that in the Williamstown area and to the east thereof, the Proterozoic rocks belong to an older series (his Para Series) than those (his Narcoota Series) developed so well on the western flank of the Mount Lofty Ranges.

There is considerable evidence to support the contention that much of the eastern flank of the Mount Lofty Ranges is occupied by rocks of Mosquito Creek Age. Certainly in the Olary - Broken Hill region there is a large development of sedimentary rocks intruded by the younger little-stressed granites, which underlie with violent unconformity the Sturtian tillite formation and may be regarded as stratigraphically equivalent to the Mosquito Creek Series of Western Australia. These intrusive granites have associated with them pegmatite apophyses notable for containing beryl, tantalite, columbite and uraniferous minerals, just as is the case in Western Australia.

Thus the stage now reached is that, henceforth, we shall regard the Mount Aroona quartzite as equivalent to the base of the Adelaide Series which, in the vicinity of Adelaide, is taken to be the Aldgate Sandstone. But the equivalence of the Grey Spur - Blackfellows Creek basal boulder beds and the Mount Aroona quartzite, while possibly correct, has yet to be convincingly proved.

OTHER CORRELATIONS

The Late Proterozoic, Nullagine Series, of the north-western and northern Australia has long been correlated (Cotton 1930) with the Adelaide Series. In Central Australia the Pertaknūrta and Pertatataka Series exhibit a close relationship in sequence of beds with the exception that the glacial horizon has not yet been recognised there.

As already published (Mawson 1946), a comparison with the Pre-Cambrian record of South Africa is convincing that this division of the Australian record has its equivalent in the Transvaal system and extensions of the latter in other areas of Africa. The detail of the South African succession bears a broad

general correspondence to that existing in South Australia. Thus the Dassport Glacial Horizon, the Lower Griquatown Tillite and the Numees Tillite (all apparently records of the same glacial epoch) may be said to be broadly equivalent to our Sturtian Tillite. The underlying dolomites and overlying limestones rich in "algal" structures are a feature of the sequence in both cases. The great conglomerate-quartzite formation at the base of the Transvaal System, resting with violent unconformity upon older formations, appears to correspond to the conglomerate-quartzite formation of the Emeroo Range and the Tent Hill Formation of Yilgarnia further west.

SUMMARY

Consideration is given to the succession of sediments occupying the great geosynclinal basin which developed off the eastern margin of Yilgarnia during Late Proterozoic to Middle Cambrian time. The present contribution deals only with accumulations along the western side of the basin in the region of the Flinders Ranges. Subsequent contributions will deal with depositions respectively of the eastern margin and of the central region of the depression.

The sediments accumulated in two locations near the western side of the basin are considered in some detail. The first is the neighbourhood of Copley, the second is the district to the west of Quorn. The latter is relatively nearer to the western margin of the geosynclinal basin than in the former.

The sediments considered are of Upper Proterozoic age, equivalents of the Adelaide Series of the Mount Lofty Ranges and of the Nullagine Series of North Western Australia.

Attention is drawn to a remarkable correspondence, so far as the broader features of sedimentation of this geological period are concerned, of the Australian record with that of South and Equatorial Africa.

Finally, the basal formation of the sedimentary accumulation in this geosynclinal area has been traced westward as an attenuated transgressional deposition overlapping the margin of Yilgarnia where it is known as the Tent Hill Formation. This settles the age of this latter feature, a long-disputed problem in South Australian stratigraphy.

A further deduction of some importance is that both the Gawler Range Porphyry and the Iron Knob iron-ore formation pre-date the deposition of the Adelaide Series. Reference is made to the occurrence in the Olary - Broken Hill region of sediments of Mosquito Creek age underlying the Sturtian glacial horizon, and it is suggested that further detailed field investigation of the sediments and meta-sediments of the eastern flank of the Mount Lofty Ranges may prove them to be of similar age.

ACKNOWLEDGMENTS

The photograph from the summit of Iron Knob is reproduced by courtesy of the Broken Hill Proprietary Coy. In the prosecution of field work associated with this contribution, I have been assisted by the co-operation of students, amongst whom H. F. E. Brock and R. C. Sprigg have been notably helpful.

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View from the summit of Iron Knob, looking north. In the distance is the Corunna Range, a flat-lying synclinal outlier of the rudaceous and arenaceous basal formation of the Adelaide Series, which lies with violent unconformity upon the older steeply dipping Iron Knob formation.

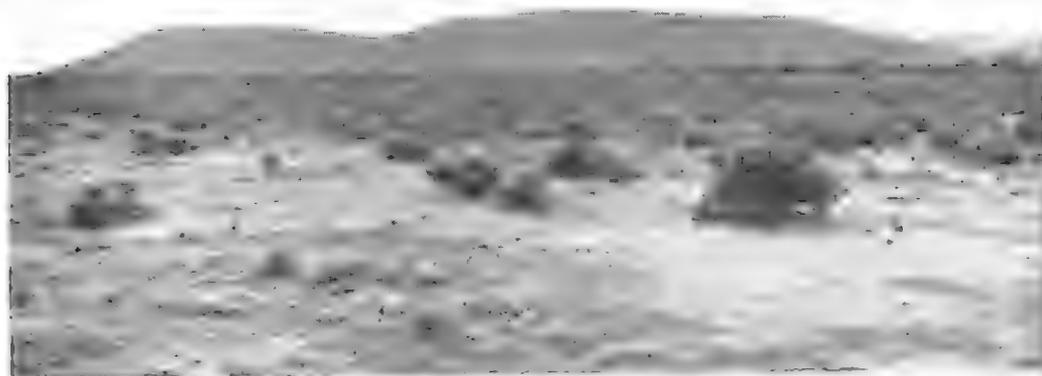


Fig. 1

View of the Lincoln Gap Range from the main highway to the west of Port Augusta. This is a formation of but slightly inclined quartzites and some pebble beds. It represents an overlap of the basal formation of the Adelaide Series onto the shield mass of Yilgarnia.



Fig. 2

The western scarp face of the Emeroo Range as viewed from the Port Augusta—Lake Torrens sunkland. The entire range is constituted of steeply dipping beds of the redaceous and arenaceous basal formation of the Adelaide Series and represents depositions along the western margin of the Proterozoic geosyncline.

THE GEOLOGY OF THE JAMESTOWN DISTRICT, SOUTH AUSTRALIA

BY T. LANGFORD-SMITH

Summary

The survey includes an area of over a hundred square miles in the Jamestown district. The beds consist of Proterozoic sediments, which have been folded into synclines and anticlines with north-south axes. Jamestown is situated in an anticline which has been differentially eroded to produce a series of parallel ridges and valleys, while to the east of the town is a broad synclinal valley.

THE GEOLOGY OF THE JAMESTOWN DISTRICT, SOUTH AUSTRALIA

By T. LANGFORD-SMITH *

[Read 9 October 1947]

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SUMMARY

The survey includes an area of over a hundred square miles in the Jamestown district.

The beds consist of Proterozoic sediments, which have been folded into synclines and anticlines with north-south axes. Jamestown is situated in an anticline which has been differentially eroded to produce a series of parallel ridges and valleys, while to the east of the town is a broad synclinal valley.

There is a fair degree of correlation between the sediments in the vicinity of Jamestown district and the Precambrian beds in the Adelaide district, the vertical range including the beds between the Upper Phyllites and the Brighton Limestones of Howchin's classification. There are also very marked correlations between the Jamestown beds and the Precambrian at Appila Gorge and Orroroo.

The *sediments below the glacial beds* are about 13,700 feet in thickness. They include phyllites, slates, hornfels, shales, quartzites, dolomites and dolomitic limestones. A feature of this group is the large number of thin bands of dolomitic limestone. Phyllites and slates dominate the lower portions. In the central section is a bed of arkose sandstone and quartzite about 200 feet thick. Above the latter are more slates and phyllites, and also two distinctive beds of quartzite, the upper of which underlies the glacial beds. These beds of quartzite outcrop very prominently in the highest points of the Campbell Range, and its northern continuation through Mount Lock.

The *glacial beds* are noted for their great thickness (3,000 feet). They include a variety of tillite and fluvio-glacial sediments. Erratics are numerous.

Above the glacial beds is a transitional zone (300 feet) of fluvio-glacial sediments, banded slates, and thin bed of limestone. Above this occur about 10,000 feet of shales and slates with the typical Tapley Hill ribbon banding, which in turn are overlain by a series of banded siliceous limestones.

INTRODUCTION

The field work of the following paper was carried out in 1941 and 1942, while the writer was a member of the Council for Scientific and Industrial Research party engaged on a Soil, Soil Erosion and Land Use Survey of County Victoria (fig. 1). It is the first of a series of papers dealing with various aspects of the Geology and Geography of the County Victoria area, publication of which was delayed on account of the war.

* Department of Post-War Reconstruction, Canberra, A.C.T.

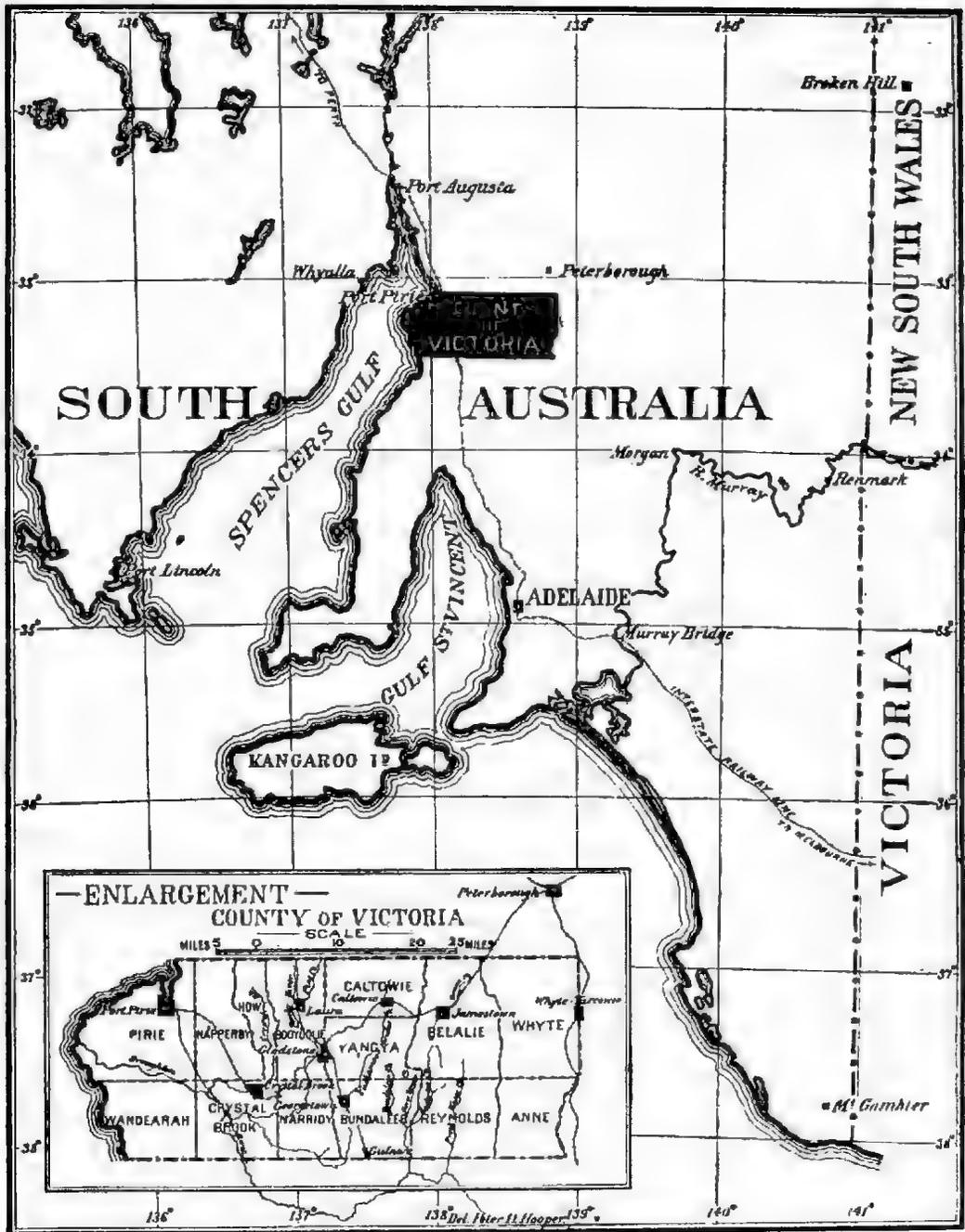


Fig. 1

GEOLOGICAL SUCCESSION OF PROTEROZOIC SEDIMENTS IN THE VICINITY OF JAMESTOWN, SOUTH AUSTRALIA

(SHOWING PROBABLE CORRELATION WITH HOWCHINS CLASSIFICATION OF THE ADELAIDE SERIES)

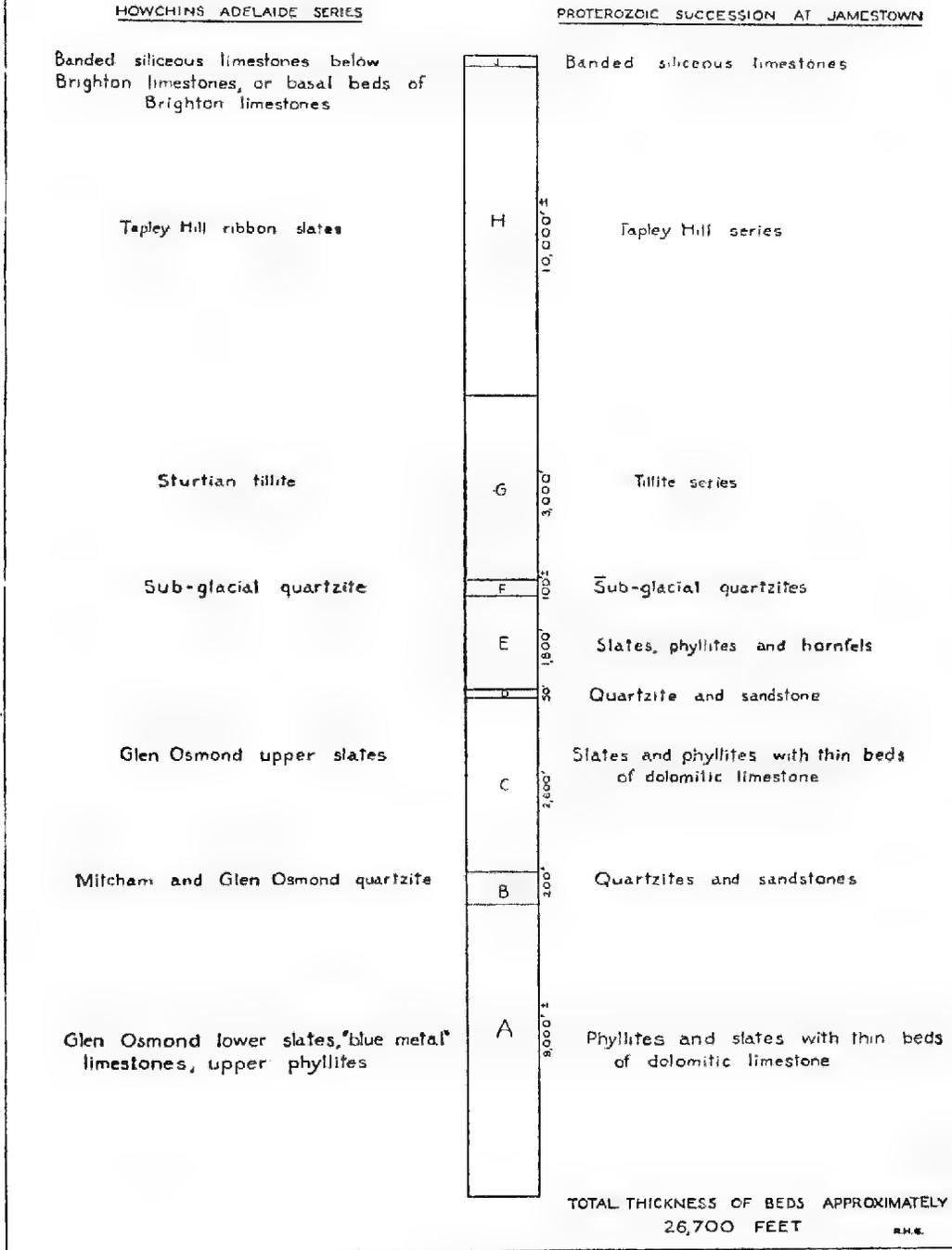


Fig. 2

In the neighbourhood of Jamestown very little geological work has been attempted in the past. Investigations have been carried out by Howchin and Segnit in the Appila Gorge near Tarcowie, by Howchin in the Orroroo district, and by Hossfeld in the North Mount Lofty Ranges. The detailed stratigraphy of the immediate vicinity of Jamestown has been neglected. No doubt this has been due largely to the scarcity of surface outcrops in this district.

In 1941 the complete coverage of the district by air photographs of a scale 4 inches to 1 mile made a new approach possible, as small, obscure outcrops were clearly shown in numerous localities. Apart from natural rocky gullies, soil erosion gullies of recent occurrence proved of great assistance, as they frequently exposed the bed-rock for long distances. Scattered through the ploughed fields, numerous low rocky outcrops which otherwise would have been most difficult to detect were revealed by the photographs. Not only were the photographs invaluable in the detection of outcrops, but also in later mapping work. Outcropping series could be accurately traced for miles with great facility.

In general, the region consists of parallel alternating ridges and valleys, running in an approximate north-south direction. The area covered by the survey is folded into a syncline to the east, and an anticline to the west. The syncline conforms in topography to a broad, gently sloping valley, while the anticline (on which Jamestown is situated) has been differentially eroded to form an alternating series of ridges and valleys.

As a result of the investigations, it is now evident that many of the beds in the vicinity of Jamestown are largely analogous to beds in the Adelaide district described by Howchin and others. The vertical range appears to correspond to Precambrian beds of the Adelaide district between the Upper Phyllites and the Brighton Limestones (fig. 2).

Sections were run eastwards from the tillite-containing ridge directly south of Mount Lock in the Hundred of Caltowie, to the tillite-containing ridge of the Browne Hill Range in the western part of the Hundred of Whyte, a distance of about 10 miles. These sections are shown on the accompanying plan and in fig. 3 by the lines PQ and RS. PQ runs in an easterly direction six miles north of Jamestown, and RS continues the section along a path running almost due east of the town.

Considerable work was carried out both north and south of the section lines, and eventually an area of over a hundred square miles was surveyed and mapped in detail. The findings of the survey are presented in the following text, with accompanying sections, maps and photographs.

DETAILS OF STRATIGRAPHY

SERIES "A"

PHYLLITES AND SLATES WITH THIN BEDS OF DOLOMITIC LIMESTONE

This series is in the form of a large eroded anticline which has been produced by folding through a north-south axis (see section "PQ"). It is bounded to both east and west by quartzite and sandstone ridges ("E" and "B1"). In the few exposures where the junction between the series "A" and "B and B1" could be observed, the rocks of "A" were contorted, and it was not possible to determine whether there was any unconformity. From the general trend of the dips, however, it was apparent that if an unconformity did exist, it was not particularly marked.

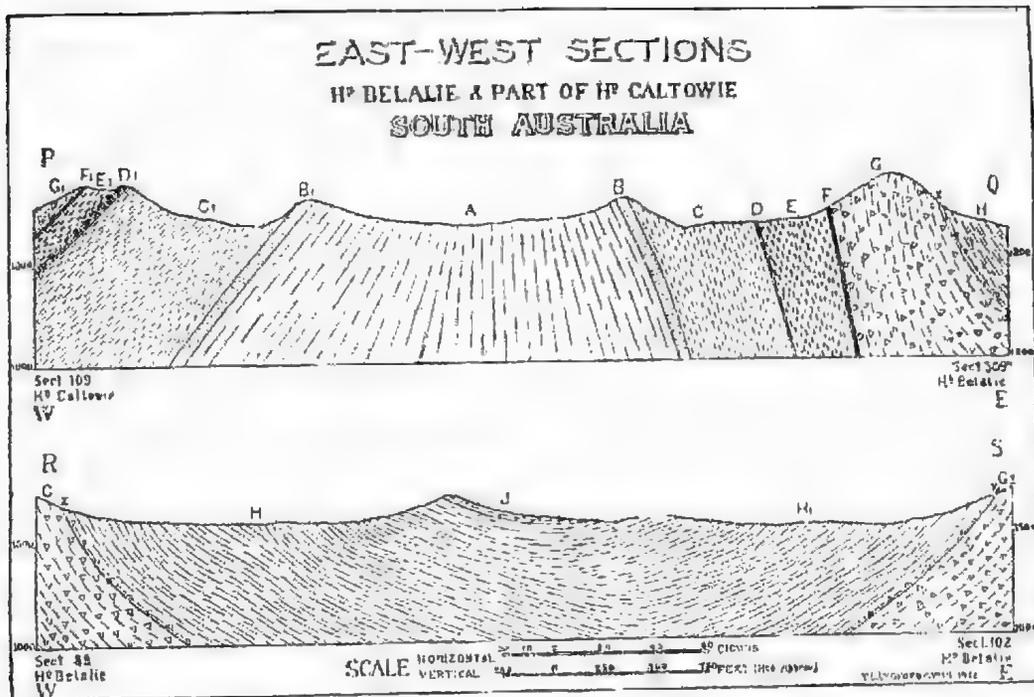


Fig. 3

Dips were measured at numerous localities through series "A". They varied from about 45° W. near "B1" through the vertical to about 70° E. near "B". Except for some slight local variation due to minor folding the gradation in dips through the range of angles given was comparatively regular.

The width of outcrop of the beds of this series ranges from 4,000 feet in Sections 140 and 139, Hundred of Belalie, to 9,300 feet one mile north of the Belalie - Mannanarie Hundred line. Compression has badly crushed and folded the former region, and the areas further south near Jamestown are almost completely covered by soil; thus detailed investigation was restricted to the northern areas towards Mount Lock. Here the true thickness of the beds is approximately 5,000 feet.

The rocks of the series are highly metamorphosed. Phyllites easily dominate the group, but slates, some of which are arenaceous, are fairly well represented. Pyrites crystals in the form of little cubes are quite commonly found in both these types; they frequently show decomposition to limonite, and often cubes of limonite occur as pseudomorphs. Both phyllites and slates, when fresh, are characteristically grey to blue-grey, but show a great variety of colours when weathered. Shades of yellow and red as a result of iron-oxide staining are common.

A few thin bands of quartzite impregnated with quartz veins were found in parts, but this was not typical of the series.

A number of very thin beds of dolomite and dolomitic limestone occur through the series. These are well exposed along the road to the west of Sections 156 and 157, Hundred of Belalie, where they dip nearly vertically. A sample of these dolomitic limestones was subjected to a rough quantitative analysis, the assumption being made that calcium and magnesium would be almost entirely

in the form of carbonates, and iron and alumina of sesqui-oxides. The following figures were obtained:

SiO ₂	-	-	-	-	24%
CaCO ₃	-	-	-	-	45%
MgCO ₃	-	-	-	-	20%
Fe ₂ O ₃ + Al ₂ O ₃	-	-	-	-	6%
					95%

Howchin (1) described as "Glen Osmond Lower Slates" beds in the Orroroo district which closely resemble the series "A". He found calcareous zones in these slates, which he believed represented the Blue Metal Limestones of the Adelaide district.

Mawson (2) has compiled a detailed description of Middle Proterozoic beds underlying the tillite in the Copley district. He found a large amount of dolomite in these beds, which appears very similar to that in the series "A".

Hossfeld (3), in his surveys of the North Mount Lofty Ranges, defined two distinct series, the Para (older Adelaide) and Narcoota (younger Adelaide), which were separated by an unconformity. He assumed that the basal beds of the Narcoota Series were contemporaneous with Howchin's Mitcham and Glen Osmond Quartzites (4). There is little doubt that the quartzites "B" and "B1" in the Jamestown district are contemporaneous with the Mitcham and Glen Osmond Quartzites, and it would therefore appear that they are representative of Hossfeld's basal Narcoota beds. Although there is no proof of unconformity between beds "A", "B", and "B1", it is considered that the series "A" must represent the upper beds of the Para series.

Summing up, it is most probable that the series "A" is contemporaneous on the one hand with Howchin's Upper Phyllites, Blue Metal Limestones, and Glen Osmond Lower Slates of the Adelaide district, and on the other with Hossfeld's Para series in the North Mount Lofty Ranges. It also appears similar to Middle Proterozoic beds described by Mawson at Copley, and by Howchin at Orroroo.

SERIES "B" AND "B1" QUARTZITES AND SANDSTONES

"B" and "B1" are respectively the easterly and westerly outcrops of an anticlinal fold.

THE EASTERN OUTCROP ("B")

The beds of "B" are exposed in the ridge which strikes roughly north and south through the central portions of the Hundred of Belalie. The direction of strike passes through Jamestown, although no outcrop is visible in the town itself.

Proceeding from the town in a northerly direction, the series is first exposed in a low ridge immediately west of the railway crossing, where it has been quarried. The ridge rises gently for about 3½ miles, and then falls again, and finally dips out of sight in Section 8S, Hundred of Mannanarie, approximately 8 miles north of Jamestown.

Half a mile south of Jamestown there is a small outcrop in the form of a low hummock a quarter of a mile in length, where the rock has been quarried for road metal. A mile further south it outcrops in Section 75, Hundred of Belalie, and forms a gently rising ridge which continues in a southerly direction for several miles.

The rocks of "B" are highly felspathic, the felspar in most cases showing an advanced state of decomposition, which gives the rock a very distinctive speckled appearance. In many instances the kaolin has been weathered away, leaving numerous small cavities between the silica grains, which causes the rock to crumble easily. Textural gradations within the series range from fine-grained sandstones and quartzites to grits. Sandstone is dominant, but siliceous quartzites do occur. Quartz veins are common throughout the series. When these veins were found in the sandstone it was noted that they had not affected the impregnated rock, indicating the intrusion of cold siliceous solution. Well-defined ripple marks are a feature of the series, implying shallow water deposition.

At a distance of $4\frac{1}{2}$ miles north of Jamestown there has been some strike faulting, resulting in repeating outcrops of the beds for a short distance. This faulting has been caused by the same pressure which was responsible for the faulted zone to the west (see plan).

The true thickness of "B" ranges from 150 to 250 feet, and the beds dip to the east at 65° to 72° . There is no evidence of unconformity between "B" and the overlying shales and slates of "C".

THE WESTERN OUTCROP (B1)

"B1" outcrops in a high ridge half a mile east of Mount Lock (see plan) running almost due north and south of this point.

To the north, this ridge was followed as far as the Mannanarie-Tarcowie road, and from here it was seen to be continuing in a northerly direction.

To the south the ridge was traced to Section 140, Hundred of Belalie. From here to Section 41, Hundred of Caltowie, there has been a great deal of faulting and shattering. From the latter point the series again outcrops in a ridge, and this was followed for five miles to the south, into the heart of the Bundaleer Forest. There has been much faulting in this area, and this has resulted in the repeated surface outcropping of "B1". Close to the eastern margin of one of these outcrops, located in the forest just west of Section 287, Hundred of Belalie, is a bed of crystalline limestone, composed of large calcite crystals. This bed was followed for some miles to the south, and was found to be the same as that mentioned by Lockhart Jack (5) in connection with the occurrence of rock phosphate in the Hundred of Reynolds.

The beds of "B1" are almost identical in rock type to those of "B", although they are generally more highly metamorphosed. Near Mount Lock the rock in general is a fine-grained, highly siliceous, and extremely brittle quartzite. It is often arkose, although some of the more highly silicified types do not appear to contain any appreciable felspar or kaolin. Very small pyrites crystals were observed in one specimen.

Howchin (*loc. cit.*) has described some quartzite beds near Mucra Hill as Glen Osmond Quartzites. Since Mucra Hill is only 10 miles north of the outcrop of "B1" on the Mannanarie-Tarcowie road, and also since "B1" could be seen continuing in the form of a ridge for some distance to the north, it is probable that the outcrop near Mucra Hill is a continuation of "B1". In any case, there is little doubt that "B" and "B1" represent the Mitcham and Glen Osmond quartzite of the Adelaide district. They would thus also be representative of the basal beds of Hossfeld's Narcoota series.

SERIES "C" AND "C1"

SLATES AND PHYLLITES WITH SOME SHALES AND HORNFELS, AND THIN BEDS OF DOLOMITIC LIMESTONE

The beds "C" and "C1" overlie "B" and "B1", and are conformable to them.

This was clearly shown in Section 137, Hundred of Belalie, and in areas near Mount Lock.

THE EASTERN OUTCROP (C)

The beds consist mainly of grey to dark blue-grey slates and phyllites, with some shales and grey hornfels. The slates are mostly thinly laminated, although there are a few instances of strong banding. Much of the rock is weathered on the surface to a soft, yellow-brown slate which shows the bedding planes very clearly. Cleavage planes are strongly developed and the cleavage angle is fairly consistent at about 65° to the west. The true dip of the beds ranges from 65° east near "B" to 75° east at "D". The average thickness is about 2,600 feet.

THE WESTERN OUTCROP ("C1")

The rock types of "C1" are very similar to those of "C". The slates in parts are arenaceous, and there are a few thin bands of sandstone and quartzite, which sometimes occur as small lenses. There are also a number of very thin beds of dolomitic limestone. These outcrop in the eastern part of "C1" in the Mount Lock area, in the bed of a small creek in Section 150, Hundred of Belalie, and on the road between Sections 120, 116E, and 117, Hundred of Belalie. Several bands of very similar rock were found at the northern corner of the Bundaleer Forest Reserve. Analysis of a sample from Section 150, Hundred of Belalie, yielded the following results:

SiO ₂	-	-	-	-	37.9%
CaCO ₃	-	-	-	-	48.0%
MgCO ₃	-	-	-	-	21.0%
Al ₂ O ₃ + Fe ₂ O ₃	-	-	-	-	3.0%
					109.9%

This analysis was conducted on the same basis as that of the dolomitic limestone in "A".

There is evidence of some minor folding and faulting in the beds of "C1" just east of Mount Lock peak, and it is evident from the accompanying geological plan that there has been considerable pressure in this area. It is consequently difficult to measure the true thickness of the beds. On the line PQ (see plan) the thickness is approximately 3,500 to 4,000 feet.

The beds of "C" and "C1" appear to represent the lower portion of the Glen Osmond Upper Slates in the Adelaide district. With the exception of the dolomitic limestones, they also appear analogous with the lower members of beds in the Orroroo district described by Howchin (*loc. cit.*) as Glen Osmond Upper Slates.

SERIES "D" AND "D1" QUARTZITES AND SANDSTONES

THE EASTERN OUTCROP ("D")

This is a prominent bed of quartzite and sandstone, which, however, has an average thickness of only 18 feet. The rock is fine-grained, and is white to yellowish-brown in colour when fresh. When found as a quartzite it is sometimes very compact and brittle. The bed is impregnated with numerous quartz veins.

Outcrops occur as a series of small hummocks. These were traced from Section 120, Hundred of Belalie, in a northerly direction, as far as Section 325. The dip was found to be fairly constant at 75° to the east.

A small quarry in Section 135, Hundred of Belalie, shows that beds "C" and "E", on either side, are conformable to "D".

THE WESTERN OUTCROP ("D1")

The beds of "D1" comprise the peak of Mount Lock. Together with the sub-glacial quartzites "F1", they constitute most of the highest parts of the range containing Mount Lock. They also constitute the highest parts of the Campbell Range on the western margin of the Bundaleer Forest, the latter range being the southern continuation of that containing Mount Lock. Both "D1" and the sub-glacial quartzites "F1" form the backbone of the two parallel ridges which are a very prominent feature of these ranges for many miles, to both north and south of the Jamestown area.

The thickness of "D1" is very difficult to measure on account of the large amount of rock talus on either side. At Mount Lock the thickness is between 45 and 90 feet, and the dip 45° to 48° to the west. The beds "C1" and "E1" on either side appear to be conformable. The rock is very similar to that in "D", except that it is more highly metamorphosed. Most of the quartzite is dense, siliceous, and very brittle, and contains quartz veins. It is extensively fractured.

The quartzite "D1" has its counterpart in the Appila Gorge, some miles north of the Jamestown area. In fact, comparison between the outcrops in both places showed that the whole sequence of beds immediately below the tillite corresponded very closely. Segnit (6), from his observations in the Appila Gorge, concluded that a large part of the Middle Precambrian formations are missing, and have either been faulted out by strike faulting, or removed before the deposition of the tillite. If this be so, then the great similarity of the sequence in the Jamestown area infers that here also the Middle Precambrian beds must be missing. However, it seems to the writer most improbable that strike faulting should have occurred in exactly the same manner and position in these two localities. Also, if the missing formations had been removed by erosion, then an identical amount of erosion must have occurred at both places, which seems very unlikely. It is not considered, therefore, that there has been any large-scale removal of beds, either here or at Appila.

SERIES "E" AND "E1"

SLATES, PHYLLITES, AND HORNFELS

With the exception of the dolomitic limestones found in "C1", the beds of "E" and "E1" are identical with those of "C" and "C1", consisting of slates and phyllites with some hornfels and shales. The slates, in parts, are arenaceous.

The beds of "E" are 1,800 feet thick, and dip at angles ranging from 70° to 81° to the east.

There is great variation in the apparent thickness of "E1", as these beds have, in parts, been subjected to intense pressure. Near Mount Lock the thickness is about 600 feet. There has been considerable compression due to folding in the neighbourhood of Section 44, Hundred of Caltowie, while about 7 miles south of this point, in the Bundaleer Forest, the thickness increases to about 1,000 feet.

Near Mount Lock the dip is west at about 47°. The beds are conformable with those above and below ("D1" and "F1").

SERIES "F" AND "F1"

SUB-GLACIAL QUARTZITES

THE EASTERN OUTCROP ("F")

The sub-glacial quartzite "F" which underlies the tillite in the central parts of the Hundred of Relalie, is not a prominent physiographic feature, as is com-

monly the case elsewhere. It outcrops on the lower western slopes of the tillite-containing ridge "C". In some areas it is almost entirely obscured by talus and soil, and as even the best exposures are not complete it was impossible to secure much detail.

The total thickness of "F" is about 100 feet, but it was not possible to determine whether the whole of this was quartzite. Surface material indicated that there are intercalated beds of shales and slates. The dip of "F" was difficult to measure accurately, but it is approximately the same (81° E) as the underlying shales and slates of "E". There is no apparent unconformity between "F" and the overlying tillite "G".

The quartzite is characteristically brown in colour. It is fairly compact and is moderately felspathic.

THE WESTERN OUTCROP ("F1")

The sub-glacial quartzites "F1" are in two major beds, separated by beds of shales and slates, amongst which is a little tillite. There is no tillite at all below the lower quartzite.

In the Mount Lock area each of the quartzite beds is between 20 and 40 feet in thickness, and the shales, slates, and tillites in between amount to about 130 feet.

The only outcrop which provides a clear section through the series is about 7 miles north of Mount Lock, in the gorge through which runs the Mannanarie-Tarcowie road. The lower quartzite here is a massive bed 100 feet in thickness, while the upper bed is only 20 feet thick. Between the quartzite is 170 feet of shales and slates, which do not contain any tillite. The tillite commences abruptly above the upper quartzite, without any apparent unconformity. No unconformity could be detected between the lower quartzite and the beds underlying it ("E1"). The Appila Gorge is only 6 miles due west of these outcrops, and the relationships between the exposures in the two localities are very close. At Appila the tillite commences very abruptly, resting on a bed of quartzite 50 feet thick. Under this quartzite is about 15 feet of shales, and then another bed of quartzite 40 feet thick. It is notable that neither at Appila nor on the Mannanarie-Tarcowie road is there any tillite between the two beds of quartzite, although a little tillite is present in the Mount Lock region in association with the shales and slates.

As previously noted, the sub-glacial quartzites "F1" and the quartzites "D" form the central axis of the mountain range running north through Mount Lock, and continuing to the south as the Campbell Range on the western margin of Bundaleer Forest.

In Sections 325 and 327, Hundred of Yangya, near the Bundaleer Forest, the sub-glacial quartzites and adjacent series have been displaced by a considerable dip fault, the horizontal displacement being about 2,400 feet.

SERIES "G," "G1," AND "G2"

TILLITE

THE CENTRAL OUTCROP ("G")

This tillite outcrop forms quite a prominent ridge running north and south through the centre of the Hundred of Belalie. Except for the gorge near Jamestown, through which runs the Belalie Creek, the ridge constitutes a stream divide for many miles. The average height of the ridge above the surrounding country is about 200 feet.

The most useful section through "G", or in fact through any of the tillite in the district, occurs in a small creek gorge running through the northern part of Section 303 and the southern part of Section 160, Hundred of Belalie, about 6 miles N.N.E. of Jamestown. The gorge has been formed by the headward

**VERTICAL SECTION
TILLITE SERIES "G" IN SECTIONS 303 & 160, HUNDRED OF BELALIE
TOTAL THICKNESS OF BEDS 3,000 FEET (APPROX).**

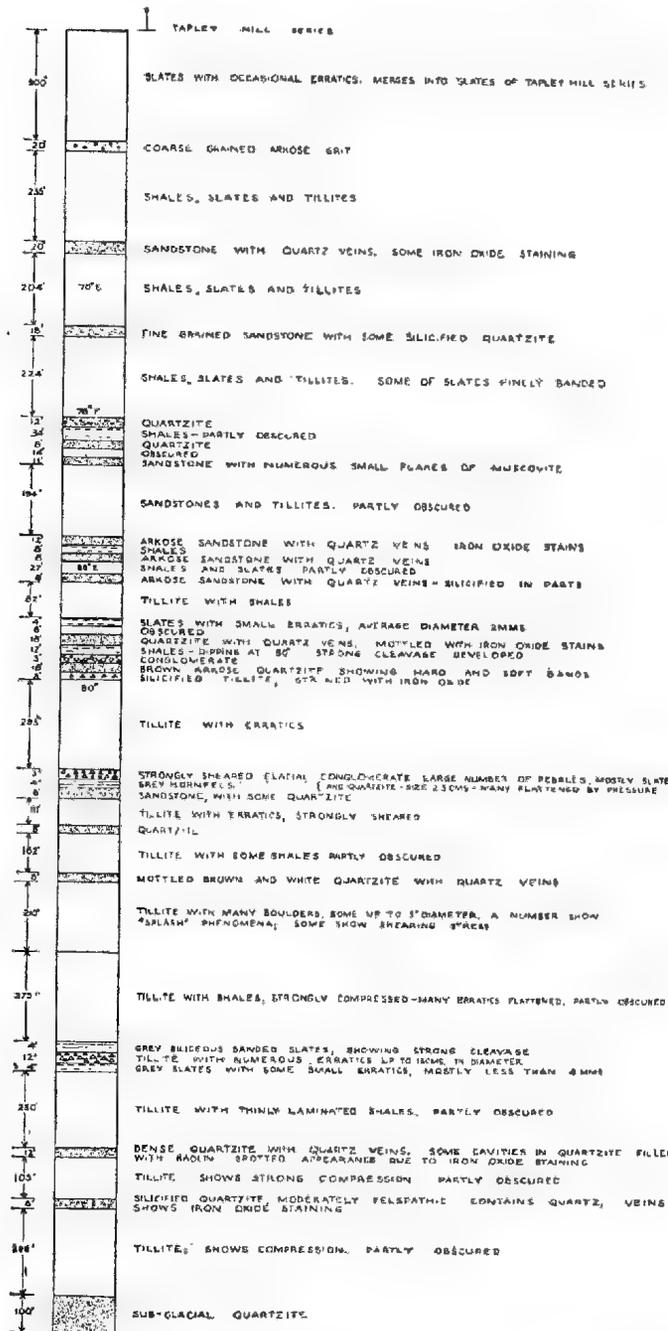


Fig. 4

erosion of a stream following the line of a slight dip fault which has caused a horizontal displacement of about 50 feet.

It was found that when continuous exposures of the series could not be obtained from the sides and bed of the creek, the missing beds could very often be found outcropping in the hillside above. Thus by the correlation of a number of small sections in the gorge, one almost continuous section was built up showing great detail. The main features of this section are illustrated in the accompanying diagram (fig. 4).

There is no evidence of major strike faulting in the series, and the details of the section are such that if repetition of beds were present, it would almost certainly be revealed. There is little doubt that the measured section represents a continuous sequence.

The most notable feature of the series is the great thickness of the tillite, which amounts to approximately 3,000 feet. As far as the writer is aware, this occurrence in the Jamestown district is the thickest Sturtian tillite formation yet recorded. It is considerably greater than that recorded by Segnit (*loc. cit.*) in the Appila Gorge (1,680 feet). A recent summing up by Sprigg (7) of work in the Mount Lofty Ranges indicates that the greatest measured thickness of tillite there is about 1,200 feet.

The tillite series is underlain by the sub-glacial quartzites "F" (which have already been described), the tillite commencing very abruptly above the quartzite. Although unconformity has been recorded between the tillite and sub-glacial quartzite from other parts of the State, there is no evidence of this in the Jamestown district. Unlike the base of the series, there is no abrupt upper limit to the tillite. A prominent feature of the upper part of the series is a bed of very coarse arkose grit. It has a most distinctive appearance and proved most useful as an index bed when examining the tillite outcrop "G2" on the eastern margin of the syncline, in the Brown Hill Range. Above this arkose grit the glacial and fluvio-glacial beds gradually grade into those of the Tapley Hill series, the rocks of the latter series exhibiting their characteristic form from 250 to 300 feet above the grit. The transitional beds are described in greater detail in the following section, "H". The fact that no sudden break is evident at the close of the glacial period would indicate that conditions gradually became warmer, introducing a period when fluvio-glacial deposition was dominant. Evidence from the Jamestown area lends further support to the hypothesis that the Tapley Hill beds have a varve-like origin.

There is less pure tillite in the upper than in the central and lower parts of the tillite formations. Fluvio-glacial shales and slates are dominant, and in many sections the only direct evidence of glacial conditions is the occasional presence of erratics. Although the central and lower horizons have a much higher proportion of pure tillite, even here intercalated beds of sandstones, quartzites, shales, and slates are very numerous.

Erratics are particularly numerous in parts of the series, and in some instances range up to 3 feet in diameter. The erratics represent many rock types, although quartz, quartzite, slate, schist, granite, pegmatite, gneiss, and porphyry predominate.

The beds dip vertically in the central parts of the Series "G", and at a steep angle to the east in both upper and lower parts. There are signs of compression throughout the series, and some shearing stress is evident in parts. Cleavage planes are strongly developed, and these have a fairly constant dip of about 65° to the west throughout.

THE WESTERN OUTCROP ("G1")

The tillite "G1" outcrops in the western fold of the anticline. It is found above the sub-glacial quartzites "F1" in the central and western parts of the Campbell Range, and the northerly extension of this which runs through Mount Lock. No complete sections could be obtained from these areas, but examination of the basal beds of the series revealed the same characteristics as those of "G", which have already been described.

Isolated outcrops of the tillite in its upper horizons showed that the angle of dip becomes progressively smaller to the west, until the series grades into the Tapley Hill series in the broad valley in which lies the township of Caltowie. Structurally, this valley is a syncline, contrary to the neighbouring Jamestown valley, which is an eroded anticline. On the western margin of the Caltowie syncline the Tapley Hill series and tillite once again outcrops in a ridge which is the southern continuation of the Narrien Range. The latter contains the Appila Gorge, to which reference has already been made in discussing Series "G" and "F".

THE EASTERN OUTCROP ("G2")

The arkose grit in the upper part of the tillite series "G" proved a useful indicator when working on "G2", where it is a distinctive bed 45 feet thick. "G2" outcrops as the eastern fold of the syncline, in the Browne Hill Range—known locally as the "Caltowie Belt."

The tillite was traced to the north as far as Section 469, Hundred of Whyte. In this part of the range faulting and folding is very prevalent, and there are numerous intrusions of quartz veins. Frequently associated with the quartz is a siliceous iron ore. To the south, it was noted that the tillite continues for a number of miles south of the Hundred of Belalie.

The Jamestown-Terowie road follows a valley through the tillite in the vicinity of Section 202, Hundred of Belalie. This valley is the result of stream erosion in the zone of weakness following a small transverse fault.

SERIES "H" AND "H1"

TAPLEY HILL SILICES AND SLATES

The beds composing this series are folded into a broad syncline with a north-south axis. This syncline extends from the tillite-containing ridge "G" east of Jamestown, to the tillite-containing Browne Hill Range "G2", and has an approximate width of 5 miles. The syncline is responsible for the presence of a wide valley, which becomes broader and more clearly defined in a southerly direction towards Spalding. In the latter area the valley has a comparatively flat floor, but proceeding north it is broken with increasing frequency by small rounded hills and ridges. These reach their maximum development in the North Belalie district, where the valley floor is almost completely replaced by a series of alternating rises and depressions. The hilly parts are covered by a relatively shallow grey residual soil (Yangya silty loam) in contrast to the deeper red-brown colluvial soils (Belalie Series) found in the depressions and on the valley floor.

On account of the persistent soil covering on the beds of this series, it was only after detailed investigation that a satisfactory number of outcrops showing dips could be found. In general the rocks have well-developed cleavage planes, with an angle of 50° to 80° to the west, and these are frequently more clearly defined than the bedding planes. Towards the Browne Hill Range the cleavage and bedding planes are largely coincident, and this has produced some very fine flagstones.

It has already been noted in the discussion on the tillite series that the upper horizons of glacial beds gradually merge into beds of the Tapley Hill series. This transitional zone is about 300 feet in thickness, and consists largely of fluvio-glacial slates in which occasional erratics occur. The lowest beds, which can be safely assigned to the Tapley Hill series, are thinly laminated argillaceous shales and slates, which in parts show ribbon banding. Most of these rocks are non-calcareous, but interbedded here and there are very thin bands of dark blue-grey impure limestone. These limestone bands appear to be similar to limestones which overlie the tillites in many other parts of the State. The basal shales and slates were mostly weathered to a soft yellowish-brown rock, while in some cases slates were stained a deep purple. These basal beds of the series are similar in character on both sides of the syncline.

The basal beds gradually merge into the more typical ribbon slates, which dominate the series. However, occasionally the banding is not clearly defined, and in some instances the slates are replaced by grey siliceous hornfels.

The banded slates are very fine-grained. They closely resemble the Tapley Hill slates in the Mount Lofty Ranges near Adelaide, and in the Flinders Range further to the north. They are very similar to those described by Howchin (*loc. cit.*) at Orroroo.

The true thickness of the Tapley Hill series in the localities examined is from 10,000 to 11,000 feet.

SERIES "J"

BANDED SILICEOUS LIMESTONES

In their upper horizons the rocks of the Tapley Hill series ("H") merge into impure banded siliceous limestones. Although outcropping in parts of the north Belalie district, they are best exposed about four miles east of Jamestown in Sections 319 and 320, Hundred of Belalie, where they are seen in a low hill rising from the main valley floor.

The limestone has been used on a small scale for cement manufacture, and has been quarried in Section 319. The rock is fine-grained, very hard and compact, and is dark blue-grey in colour. Banding is shown clearly on weathered surfaces.

A representative sample of the limestones was analysed, using the assumption that calcium and magnesium would be present as carbonates, and iron and aluminium as sesqui-oxides. The following results were obtained:

SiO ₂	-	-	-	-	71.5%
CaCO ₃	-	-	-	-	16.2%
MgCO ₃	-	-	-	-	6.4%
Al ₂ O ₃ + Fe ₂ O ₃	-	-	-	-	7.2%
					101.3%

Although the rock is characteristically siliceous, the percentage of silica shown here is much higher than would be given by limestones from specially selected horizons. The sample chosen for analysis was reasonably representative of the whole outcrop. A significant feature is the low proportion of magnesium compared to that in the analyses of limestones from series below the tillites.

It is believed that these limestones, "J", may represent the siliceous limestones below the Brighton limestones at both Adelaide and Orroroo, or else the basal beds of the Brighton limestones themselves.

FAULTING AND FOLDING

The folding which has produced the alternating anticlines and synclines is typical of a very large part of the Mount Lofty and Flinders Ranges. In this particular region, the fact that the pressure was not completely uniform is shown by the arcuate form which the outcropping beds now exhibit (cf. plan).

There has been strike-faulting south-west of Jamestown, which has caused some repetition of beds in this sector. Repetition of part of the arkose sandstone and quartzite bed ("B") in the central part of the Hundred of Belalie has also been caused by strike-faulting. There is no evidence of strike-faulting along the lines of section ("PQ", "RS").

Although there has been a considerable amount of minor cross-faulting, there has been little on a major scale. The largest cross-fault has resulted in a displacement of nearly half a mile in the sub-glacial quartzites of the Campbell Range (cf. plan). Minor cross-faulting has been responsible for the development of zones of weakness in some of the beds, which has facilitated the down-cutting of streams.

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SUBMARINE CANYONS OF THE NEW GUINEA AND SOUTH AUSTRALIAN COASTS

BY REG. C. SPRIGG

Summary

During the course of the second World War, officers of the Hydrographic Survey Branch of the Royal Australian Navy discovered several huge gashes along the normal course of the continental platform of New Guinea in the Morobe area. These are submarine canyons. More recently, following an official request to the Navy on the writer's behalf, further examples have been located off the South Australian coast (fig. 1).

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By REG. C. SPRIGG *

[Read 9 October 1947]

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INTRODUCTION

During the course of the second World War, officers of the Hydrographic Survey Branch of the Royal Australian Navy discovered several huge gashes along the normal course of the continental platform of New Guinea in the Morobe area. These are submarine canyons. More recently, following an official request to the Navy on the writer's behalf, further examples have been located off the South Australian coast (fig. 1).

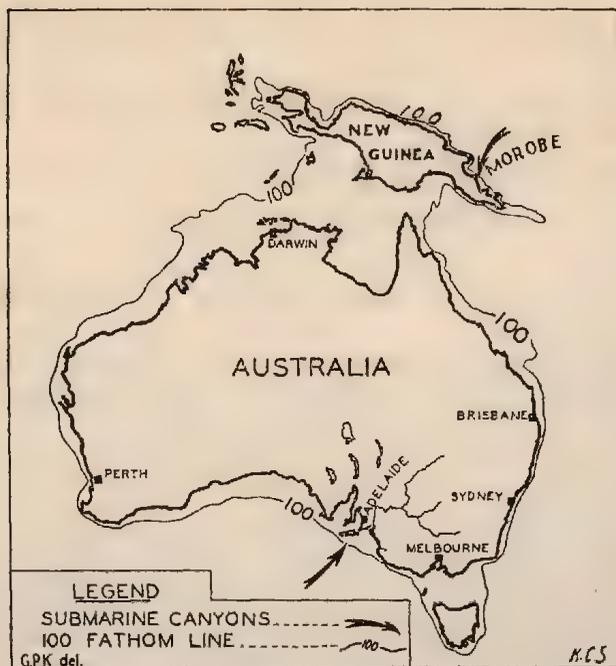


Fig. 1 Locality Plan

The New Guinea submarine valleys have been named respectively (from west to east), the Waria, Eia and Gira Canyons, after the rivers which enter the sea near their heads. The Murray examples are referred to as the west, central and east submarine canyons, and they occur south of the centre of Kangaroo Island. Their association with the River Murray at the time of development is inferred, but the case is not yet proved. It is hoped that more light will be thrown on this problem when several more echo-sounding traverses are completed in their vicinity later this year.

* Assistant Government Geologist, South Australian Geological Survey.

It is emphasised that, whereas the New Guinea examples have been covered extensively by sounding traverses aggregating several hundred miles in the immediate canyon vicinity, the South Australian examples are known only from a single traverse. This was designed by the writer to locate the 100 fathom line more accurately and to seek possible canyon structures which could be related to the River Murray.

GENERAL FEATURES OF SUBMARINE CANYONS

More than 100 submarine canyons are known from various parts of the world, and the list is steadily increasing. These structures have many features in common, *viz.*:—

1. Distribution is world wide.
2. The furrowing is obviously the work of running water.
3. Most of the erosion appears to have been in soft water-soaked sediments.
4. Many submarine canyons are obviously genetically related to adjacent rivers.
5. Their greatest development occurs at the "fall off" from the continental shelf.
6. By analogy with subaerial valleys, they are youthful features of the earth's topography.
7. General similarities of canyons suggest simultaneous formation.
8. They are definitely post-Pliocene features, as evidenced by youngest wall rock.

THEORIES TO ACCOUNT FOR SUBMARINE CANYON FORMATION

Numerous theories have been put forward in an endeavour to account for these interesting topographic phenomena. One school considers them to have been subaerially eroded, while another regards them as a result of submarine currents.

In this paper the main theories will be outlined very briefly, and particular attention will be paid to that theory concerned with sea bottom density currents, which is the one favoured by the writer. In making this latter statement, it is recognised that under special circumstances various processes may have interacted in canyon erosion. For example, where the canyon walls are steep submarine slumping of sediments would almost certainly take place, and these effects could be intensified by seismic activity, the net effect being increased erosion.

(a) REGIONAL UPLIFT OF THE LAND

This theory postulates world-wide continental uplift at the time of canyon formation to extents of 5,000 to 10,000 feet. This would expose the continental slope to powerful subaerial stream erosion. Such a theory has little, if any, factual basis. The earth's crust is almost certainly too stable to allow of such rapid and extensive land movement. Even supposing such movements could occur, it is considered very unlikely that the return to the present state could be accomplished without much relative warping along the strike of the continental platform, producing much greater irregularities of depth at the outer continental shelf margin than is apparent today.

(b) TEMPORARY EUSTATIC FALL OF SEA LEVEL

A geologically recent, world-wide lowering of the sea level of up to 10,000 feet, would perhaps account for the formation of the structures by subaerial erosion. However, the most extreme temporary sinking of ocean basin floors, superimposed on effects of glacial eustasy, would have to be involved, and, up to the present, there is no reliable evidence for such great vertical movements.

within recent times. Eustatic lowering of the sea level (Zeuner 1946) is estimated to account for a fall of only about 55 fathoms (330 feet or 100 metres) at the height of Pleistocene glaciation (by extracting water from the sea and tying it up in ice caps). Such a lowering of sea level will obviously explain the existence of many river channels across the shallow portions of the continental platform.

(c) CURRENTS OF THE OCEAN BOTTOM

There are several theories based on the above. Some are very ingenious, but they appear to be unsupported by fact. For example, Douglas Johnson (1939), suggested a special type of current called "spring sapping," which assumes that water from subaerial sources, under special circumstance, seeps into submarine (continental platform) sediments and escapes somewhere on the continental slope. The water is thought to issue with dissolving power and kinetic energy sufficient to erode canyons. Another theory by W. H. Bucher, 1940, postulates reflex currents generated by powerful earthquake waves in the ocean. However, as many of the largest canyons occur in areas least effected by earthquake shocks, this theory is of little importance.

The most satisfactory theory, at least to the author's mind, and one which is very strongly supported by field analogy and laboratory research, is one by R. A. Daly (1942), which is based on special types of bottom density currents in aqueous environments. The canyoning is considered to be brought about by gravitational muddy bottom currents temporarily endowed with a density greater than that of the normal water of the overlying medium. Daly suggests further that such muddy bottom currents were a feature of the Pleistocene glacial periods when the sea margin was closer to the fall off from the continental shelf, and when much of the earth's climate was decidedly more pluvial in character than today.

Studies in natural and artificial lakes (*e.g.*, Lake Geneva in Switzerland and Lake Mead Reservoir in U.S.A.) indicate that muddy suspensions of the type mentioned are by no means uncommon, and that their powers of erosion are considerable. They are capable of deep excavation, and they frequently move quite coarse gravels along the sloping lake bottoms.

Dr. P. H. Keunen, of Holland (1938), has shown by laboratory experiment that silt-laden bottom currents can erode and maintain themselves and become self-accelerating down slopes typical of the continental shelf. Keunen conducted his experiments in a large tank with bottom topography designed to represent a typical section across the continental shelf and continental slope. He found, on releasing muddy suspensions on the upper shelf area, that they gravitated down the continental slope, and that if a slight crease existed down such a slope, silt-laden water was pirated from either side, thickening the current along the crease and increasing its velocity. Moreover, if the bottom was covered by clay, the density current became turbulent beyond the continental shelf "fall off," causing the current to erode deeply and thereby adding to the current's density, mass and acceleration.

Knowing the slope factor and the density of the silty suspension, and by measuring the velocity and the so-called hydraulic mean depth of the current, Keunen arrived at an empirical formula which can be used to calculate the velocity of given suspensions down particular continental slopes.

Applying this formula, Daly has found that on a continental slope of 1 in 15, and with an effective density of the flowing water and silt mixture of 0.0005, the velocity is about 4 miles per hour. This would be sufficient to sweep along

coarse gravel and, therefore, to erode silt and sand with great ease. In this way, there is an effective means of submarine erosion available for canyon excavation under the right conditions.

LOW SEA LEVELS OF THE PLEISTOCENE AND POSSIBLE CANYON RELATIONSHIPS

According to the theory of glacial eustasy, the low sea levels of the Pleistocene were due to the extraction of water from the sea caused by accumulation of ice, particularly on sub-polar landmasses of the Northern Hemisphere. According to Zeuner (1946), and other authorities, the last glaciation reduced general sea level by about 100 metres below its present stand (the Pre-Flandrian Regression). The geographic consequences of these various changes in sea level, correlated with at least four glacial periods, must have been far-reaching. Coastline configurations must have changed greatly and rapidly, while rivers were at the same time alternatively befronked or engrafted. In addition, coastal features were at the same time drowned or stranded.

In the present case, our concern is with the lower stands of sea level, which resulted in coastal advance over considerable widths of the continental platforms of the world. Muddy river waters were now carried far across the continental platform and closer to the steeper slopes of the continental shelf before encountering the sea. At the same time, the related change of climate and relative altitudinal increases of the local landmasses would tend towards increased pluviality, at the same time swelling the volume of local rivers and consequently increasing their sedimentary load. In most situations the soft sediments of the partially exposed continental platform supplied further material for river transport, both by traction and in suspension. Ocean waves also had access to these sediments, extracting much material in suspension. The scene seems now to have been set for the operation of the most active canyon-forming processes.

The various muddy suspensions, and particularly those associated with rejuvenated rivers, provided the bottom density currents, which, according to Daly and others, in many cases were able to gravitate and maintain themselves across the narrowed shelf zone to the greater slope beyond the shelf edge. This, in turn, accelerated the suspension currents causing local canyon formation. In this way many furrows were produced on the shelf edge, but, particularly where muddy rivers entered the sea, deeper canyon structures were formed.

THE NEW GUINEA SUBMARINE CANYONS

The New Guinea submarine canyons are quite typical examples of submarine valleys which can be related very satisfactorily to local river mouths (fig. 2). They reach the large dimensions for which such structures are noted, and their courses lie fairly directly across the continental platforms.

They differ somewhat from the celebrated eastern United States examples in that their respective canyon heads approach within less than one mile or so of the modern coast. In their close relationship with river mouths, they are akin to the Congo type of submarine canyon (see Veatch and Smith, 1939).

Statistical details of the canyon structures are summarised in Table I. It is seen that lengths of the various canyons from their "heads" to the (projected) continental shelf edge vary from $7\frac{1}{2}$ to 10 miles and that separation of the "heads" from land is between 0.8 and 1.2 miles. This information, considered in the light of the local width of the continental platform (7 to 9 miles), indicates the relatively direct courses taken by the canyon beds. At the shelf edge the structures range in width between 2 and 4 miles and their respective beds lie from

4,500 to 4,800 feet below sea level in the same region (fig. 3). The canyon bottom gradients are relatively steep, averaging between 1 in 10 and 1 in 13 (i.e., 10.0 and 7.7%). Little is known of canyon development beyond the continental shelf edge, but the structures obviously continue strongly down the continental slope to abyssmal depths.

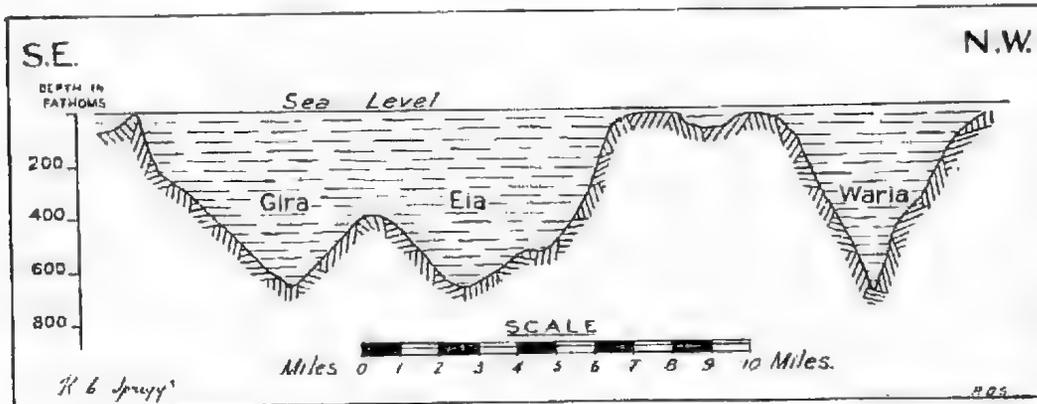


Fig. 3

Section through submarine canyons of the Morobe area, drawn along the projected continental shelf edge. The portions of the section remaining above 50 fathoms are barrier (coral) reefs.

Available information indicates that the sea bed and canyon walls generally are of soft volcanic mud, except in shoals where it is coral. The muddy sediments are excellent media for swift erosion and have certainly aided the rapid enlargement of the canyons, laterally and longitudinally.

The Eia submarine canyon differs from the other two in that its present head does not oppose the modern mouth of its parent river. The old river outlet is still to be observed opposite the canyon, but the new mouth is further westward and is not opposed by a secondary canyon.

In view of the close relationship with rivers entering the sea locally, statistics of the respective parent river development, namely trunk stream length and basin area, have been included in Table I. As the area is one of high rainfall (Eddie Creek and Kokoda average 107 and 143 inches per annum respectively), it is obvious that huge volumes of water are discharged into the local seas annually. The highest average monthly rainfall exceeds 16 inches, and probably during the Pleistocene glacial periods was much greater, giving some indication of possible erosive or transporting power of the local streams under most favourable conditions. Turbulent waters such as these, crossing an exposed sea bed of volcanic ash, would certainly become extremely well loaded with sediment, sufficient to form powerful density currents.

TABLE I
Submarine Canyon Statistics (New Guinea Group)

Name	Width of local continental shelf	Length of course across shelf	Width at edge of continental shelf edge	Submarine canyon depth at continental shelf edge	Average canyon bottom gradient	Proximity of 100 fathoms line to land at canyon head	Modern "Parent" Rivers Area of intake basin	Length of trunk stream
Eia -	7	8	4	4,500	1: 10.0	0.9	276	42
Gira -	7	7½	2	4,800	1: 9.6	1.2	425	54
Waria -	9	10	3 to 4	4,500	1: 12.7	0.8	1,520	96

CORAL REEF RELATIONSHIPS AND SEA LEVEL VARIATIONS

Massive coral reefs skirt the outer margin of the continental platform in the Morobe area. Between them and the shore line, small isolated coral colonies are common. The outer barrier is breached by the submarine canyons which are lined on either side by irregular but extensive coral reefs.

The outer reef base extends to at least 70 fathoms below present sea level, and as deep water lies between these corals and the land, they appear to be typical barrier reefs. Nothing is known of their present condition of growth, *i.e.*, whether their general sunken aspect is due to recent negative land or shelf movement, or whether the corals are dead and cannot therefore build up to the modern sea level.

According to Vaughan and Wells (1943) and Yonge (1940) reef corals will not flourish in depths exceeding 25-30 fathoms, the controlling factor here being light penetration. Under these controlling circumstances, reef corals could not therefore have established themselves on the outer margins of the continental shelf under the modern high sea level. As the shelf adjacent the reefs exceeds, on occasions, 70 fathoms, a lowering of the sea surface by 40 to 50 fathoms may be assumed for their establishment (unless equivalent land movements could be proved). This assumption is in keeping with figures for the Pleistocene pre-Flandrian regression,⁽¹⁾ and it therefore seems probable that the coral reef development commenced at this time or during an even earlier Pleistocene (glacial) low sea level.

Furthermore, on the assumption that the formation of all submarine canyons was contemporaneous (post-Pliocene), it can be inferred that barrier reef formation could not have pre-dated this period as such reefs would have dammed back and destroyed bottom density currents, and therefore prevented canyon excavation. This is in keeping with Gardiner's theory (1931, p. 115) that "there are no indications of any true reefs living or elevated before late Tertiary (Cenozoic) time." According to Daly's theory, discussed previously in this paper, the lowering of sea level (here considered necessary for the introduction of coral growths at the shelf edge) would also have been the most favourable for submarine canyoning, due to increased pluviality and to exposure of soft continental platform sediments. It seems reasonable, therefore, to assume that the formation of submarine canyons and the establishment of barrier reefs was contemporaneous.

Another condition for thriving coral growth is that the local water should not be muddy, as muddy conditions reduce light penetration, and smother the coral animal. If it is to be assumed that submarine canyon and reef establishment occurred during the low sea level phases of the Pleistocene, it would appear that muddy suspension currents from *coastal waves* as distinct from river action on exposed continental platform sediments, were insignificant in this area, at least for portion of the period of low sea level.⁽²⁾ If the former muddy currents had been widely developed during the shallow sea level stand, the shelf edge reefs

⁽¹⁾ The fall of sea level, which was contemporaneous with the Last Glaciation, probably attaining almost 100 metres (approximately 330 feet or 55 fathoms) below modern sea level.

⁽²⁾ Daly (1935) has suggested that during the earlier periods of the respective Pleistocene low sea levels, the muddy fractions of the outer continental shelf sediments were winnowed out to be deposited in deeper, quieter waters, leaving less muddy sediments in the littoral zone. This is logical, but it would suggest that canyon furrowing, if resulting purely from bottom density currents initiated by shore wave action, would be active only for short periods during the successive low sea levels. This surely would reduce their significance considerably.

could not have been established due to the muddiness of the bottom waters, even though other factors may have been favourable. It suggests, therefore, that the density currents responsible for most of the canyon excavation were initiated by silt-laden river waters entering the sea in confined zones. According to Keunen (see earlier), once significant channels are formed down submarine slopes, density currents become more restricted, and in this way adjacent stretches of shelf edge would remain free of silty suspension currents, thus allowing establishment of coral growths while depth and conditions were satisfactory. At the same time, it is obvious that coral growth within the course of the muddy density currents would be completely inhibited. Hence the presence of gaps in the barrier reefs at the point where the currents discharge across the outer edge of the continental shelf. These gaps would be subsequently widened by undermining and collapse in the normal course of canyon development. The two processes would also affect reefs skirting the margins of the canyons, but here there would be a tendency to restriction of lateral expansion and a steepening of the canyon walls.

It has been suggested previously that the low sea level stands, necessary for the establishment of coral reefs in such positions, were correlated with one or more Pleistocene glaciations, and, as reef corals do not flourish in waters below 20° Centigrade, a minimum temperature of this order seems probable. However, without detailed knowledge of reef sections, which may reveal horizons of repressed or completely inhibited coral growth, this can only be conjectured. Coral growth may have been destroyed locally, to be re-established only when the seas warmed again during subsequent interglacials. As the minimum average monthly temperature of the local coral seas appears to be at least 25° Centigrade, such a marked lowering of temperature is improbable.

From the foregoing discussion, it is obvious that the Antecedent Platform theory of the origin of coral reefs (Hoffmeister and Ladd, 1944), is applicable in this area if it is correct to infer that Pleistocene sea levels fell by as much as 40 to 50 fathoms. This theory states that any bench or bank that is located at a proper depth within the circum-equatorial coral reef zone is potentially a coral reef foundation.

In considering the survival of coral reefs in competition with the rising sea level at the onset of a severe interglacial, it is to be noted that Daly (1935) has calculated that the rate of rise probably never exceeded 3 mm. per annum. This figure is well within the range of reef upgrowth. Gardiner (1903) concluded from his experiments that normal upgrowth may be 27 to 45 metres per thousand years, and later studies have confirmed such phenomenal growth rates. As a corollary of this it would appear that modern coral reefs evolved to their present massive proportions only with the abnormally large (and relatively rapid) fluctuations of the Pleistocene sea level. Such fluctuations would alternatively reduce pre-existing reefs with falling sea level, and initiate new ones with the rising. The rapid sea level upgrade would facilitate maintenance of the prodigious food supply necessary for rapid and healthy reef upgrowth.

Speaking generally, there is no positive evidence from any part of the world that *new* submarine canyons are being formed under the present high sea level stand, but it is quite possible that some well-established canyons are still being extended, especially in areas where the canyon heads approach close to the shore and pluviality is relatively high—as in the Morobe area. In this case, two of the canyon heads (Gira and Waria) approach within less than a mile of their respective river mouths (although the local continental shelf is about 10 miles wide), thus providing very steep sea-bottom gradients for silty suspension currents. In the third instance, that of the Eia submarine canyon, the canyon head does not oppose the mouth of the modern Eia River, although an older outlet of the same

river obviously once did so. There is no evidence that the modern outlet is producing a new submarine valley, even though the 100 fathom line lies relatively close to the river mouth. This may suggest that either the shelf slope from the newer mouth, although relatively steep, is still insufficient to maintain bottom suspension currents over the distance, or that the amount of material in suspension, produced by Eia River waters, is now insufficient to produce significant density currents. There is the further possibility that well-established coral shoals which effectively block and destroy any gravity currents intervene at the edge of the local 100 fathom line. It may be that all three factors are operating simultaneously.

In the foregoing discussions little has been said of possible large vertical movement of the New Guinea land mass intensifying or diminishing Pleistocene variations in sea level. The fact that the outer continental platform is relatively constant at 60-70 fathoms below sea level suggests that the region has not moved vertically very much in relatively recent times. The outer depth figure shows fair correspondence with similar continental platform relationship elsewhere in the world, particularly in the coral seas. Nevertheless, this aspect is one which demands close field investigations, as there are reports of late Tertiary or Pleistocene coral reefs now raised many hundreds of feet above sea level in parts of New Guinea (see David 1932).

It is noticed that the continental platform is generally shallower to the south-east, and this may argue in favour of at least minor local warping movements in relatively recent times. This aspect may repay further investigation.

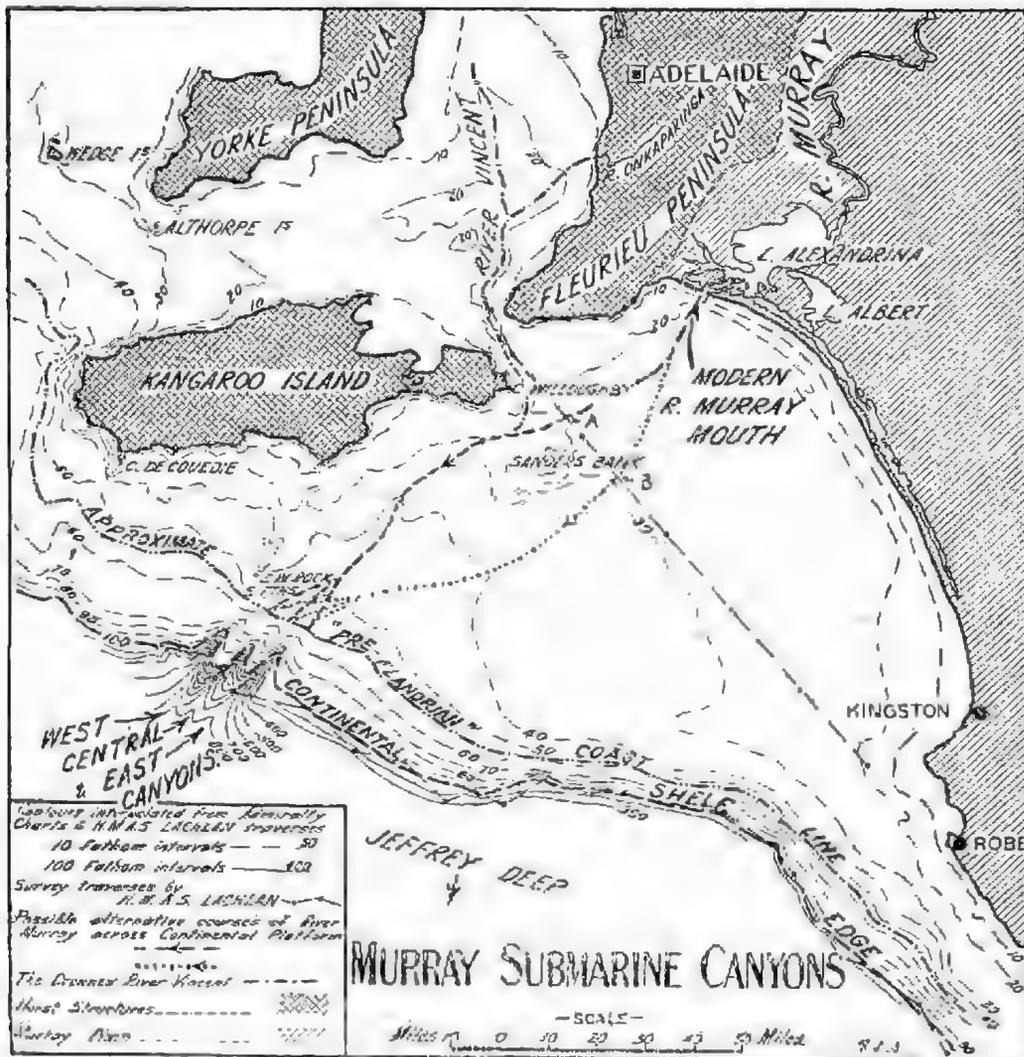
THE MURRAY SUBMARINE CANYONS

The present discoveries are the first to be found along the Australian coast. Original soundings in the canyon vicinity by the Admiralty were obviously very scattered, and even if odd very extreme soundings had been recorded at the canyon site, they would almost certainly have been disregarded in the preparation of sea-charts on the grounds that they might have been inaccurately located.

The little information at present available on the submarine canyons is limited to a single "continuous" echo-sounding traverse across them (fig. 4). The traverse was designed to follow the 100 fathom line, as this was considered to offer the best means of locating possible canyons. It ran from opposite the western end of Kangaroo Island to near Beachport, a distance of almost 180 miles. As a result of the survey, the platform edge has been found to be remarkably regular, broken by major structures in only one locality, approximately due south of the centre of Kangaroo Island. There is little or no doubt that these structures are submarine canyons, as the wall slopes reach at least 1 in 4.7 as against the continental slope hereabouts of 1 in 20 or less.

It is not yet proved that the canyons are genetically related to the River Murray, but there is good reason to assume such a relationship. The presence of three canyons closely spaced on the shelf edge, which otherwise is remarkably even, suggests that one process or one group of processes only has controlled canyon excavation, rather than that the process has been a fortuitous one. The most likely control seems to have been by an ancient river entering the sea locally during a low sea level stand. The only large river available would be the River Murray, although, of course, a secondary river from the drowned St. Vincent Gulf bed could have entered the sea in this region, but it seems more likely that such a river would be engrafted on the extended River Murray.

The three separate submarine valleys occur in a shelf edge distance of only three miles. They range to at least 750 fathoms (4,500 feet) at the survey line, and almost certainly continue down the continental slope to abyssal depths



Plan 4

Plan of the continental shelf, showing major physiographic features in the submarine canyon vicinity. Sites "A" and "B" on the fathometer traverse from Robe to Cape Willoughby are the low points indicated in fig. 7.

extent landward is completely unknown, but it is unlikely to be extensive. The (Jeffrey Deep which lies to the south exceeds 3,000 fathoms). The canyons' separate submarine valleys are so close together that definite ridges occur between two of them (fig. 5). From west to east, along the line of traverse, they range in depth to 550, 625, and 750 fathoms respectively.

THE CONTINENTAL SHELF AND CANYON RELATIONSHIPS

The continental platform is relatively narrow in the Beachport-Robe coastal run. It varies in width from about 16 miles opposite Cape Banks to 30 or more opposite Cape Jaffa. From this latter point the shelf widens to more than 100 miles, due to the westerly sweep of the 100 fathom line and to the marked coastal concavity associated with the Coorong. The shelf narrows again very considerably west of Kangaroo Island. A sketch section across the continental platform

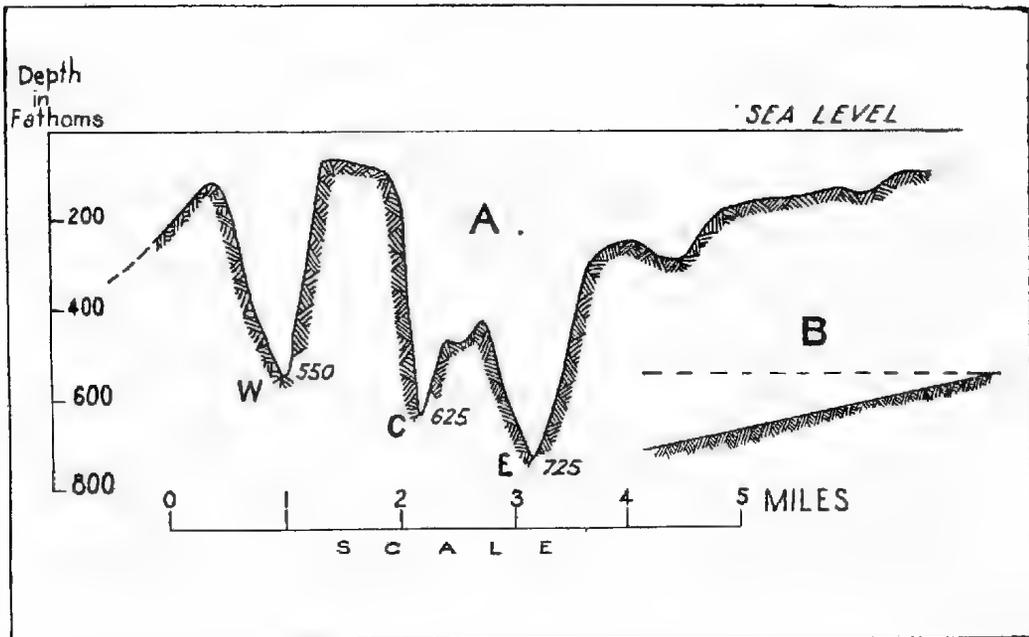


Fig. 5
Profile section ("A") through the Murray Canyons. Note steep wall gradients as compared with the general gradient of the local continental slope ("B").

at its widest development is given in fig. 6. The very approximate grades of the critical sections of this shelf are as follows:—continental shelf, 1 in 880; and steeper continental slope 1 in 20.

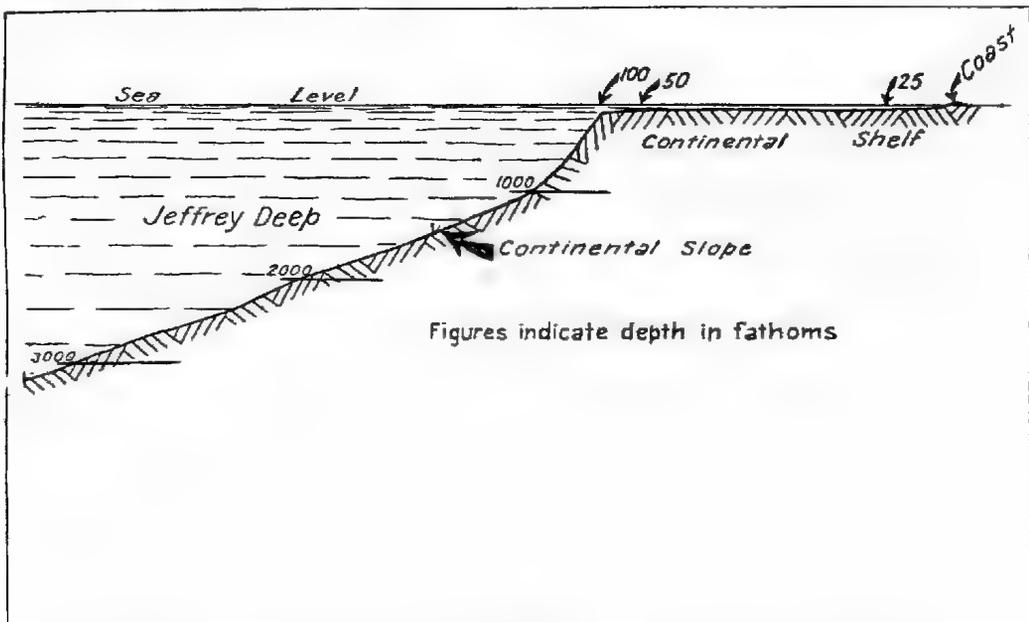


Fig. 6
Generalised section across the continental platform fronting Jeffrey Deep. The true shelf, as indicated, is more than 100 miles wide and represents conditions opposite the Murray River mouth.

Fig. 4 has been produced from admittedly insufficient data. The soundings used in the interpretation of the form line are mainly from Admiralty charts, and while these are distributed more copiously nearer the coast line, they are far too few in deeper waters. Hence, while the plan probably gives a reasonable general picture of shelf development, it must be considered as unreliable in detail. The representation then is partly conjectural, but it is felt that it is a reasonable approximation of the natural features. It is hoped that in the coming season several more traverses will be made across the zone, and that a more definite picture of the structures will thus become available.

The lines of the two traverses already made across the continental platform are included on the plan, and the sea floor detail from the Admiralty charts has been modified slightly in accordance with these. The first to be run was the Robe-Backstairs Passage traverse, but it failed to locate any definite "gorge" in a favourable situation for a possible drowned River Murray course. However, at least two possibilities apparent on the traverse (fig. 7) are indicated, and through these two points alternate courses for the inferred drowned section of the River Murray are drawn on fig. 4. Minor seaward concavities in the 40 fathoms form line have been used in designing these two courses, but it is realised that these form line deviations themselves represent only the best one can do with such a paucity of soundings in this area. The immediate submarine canyon area is not covered by Admiralty charts, so the amount of interpolation in this area is obvious.

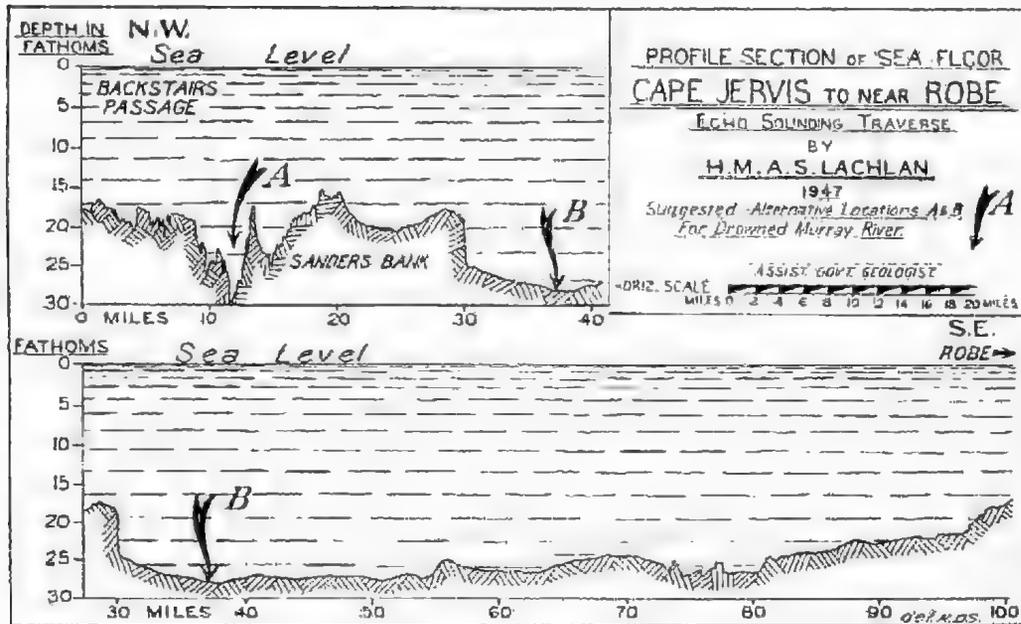


Fig. 7

The great exaggeration of the vertical scale in relation to horizontal distance is to be noted carefully. The sea floor over much of the section is extremely flat; it varies less than 30 feet vertically from the 30 mile to the 80 mile indications on the section.

Shallows occur immediately north of the submarine canyons, and these may be associated in some way with Pre-Flandrian shore-lines. They do not come within less than 5 fathoms of sea level (South West Rock is the shallowest) and

the nature of the rock is unknown. It is possible that it may be consolidated beach sand-dune material, such as that which occurs at Wedge Island at the foot of Spencer Gulf. If this is proved, it would be additional evidence favouring an old coastline stand at about 40-50 fathoms (? Pre-Flandrian Regression).

Form lines in St. Vincent Gulf area indicate that there is a fairly definite longitudinal depression line in this region. It is most probable that there was a river in this zone during the Pleistocene low sea level stands, and that this river flowed south, possibly to join the River Murray near Sanders Bank. A sounding traverse has been run from Port Adelaide to Troubridge Lighthouse in an endeavour to locate an actual river course, but without success. However, considerations of gulf bottom topography will be discussed in a later paper.

In the continental platform area facing the Southern Ocean, it must always be borne in mind that littoral wave action and other blanketing processes may have effectively destroyed much or most of any old submerged river courses.

Concerning the inferred submarine canyon "detail," the valleys have been represented diagrammatically as parallel structures trending down the continental slope. This appears to be the safest assumption in view of the information available. It is realised though that there is every possibility that two or all the structures may unite at some lower point or points on the continental slope, in dendritic fashion.

POSSIBLE HISTORICAL DEVELOPMENT OF THE MURRAY CANYONS

Thalassostatic terraces (see Zeuner, p. 130) at Murray Bridge indicate that within relatively recent times the local base level (and therefore sea level) has been at least 100 feet below its present position. The river bed in this locality may have been eroded even lower if granite bars had not intervened preventing rapid deepening in that locality.

This lowering of base level is in keeping with the postulated low sea level stands of the Pleistocene epoch which, according to Zeuner (1946) were as low as 100 metres (330 feet or 55 fathoms) below present sea level datum. With the retreat of the sea level to this extent the coast migrated seaward (Pre-Flandrian coastline, see fig. 4) causing the River Murray, and possibly other streams to advance over soft continental shelf sediments. The most direct course from the modern Murray mouth region to the sea would bring the Pre-Flandrian river mouth to a position about 40-50 miles east of the Murray Canyons. It seems probable, therefore, that if the canyons were directly related to an old River Murray mouth or mouths, the river must have pursued a much more westerly course than that of the shortest route. As gradients of the local continental shelf average 1 in 880, and in many places are far lower, it is not surprising if the course did wander considerably. The river apparently hugged the Mount Lofty-Kangaroo Island horst structure to some extent, much in the manner that the existing river hugs the Mount Lofty horst today.

Such a course may have been fortuitous or controlled to a degree by minor north downward movements, known to have occurred in south-east sub-coastal regions during the Pleistocene. Littoral drift may also have operated, tending to deflect the river mouth north and west with the retreating sea. However, the case for north-westward littoral drift along the south-east coast, at least to the author's mind, is far from proved, and will not be emphasised here.

A feature of the Murray canyons is their triplicity. This is particularly noticeable in the absence of other large submarine canyons either to the east or west along the shelf edge surveyed. They are unique in that only very small

distances separate each of the three canyons. From the western boundary of the most westerly canyon to the eastern edge of the most easterly is less than three miles.

There are at least two distinct sets of conditions which could have led to such development. In the first place, three separate contemporaneous outlets can be postulated, related either to three separate large rivers, or to three major distributaries of a delta system of the ancient (Pre-Flandrian) River Murray. However, it is difficult to imagine three separate and contemporaneous large rivers entering such a short stretch of coast, when for a distance of at least one hundred miles to the east there is no further evidence (*e.g.*, submarine canyons) of such outlets. Nor does it seem probable that in delta formation three distributaries would be maintained for a sufficient time to establish submarine canyons. If such a delta formation is assumed to have existed, the probable effect would not have been three separate canyons, but subparallel submarine furrowing with a tendency towards pirating by a major furrow and the ultimate formation of a single large submarine canyon.

The second hypothesis is that the canyons were formed in association with three complete changes in the course of the Murray, correlated with particular low sea level phases of the Pleistocene. It can be assumed that later canyons were formed by outlets completely separate from the "sphere of influence" of the older canyon(s), as any course which discharged its load within the vicinity of an established submarine furrow would have that load pirated by it.

A further problem is the relative age of the submarine valleys. This could possibly be determined only by detailed core sampling of the canyon walls for fossil data. It is interesting to note that the easternmost canyon is the deepest, and that the two to the west are progressively shallower along the line of section. This suggests that the east canyon has been subject to more prolonged erosion by bottom density currents. The later currents would have been products of coastal wave action during subsequent low sea level stand, although the possibility of enlargement by still a further low sea level and river association cannot be overlooked.

SUMMARY

Six new submarine canyons are recorded. Three of them occur in the Morobe area of New Guinea in close relation to modern or old river outlets. They are eroded in volcanic muds (and probably also marine Tertiaries) across a continental shelf only 10 miles wide, which descends to 50 and 70 fathoms at its outer limit. The continental shelf edge and the canyons themselves are lined by coral growths, and from this, on the assumption that reef corals cannot flourish in water deeper than about 25-30 fathoms, it is inferred that sea level had fallen probably 40-50 fathoms at the time of canyon formation, sufficient to allow barrier reef establishment at the shelf edge. However, in these estimates no allowance is made for possible land movements. These submarine canyons are of typically grand dimensions and relevant data concerning their development is presented.

The Murray submarine canyons are the first to be discovered bordering the Australian continent. They are considered to be related to the modern River Murray, although the evidence for this is not complete. Three separate canyons are apparent in a width of less than four miles. Two alternative theories are advanced for canyon triplicity, both having relation to the repeated sea level falls of the glacial phases of the Pleistocene.

ACKNOWLEDGMENTS

The writer wishes to thank the Department of the Navy for supplying Fair Charts of the Morobe area and for undertaking several survey traverses in strategic positions in South Australian waters. Also, indebtedness is expressed to Lieut.-Commander Little of H.M.A.S. "Lachlan" for the keen interest displayed in the search for submarine canyons, and to Dr. L. K. Ward for helpful suggestions during the final stages of the preparation of the manuscript.

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PROTOCHARA, A NEW GENUS OF CHARACEAE FROM WESTERN AUSTRALIA

By H. B. S. WOMERSLEY AND I. L. OPHEL

Summary

During a post-session excursion following the 1947 Australasian Science Congress in Perth, a remarkable number of the Characeae was collected by the first author from a small, shallow swamp on top of the peneplain of the "break-away" country above the Irwin River, near Minginew, Western Australia. The habit of the plant, and the enormous size of the cells, was unlike any of the Characeae commonly found in such localities. Most striking, however, was the complete absence of stipulodes, bract-cells and bracteoles, a characteristic of no previously described genus of Characeae.

**PROTOCHARA, A NEW GENUS OF CHARACEAE FROM
WESTERN AUSTRALIA**

By H. B. S. WOMERSLEY and I. L. OPHEL*

[Read 13 November 1947]

During a post-session excursion following the 1947 Australasian Science Congress in Perth, a remarkable number of the Characeae was collected by the first author from a small, shallow swamp on top of the peneplain of the "break-away" country above the Irwin River, near Minginew, Western Australia. The habit of the plant, and the enormous size of the cells, was unlike any of the Characeae commonly found in such localities. Most striking, however, was the complete absence of stipulodes, bract-cells and bracteoles, a characteristic of no previously described genus of Characeae.

Nandor Filarski (1937) described (in a Hungarian journal) two Western Australian Charophytes from specimens sent to him by G. O. Allen. These specimens were from the collection of J. Groves at the British Museum, and had been collected originally by Miss N. T. Burbidge. Filarski founded a new genus, *Charina*, on one of these specimens, although he had no fertile material. (See later notes.) The other specimen he referred to *Nitellopsis* as *N. inflata* Filarski and Allen. Unfortunately, it has not been possible to examine material of *N. inflata*, as no specimens exist in Australian herbaria, and Filarski's figures (reproduced in fig. 2) are inadequate in many details. From Filarski's figures, however, *N. inflata* appears to be closely related to our own species, also showing complete lack of stipulodes, bract-cells and bracteoles, but differing in several important details (see later).

It is therefore proposed to find a new genus, *Protochara*, with *P. australis* n. sp. as the type, and to transfer *N. inflata* to this genus as *P. inflata* (Fil. and Allen) comb. nov.

***Protochara australis* n. sp.**

Plant dioecious, totally ecorticate, to 10 cm. high, light green in colour, with no calcareous incrustation; attached by branched, colourless, several-celled rhizoids (fig. 1 B). Stem stout, simple or with a few axillary branches, bearing 4 to 7 whorls of branchlets; stem internodes 1 to 3 cm. long, 0.9-1.5 mm. thick. Branchlets stout, slightly incurved, in whorls of 4 to 7, of 3 or 4 segments; terminal segment consisting of a small mucronate cell, 110-200 μ long, ringed at the base by 5 or 6 peripheral nodal cells (fig. 1 D); subterminal segment large, 2-3 mm. long, 1-1 $\frac{3}{4}$ mm. broad, asymmetrically inflated with the inflated side distant from the stem (fig. 1 A, B, D); intermediate segments $\frac{1}{2}$ -1 cm. long, almost as thick as the stem, slightly inflated when young. Nodes consisting of 10 to 12 peripheral cells surrounding a plate of inner cells (fig. 1 C, D, G). Stipulodes, bract-cells and bracteoles completely absent. Chloroplasts minute, forming vertical series in the cells (fig. 1 C).

Oogonia verticillate in the axils of the upper whorls of branchlets, or borne singly or geminately at the nodes of upper branchlets (fig. 1 A); each oogonium arising from a separate peripheral cell of a node. Mature oogonia (fig. 1 A, E) ovoid-cylindrical, 760-940 μ long, 600-780 μ wide; corona about 75 μ high, 225 μ broad, of 5 small mucronate cells, thickened at the apices; spiral cells showing 6 or 7 convolutions, each cell encircling the oospore slightly more than once. Oospore black, cylindrical-oblong when ripe, 420-560 μ long, 310-390 μ broad, showing 4 or 5 ridges (fig. 1 E, F).

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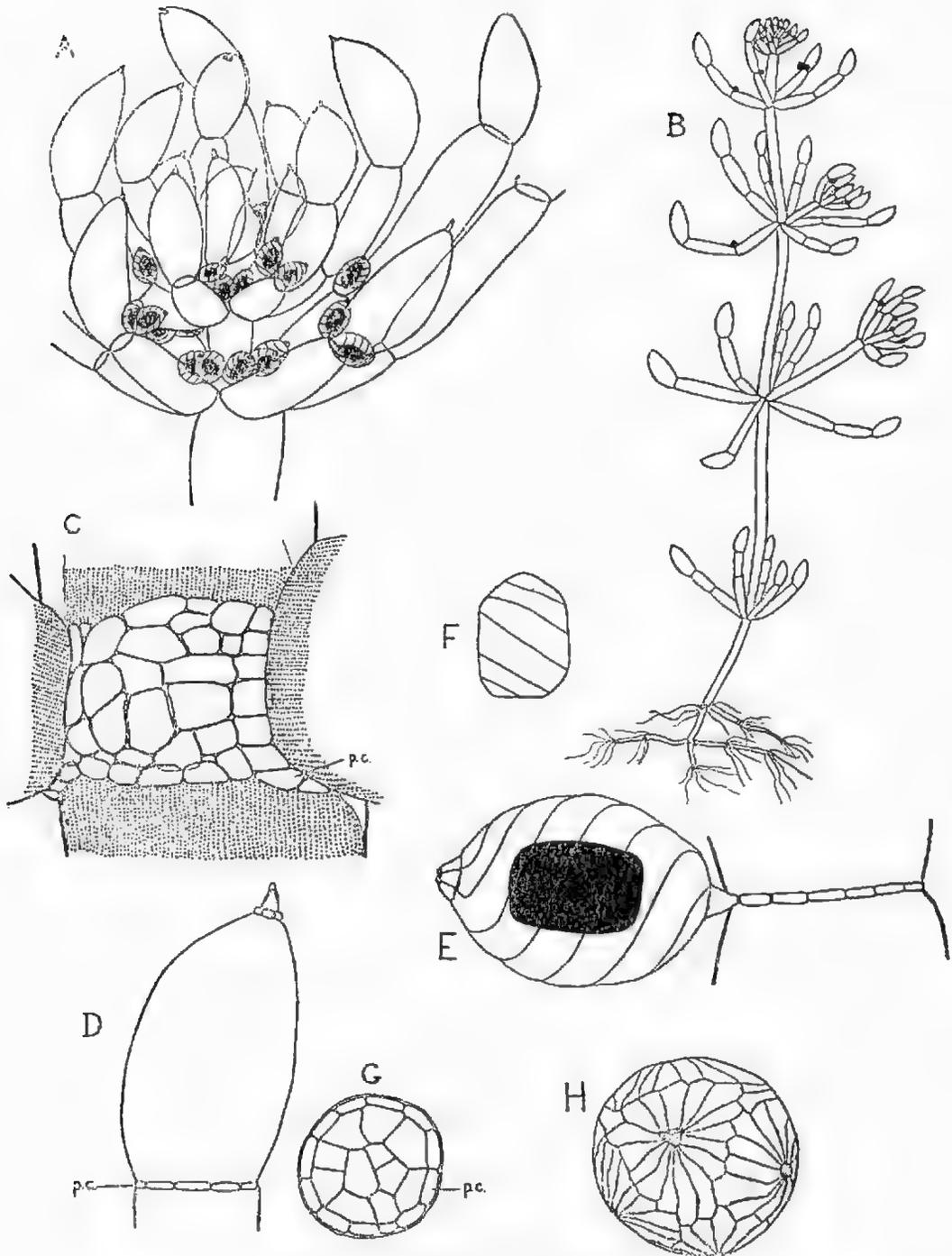


Fig. 1 *Protochara australis* n. sp.

A, Apex of branch of a female plant, showing branch arrangement and position of oogonia. B, Antheridial plant showing general habit (natural size). C, Appearance of nodal cells with a branchlet removed, the main stem being vertical, and with longitudinal rows of chloroplasts in the cells. D, Terminal mucronate cell and subterminal inflated cell of a branchlet, showing the peripheral cells of the nodes. E, Mature oogonium attached to peripheral cell of a node. F, Oospore with spiral ridges (not quite mature). G, Section of node of a branchlet, showing arrangement of central and peripheral cells. H, Antheridium. p.c., peripheral cells of node. (All drawings by camera lucida.)

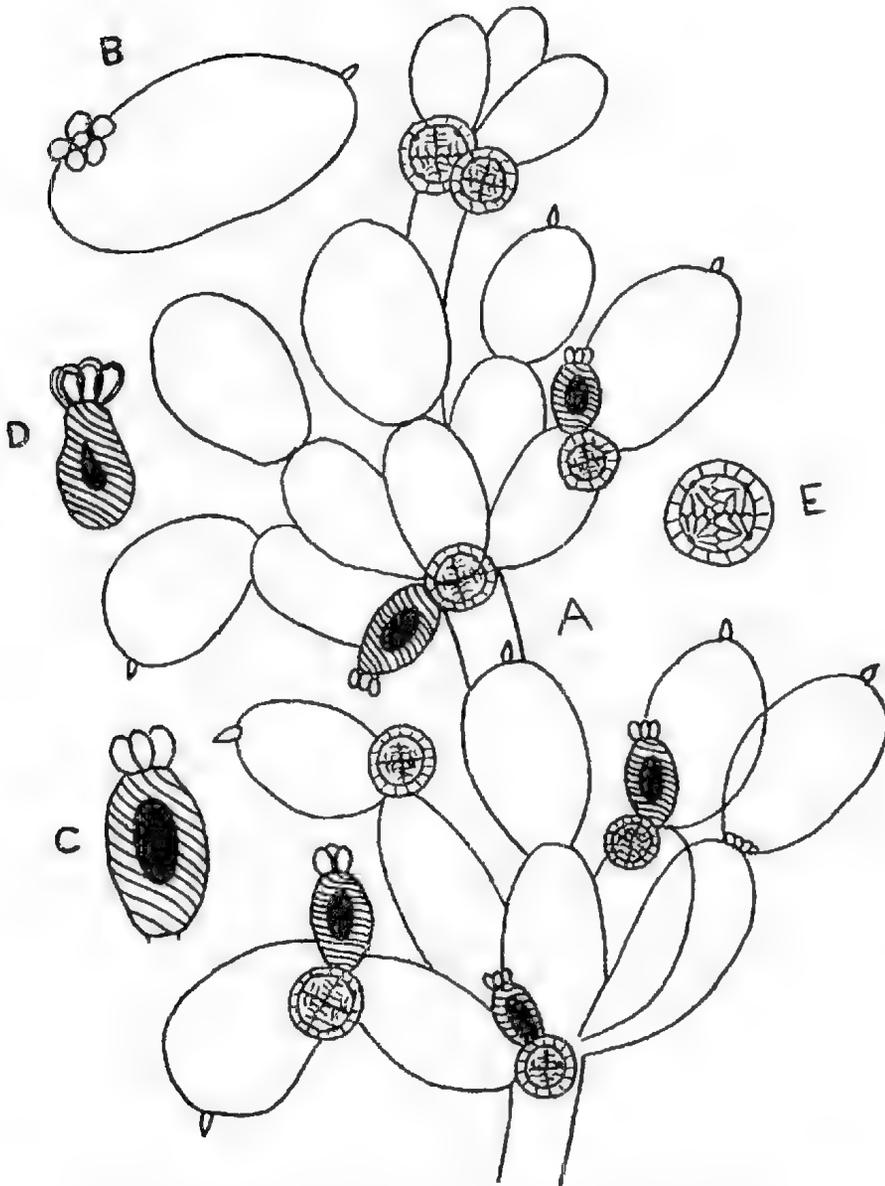


Fig. 2 *Protochara inflata* (Filarski and Allen) comb. nov.

A, Part of a plant showing the whorls of branchlets, together with oogonia and antheridia. B, End segment of a branchlet, showing the mucro and basal cells of the node. C, Mature oogonium. D, Misshapen oogonium. E, Antheridium. (After Filarski.)

Antheridia borne similarly to the oogonia, octoscutate, 800-1,150 μ in diameter.

As far as could be ascertained from limited material, the structure and development of vegetative parts and sexual organs agrees with that described for the Characcae by Fritsch (1935).

Habitat—In swampy areas of shallow water (10-40 cm. deep) on top of the peneplain of the "breakaway" country between Mingenew (about 15 miles from Mingenew) and the Irwin River coal seam, south-east of Geraldton, Western Australia.

Collected—28 August 1947.

From the same locality *Lamprothamnion macropogon* (Braun) Ophel comb. nov.⁽¹⁾ and *Nitella gelatinosa* Braun were collected.

The type specimen (No. A 5,917 a) has been deposited in the herbarium of the Botany Department, University of Adelaide. Cotype specimens have been sent to the Herbarium of the Botany Department, University of Western Australia, and to the Herbarium of the Royal Botanic Gardens, Kew, England.

PROTOCHARA INFLATA (Filarski and Allen) comb. nov.

The following description of this species (as *Nitellopsis inflata*) is given by Filarski.

Plantulae monoicae omnino ecorticatae. Folia in verticillis 4-6, uniarticulata, segmentum ultimum bicellulare, cellula ejus infima ut articulus unicus maxime inflata, ellipsoidea aut globosa-doliiformis, articulo aequilonga, cacumine mucrone minima acuta praedita. Foliola in nodo folii unico paucicellulari involuta, aut in nodo numeris 3-4 evoluta, papillaeformia, minima ventralia (anteriora). Corona stipularis in fundo verticillorum foliorum nusquam evoluta. Oogonia solitaria aut bina nodo folii et basi foliorum orta; coronula oogonii e cellularum majorum verticillo pentamero unico; antheridia oogonis majora solitaria aut pluralia, hypogyna, in verticillis superioribus plerumque tantum modo evoluta. Plantulae propter folia maxime tumida, inflata, habitu eximie differunt a Characis ceteris; tantum *Nitellam praeclaram* Groves et Steph., plantulas Africanas juxta oppidum <Cape Town> crescentes quodammodo in mentem revocant praecipue propter cellulas nonnulas internodii foliorum interdum similiter valde tumidas, fere globosas, sed folia loco mucronis corona minutissima foliolis 3 composita praedita).

Habitat—The following locality notes, given by Miss N. T. Burbidge, apply to both *P. inflata* and *Charina verticillata* (see later).

The specimens were collected from shallow water in Lake Parkeyerring, about 5 miles south of Wagin, Western Australia. The water of the lake is brackish, especially in a dry season. Collection dates given by Filarski are X. 1933 for *P. inflata* and 5-6-35? for *Charina verticillata*. On later visits Miss Burbidge was unable to find further specimens.

Filarski's figures of this species are reproduced as outline tracings in fig. 2. Details of nodal cells and antheridia are very indistinct in the original figure.

The habit of *P. inflata* is very like that of *P. australis*, as will be seen from a comparison of fig. 1 and 2. Both species show simple, whorled branchlets, large, often inflated cells, and complete absence of stipulodes, bract-cells and bracteoles. The position of the sex organs is similar in both species, and neither species shows any development of cortical cells. The species may be distinguished as follows:

1. *P. australis* is dioecious, *P. inflata* monoecious.
2. Coronal cells of the oogonium are small in *P. australis*, large and conspicuous in *P. inflata*. *P. australis* shows 6 or 7 convolutions of the spiral cells, *P. inflata* 14 or 15.
3. The sub-terminal internodal cells of the branchlets of *P. australis* show more pronounced asymmetry, and the lower cells are less inflated than in *P. inflata*.

Filarski states in his description of *P. inflata* that the antheridia are situated below the oogonia, but his figures (see fig. 2 A) show some below and some alongside the oogonia. He also describes the ultimate branch segments as bicellular, the

⁽¹⁾ See Ophel: Notes on the Genera *Lychnothamnion* and *Lamprothamnion*. Trans. Roy. Soc. S. Aust., 71, (2), 318.

terminal cell being small and mucronate. In *P. australis* a distinct ring of nodal cells occurs at the base of the terminal mucronate cell, and it seems possible, in view of the close relationship between the two species, that close examination may show this to be the case in *P. inflata*.

Why Filarski placed his plant in the genus *Nitellopsis* is not clear. The one species of *Nitellopsis* (*N. obtusa* J. Groves, from Europe) is distinguished by the presence of very long, thick "bract-cells" which arise from the nodes of the branchlets and are almost as large as the ultimate branchlet segment (Groves and Bullock-Webster 1924). "Starch stars," large, thickened, star-shaped nodes on the rhizoids are also characteristic of *N. obtusa*. The absence of bract-cells places both the Western Australian species in a distinct genus from *Nitellopsis*.

The corona of 5 cells surmounting the oogonium places *Protochara* in the tribe Chareae, as distinct from the Nitelleae which have a corona of 10 cells. It is necessary, however, to modify the description of the Chareae given by Groves and Bullock-Webster (1924) and Groves and Allen (1934), in that the branchlets usually produce bract-cells at their nodes, but not in *Protochara*.

The relationship of the genera of the Charcae, including *Protochara*, is given in the following synopsis (modified from Groves and Bullock-Webster).

- | | |
|--|------------------------------------|
| 1. Stipulodes and bracteoles absent. | |
| 2. Bract cells absent. Branchlets of 3 or 4 segments | <i>Protochara</i> n. gen. |
| 2. Bract-cells 1-2, very long. Branchlets of 2-3 very long segments | <i>Nitellopsis</i> Hy. |
| 1. Stipulodes always present, sometimes rudimentary. Branchlets simple, of 4 or more segments. Bract-cells normally 4 or more. | |
| 3. Oogonia and antheridia produced from separate peripheral cells of the node ^(*) (i.e., situated side by side). Stem corticate | <i>Lychnothamnium</i>
Leonhardi |
| 3. Oogonia and antheridia produced from the same peripheral cell of the node: | |
| 4. Oogonium normally situated below the antheridium. Stem ecorticate | <i>Lamprothamnium</i>
J. Groves |
| 4. Oogonia situated above the antheridium. Stem corticate or ecorticate | <i>Chara</i> L. |

The genera of the Chareae form an evolutionary sequence with *Protochara* as the most primitive, showing an advance in vegetative construction through *Nitellopsis*, where only bract cells occur, to *Lamprothamnium*, *Lychnothamnium* (which possesses a rudimentary cortex) and *Chara*, where bract-cells, bracteoles and stipulodes occur. The Diplostephanae-triplostichae section of *Chara* represents the culmination of the evolutionary series, showing complete 3-ranked cortication and two well developed whorls of stipulodes.

The tribe Nitelleae is best considered as a separate evolutionary series parallel to the Charcae. No genus so far described provides a satisfactory link between the two tribes.

Besides the absence of stipulodes, bract-cells and bracteoles, *Protochara* shows another primitive character in the small number of convolutions (5 or 6) of the spiral cells of the oogonium of *P. australis*. The oogonium of *P. inflata*, however, shows 14 or 15 convolutions, and must be considered less primitive than *P. australis*. According to Groves and Bullock-Webster (1924) *Nitellopsis*

(*) See Ophel, *loc. cit.*

obtusata shows about 9 convolutions, whereas most species of *Chara* show more than 12. Fossil oogonia attributed to Characeae, judging from figures given by Groves and Bullock-Webster, commonly show a relatively small number of convolutions (as low as 5 or 6).

The relatively few segments to the branchlets, and the general simplicity of the thallus, also point to the primitive nature of *Protochara*.

The naming of most fossil Characeous remains (usually oogonia), as species of *Chara*, makes *Chara* in this sense a very much wider genus than the *Chara* of living species. It is quite likely that fossil remnants would prove to belong to *Protochara* if thallus structure were better preserved.

It is evident that *Protochara* is the most primitive genus yet described of present-day Characeae, and appears to be more primitive than any genus of the Nitelleae. The general habit of the plant, however, consists of the stem with whorled branchlets that is so typical of the group as a whole, and the oogonia and antheridia are of the highly specialized type common to all species. The relationship and position of the Characeae amongst other plants remains as obscure as ever.

LATIN DIAGNOSES

PROTOCHARA n. gen.

Plantulae omnino ecorticatae. Stipulodae, bractae-cellulae et bracteolae omnino absentia. Monoecae aut dioecae, oogonia et antheridia a nodi perimetrotis cellulis orta. 5 cellularum corona.

Protochara australis n. sp.

Plantulae dioecae, omnino ecorticatae, usque ad 10 cm. alta, subvirides, non incrustatae; radicae ramulis et multicellulariac. Caulis crassus, simplex aut ramulorum verticillis 4-7; internodia caulis 1-3 cm. longa, 0.9-1.5 mm. lata. Ramulae crassae paucis incurvatae, in verticillis 4-7, quisque articulorum 3-4; segmentum mucroniformis ultimum longum 110-200 μ , perimetrotis nodi cellulis 5-6 in fundo; segmentum subultimum magnum non aequaliter inflatum; segmenta inferiora longa $\frac{1}{2}$ -1 cm., lata $\frac{3}{4}$ -1 $\frac{1}{4}$ mm. Nodi perimetrotis cellulis 10-12. Stipulodae, bractae-cellulae et bracteolae omnino absentia.

Oogonia in superiorum verticillorum ramulorum axillis verticillata, solitaria aut bina nodis ramulorum; a perimetrotis cellulis propriis orta. Oogonia oviformia-cylindrica longa 760-940 μ , lata 600-780 μ ; corona oogonii alta circiter 75 μ , lata 225 μ , composita cellularum 5 parvarum mucroniformium; cellulae spirilles convolutis 6-7. Oospora nigra, cylindrica-oblongata, longa 490-560 μ , lata 310-390 μ , rugis 4-5.

Antheridia modo oogoniorum simili orta, octoscutata, diam. 1,150 μ .

NOTES ON FILARSKI'S GENUS CHARINA

In the same paper as *Nitellopsis inflata* was described, Filarski founded a genus *Charina*, based on the one species *C. verticillata* Fil. and Allen, from Wagin, Western Australia. None of the specimens on which the genus was named was fertile.

Filarski's reasons for founding a new genus are not clear, but were apparently based on the vegetative form of the plant. His figures show a slender, verticillately branched plant bearing numerous whorled, 2-celled dactyls. The occurrence of two- (sometimes more, rarely one) celled dactyls such as these on the branchlets is a characteristic feature of the Nitelleae, as distinct from the

Chareae which bear only one-celled bracteoles on the branchlets. Filarski laid considerable stress on the apparent dimorphism shown by different branches (or plants?) of *Charina*; some branches bore only one-celled, blunt-ended, dactyls instead of the two-celled, mucronate type. A feature of some species of *Nitella*, however, is that the terminal cell of the dactyl is often deciduous, and this is probably the reason for the apparent dimorphism stressed by Filarski.

From the figures given, the general appearance of the plant and its vegetative construction offer no feature to exclude it from the genus *Nitella*. In fact, Filarski adds a note that J. Groves had suggested the plant was close to *Nitella subtilissima* Braun, and in the absence of fruiting material the naming of a new genus was hardly justified. Fertile material must be collected to prove whether *Charina* can be retained or not, and it is to be hoped that both this species and *Protochara inflata* will be rediscovered by Western Australian collectors.

ACKNOWLEDGMENTS

The authors are indebted to Miss N. T. Burbidge for information on the locality where she collected *P. inflata* and *Charina verticillata*. Mr. G. G. Smith, Department of Botany, Western Australia, also collected some of the material of *P. australis*.

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NOTES ON THE GENERA LYCHNOTHAMNUS AND LAMPROTHAMNIUM (CHARACEAE)

BY I. L. OPHEL

Summary

The genus *Lychnothamnus* was established by Leonhardi in *Lotos* XIII, 1863, p. 72, having previously been differentiated in 1845 by Ruprecht as a sub-genus to include the species in Braun's section "Charae pleurogynae," viz. *Chara barbata* Meyen, *C. papulosa* Wallroth and *C. macropogon* Braun. In "Fragmente einer Monographie der Characeen" 1882, Braun and Nordstedt recognised the genus as distinct, but *C. papulosa* (under the synonym of *C. alopecuroides* Braun) was removed into a new genus *Lamprothamnus* (later changed to *Lamprothamnium* by Groves, (1916), and *C. stelligera* Reich was added to *Lychnothamnus*, so that the latter genus consisted of three species: *L. stelliger* Braun, *L. macropogon* Braun and *L. barbatus* Leonhardi.

NOTES ON THE GENERA *LYCHNOTHAMNUS* AND *LAMPROTHAMNIUM*
(CHARACEAE)

By I. L. OPHIEL

[Read 13 November 1947]

The genus *Lychnothamnus* was established by Leonhardi in *Lotus* XIII, 1863, p. 72, having previously been differentiated in 1845 by Ruprecht as a subgenus to include the species in Braun's section "Charae pleurogynae," viz. *Chara barbata* Meyen, *C. papulosa* Wallroth and *C. macropogon* Braun. In "Fragmente einer Monographie der Characeen" 1882, Braun and Nordstedt recognised the genus as distinct, but *C. papulosa* (under the synonym of *C. alopecuroides* Braun) was removed into a new genus *Lamprothamnium* [later changed to *Lamprothamnium* by Groves, (1916)], and *C. stelligera* Reich was added to *Lychnothamnus*, so that the latter genus consisted of three species: *L. stelliger* Braun, *L. macropogon* Braun and *L. barbatus* Leonhardi.

As Groves (1919) points out, the distinguishing character of the genus *Lychnothamnus* as established by Leonhardi is that the antheridia are produced by the side of the oogonium. Of the three species placed in the genus by Braun and Nordstedt it is only in the original type (*Lychnothamnus barbatus*) that the relative position of the sex organs can be satisfactorily ascertained, since *Lychnothamnus stelliger* (now *Nitellopsis obtusa* J. Groves) is dioecious; and in *Lychnothamnus macropogon*, while the antheridia are normally produced at the branchlet nodes, the oogonia are almost invariably situated at the base and, when situated at a branchlet node, scarcely ever occur at a node where there is also an antheridium present.

Hy, in 1889, removed *Lychnothamnus stelliger* to a new genus *Nitellopsis* naming the plant *Nitellopsis stelligera*, his new genus being based on vegetative characters. Considering the state of knowledge at that time the action was hardly justifiable, since *Lychnothamnus stelliger* satisfied Leonhardi's generic description to as great an extent as did *Lychnothamnus macropogon*. However, since it is now known that the relative position of the sex organs is somewhat variable, it does seem that something more is needed on which to base generic distinctions.

The removal of *Lychnothamnus stelliger* left two species in the genus, *Lychnothamnus barbatus* Leonhardi and *Lychnothamnus macropogon* Braun.

Groves (1919) examined specimens of *Lychnothamnus macropogon* from Australia and Hongkong. He found in specimens from Victoria one instance in which an oogonium and antheridium occurred together at a free node, and in this case the two were produced side by side but proceeding from the same peripheral cell, corresponding to *Lamprothamnium* Groves (*Lamprothamnium* Braun); in *Lychnothamnus barbatus*, however, the antheridia and oogonia are produced from different peripheral cells of the branchlet node. In the specimens from Hongkong two instances were observed in which an oogonium and antheridium occurred together; in both cases the two proceeded from the same peripheral cell, but the antheridium occurred below the oogonium in each case as in the genus *Chara* Linn.

Despite the extremely close resemblance of the vegetative parts of *Lychnothamnus macropogon* to those of *Lamprothamnium papulosum* J. Groves (so much so that some sterile forms of both species would be indistinguishable—

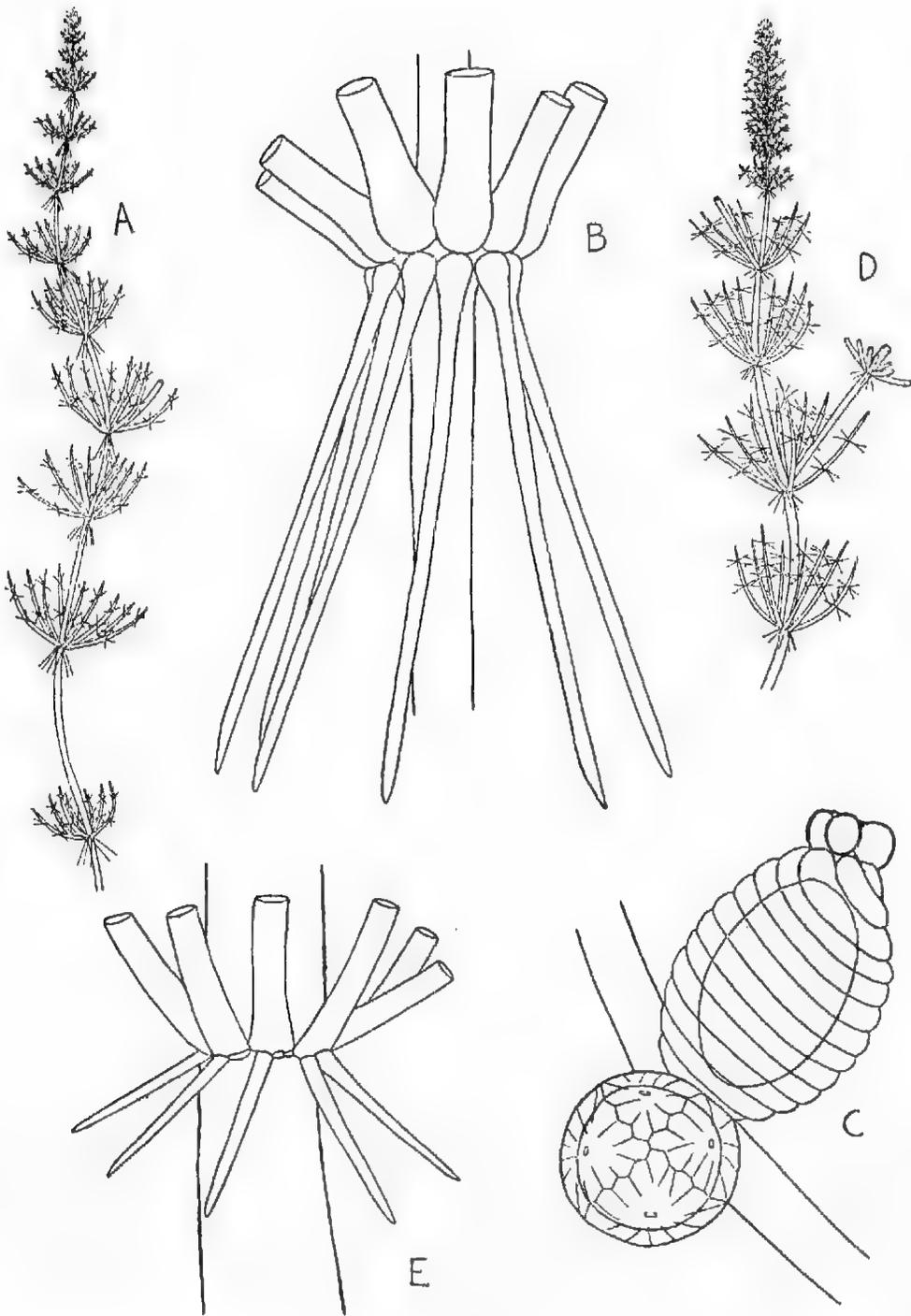


Fig. 1

A, B, C, *Lamprothamnium macropogon* (Braun) comb. nov.

A, Portion of sterile plant from Harriet River, Kangaroo Island (nat. size).
 B, Base of whorl, showing stipulodes; plant from Robe. X c. 30. C, Branchlet node, showing side-by-side arrangement of antheridium and oogonium. Plant from Harriet River. X c. 60.

D, E, *Lamprothamnium papulosum* J. Groves

(D, after Migula; E, after Groves and Bullock-Webster.)

D, Portion of plant, nat. size. E, Base of whorl, showing stipulodes. X c. 20.

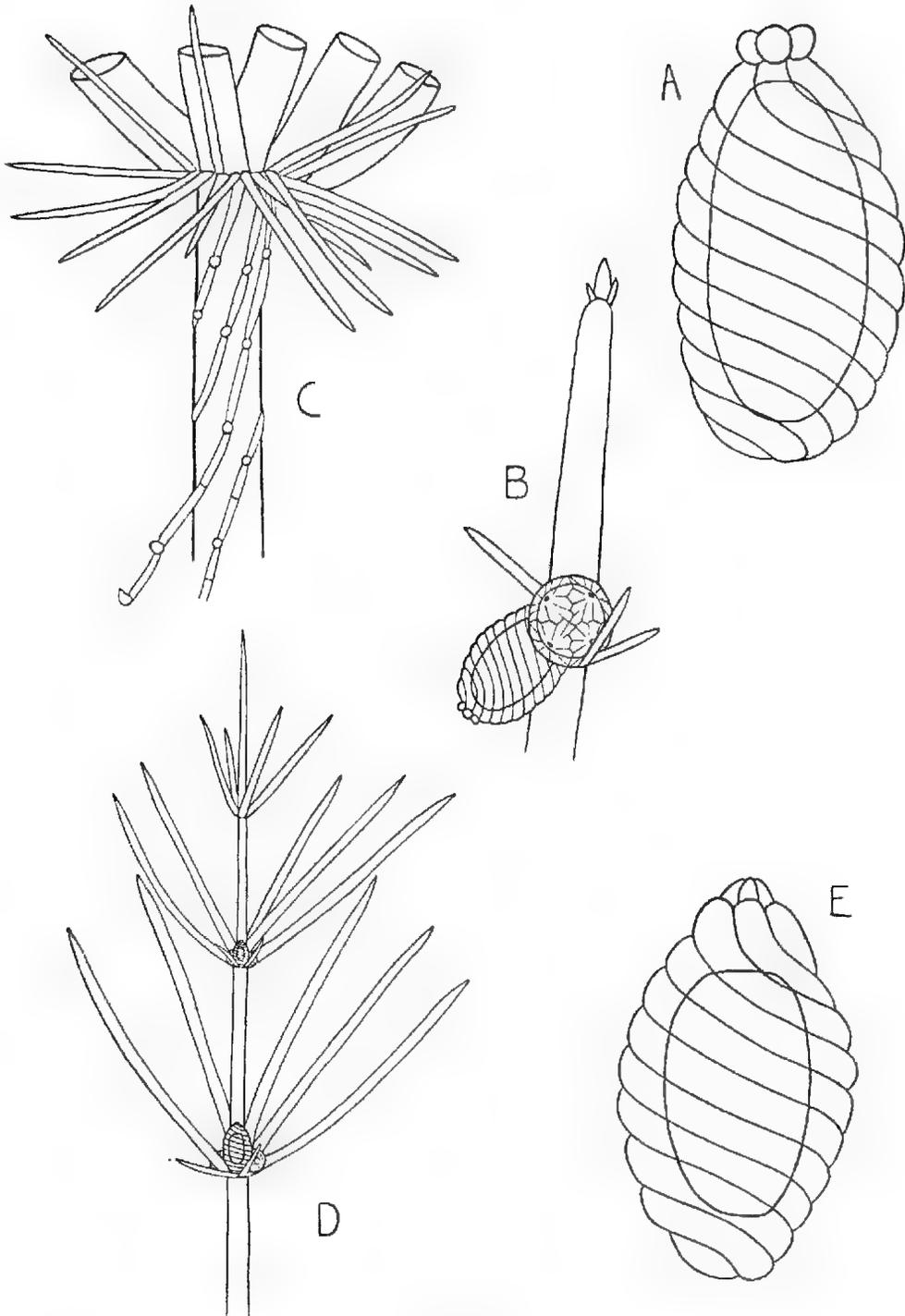


Fig. 2

A, B, *Lamprothamnium papulosum* J. Groves (after Groves)
 A, Oogonium. X c. 60 B, Upper part of the branchlet with fertile node. X c. 20.
 C, D, E, *Lychnothamnus barbatus*, Leonhardi
 C, Base of whorl, showing stipulodes and rudimentary cortex. X 10. D, Fertile branchlet. X 5. E, Oogonium. X 45.

fig. 1 and 2), and that the relative position of the oogonium and antheridium appeared variable, Groves rejected the inclusion of the species in the genus *Lamprothamnium* on the grounds that it would mean abandoning the one distinguishing character of this genus. He tentatively proposed the return of the species to *Chara*. In "Review of Queensland Charophyta" (1934), H. Groves and Allen list the species as *Chara macropogon* Braun.

In all the South Australian specimens so far examined by the author only in two have an oogonium and antheridium been found together. In one, from Kinchua (Coll. No. 25A), the antheridium was situated below the oogonium. The other case was in a specimen from Harriet River, Kangaroo Island (Coll. No. 31), and in this case the two were side by side. In both instances the two reproductive organs were derived from the same peripheral cell. Another specimen from Kinchua (Coll. No. 25 B) had two antheridia situated at a free branchlet node, one above the other, and both proceeding from the same peripheral cell.

This derivation of the sex organs from the same peripheral cell confirms Groves' observations and supports his removal of *Lychnothamnus macropogon* from the genus *Lychnothamnus*. It could not be said, however, that the above facts support his proposal of returning it to the genus *Chara*.

Groves' reasons for ignoring the obvious relationship between *Lamprothamnium papulosum* and *Lychnothamnus macropogon* are not clear. Braun and Nordstedt (1882) had remarked on their similarity, and Groves himself (1919) says, "In examining *L. macropogon* one is struck by the great similarity of its vegetative parts to our European *Lamprothamnium papulosum*."

This similarity extends to all characters of the plants (see also fig. 1 and 2). Both species are entirely ecorticate with elongated stipulodes, usually one opposite each branchlet, at the stem nodes. The upper (usually fertile) whorls are contracted into heads, the branchlets in both species being incurved and of a small number of segments (3-4-5) bearing usually five bract cells at the lower nodes with bracteoles usually absent.

Specimens of *Lamprothamnium papulosum* from South Africa (McNicol (1907) betray an even closer relationship by the production of a second row of stipulodes above the whorl of branchlets (common in South Australian specimens of *Lychnothamnus macropogon*), in the swollen segments of the branchlets of the sterile whorls, and in the production of smooth spherical white root bulbils (seen in most South Australian collections). The production of these bulbils by *Lychnothamnus macropogon* is also mentioned by H. Groves and Allen (1934).

Groves (1919) chose to ignore these similarities rather than abandon what he considered the one distinguishing character of *Lamprothamnium*—that of the oogonium below the antheridium—yet in his description of *Lamprothamnium papulosum* he states (Groves 1924, 2, 8) that the relative positions of the two are variable. In any case, instances of oogonia and antheridia occurring together in *Lychnothamnus macropogon* are so rare as to be regarded as atypical, and it would be hard to justify the use of these isolated instances as an ultimate basis of classification. Rather, the extremely close morphological resemblance of *Lychnothamnus macropogon* to *Lamprothamnium papulosum* is a much more reliable indication as to the relationship of the Australian species.

The name of this species now becomes *Lamprothamnium macropogon* Braun comb. nov. with the following synonymy:

- Chara macropogon* Braun, 1843
Lychnothamnus macropogon Braun, 1868
Macropogon australicum Migula, 1891

The amended generic description is as follows:—

LAMPROTHAMNIUM Groves, 1916
(*Lamprothamnus* Braun, 1882, non Hiern)

Stem and branchlets ecorticate. Branchlets of few segments with usually five bract cells at a node. Stipulodes, in normal forms, long and declining, pointed and opposite the base of each branchlet; occasionally secondary ones produced. Sometimes a second series of stipulodes produced above whorl of branchlets.

Monoecious. Upper fertile verticils contracted into compact heads. Oogonium derived from same peripheral cell as antheridium when both occur at same branchlet node. Oogonium situated above, by the side of, or below antheridium. Root nodes producing spherical starch bulbils.

Two species:—

- (1) Antheridia and oogonia borne at same branchlet node—*Lamprothamnium papulosum* Groves.
- (2) Oogonium at base of branchlets, antheridia at branchlet nodes—*Lamprothamnium macropogon* (Braun) comb. nov.

Three other species of *Lamprothamnus* (*Lamprothamnium*) have been described. The most important of these is *Lamprothamnus hansenii* Sonder, figured and described by Migula (1900). This species is related to *Lamprothamnium papulosum* but differs in not producing the long dense fruiting heads, in having stouter branchlets and broader oogonia. This species is also closely related to *Chara succinata* Braun, and seems to represent a well-defined intermediate form between *Chara succinata* and *Lamprothamnium papulosum*. If the modified generic description of *Lamprothamnium* is applied, then this species, because of the stated differences, is ineligible and becomes *Chara hansenii* (Sonder) comb. nov.

The two other described species are considered by Groves (1924) to be extreme forms of *Lamprothamnium papulosum*.

From the above discussion it can be seen that the typical species of *Lamprothamnium* are connected by intermediate forms with species of *Chara* and the observations cast some doubt on the validity of the genus *Lamprothamnium*. Classification of the tribe *Characeae*, with the emphasis not on the relative position of antheridia and oogonium but on their derivation would be more satisfactory. In this case the tribe falls into two sections:—

- (1) Antheridium and oogonium derived from separate peripheral cells of the branchlet node. (*Nitellopsis* and *Lychnothamnus*).⁽¹⁾
- (2) Antheridium and oogonium derived from the same peripheral cell. (*Lamprothamnium* and *Chara*.)

SUMMARY

The systematic position of the Australian *Lychnothamnus macropogon* Braun (*Chara macropogon* Braun) is reviewed. Figures are given of this and related species. From the evidence it is seen that the Australian species is more nearly related to *Lamprothamnium papulosum* Groves, hitherto the sole member of its genus, to which *L. macropogon* is now transferred.

However, the validity of *Lamprothamnium* as a genus is questioned.

⁽¹⁾ Also *Protochara*, see Womersley and Ophel, p. 311, this Journal.

ACKNOWLEDGMENTS

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LARVAL TREMATODES FROM AUSTRALIAN FRESHWATER MOLLUSCS

By T. HARVEY JOHNSTON AND ANNE C. BECKWITH

Summary

The present paper deals with two new furcocercariae which have been rarely met with by us. One, *Cercaria ancylis*, belongs to the Strigeids, while the other, *C. lophosoma*, is a lophocercaria whose unknown adult probably is a blood fluke inhabiting one of the species of fish occurring in the Murray River.

LARVAL TREMATODES FROM AUSTRALIAN FRESHWATER MOLLUSCS
PART XII

By T. HARVEY JOHNSTON and ANNE C. BECKWITH*

(Fig. 1-8)

[Read 13 November 1947]

The present paper deals with two new furcocercariae which have been rarely met with by us. One, *Cercaria ancyli*, belongs to the Strigeids, while the other, *C. lophosoma*, is a lophocercaria whose unknown adult probably is a blood fluke inhabiting one of the species of fish occurring in the Murray River.

We desire to acknowledge our indebtedness to Mr. G. G. Jaensch and his family for help during our visits to Tailen Bend; and to the Commonwealth Research Grant for financial assistance. Part XI of the series is being published in the Records of the South Australian Museum, 1947, 563-584.

Cercaria ancyli n. sp.

(Fig. 1-3)

A very small furcocercaria, *Cercaria ancyli*, has been found parasitising two different hosts, the gastropod *Amerianna pyramidata*, and the freshwater limpet, *Ancylus australicus*. It is the first occasion on which we have found larval trematodes in the latter mollusc. The cercaria was first observed as an infection of one out of six *Ancylus* collected in the River Murray swamps at Tailen Bend in April 1947. In May 1947 three out of 154 *Amerianna* from these swamps emitted the same kind of cercaria. It is possible that, owing to the superficial resemblance of this species to *C. angelae* Johnston and Simpson 1944, the former may have been collected on earlier occasions, but confused with the latter parasite.

The cercariae are very active and swim, tail first, almost constantly. They live for about 36 hours at room temperature, but keeping them in a refrigerator, at about 1° Centigrade, in a vessel of water, prolongs the life to two or three days, a useful expedient, as material was scarce.

Ten cercariae from each host, preserved in the usual manner, were measured with an ocular micrometer from a water mount. The measurements of the two lots of cercariae differ slightly, particularly in the proportions of tail-stem length to body length; but both body and tail-stem are highly contractile, and as the cercariae possess no noticeable anatomical differences, the differences in the measurements may be accounted for by their development in different hosts.

Measurements are given in micra and indicate the average, and (in brackets) the range. Cercariae from *Ancylus*:—body length, 114 (81-144); body breadth, 33 (27-41); tail-stem length, 112 (90-127); tail-stem breadth, 36 (27-41); furca length, 114 (99-124); furca breadth, 21 (18-25); anterior organ length, 34 (25-43); anterior organ breadth, 22 (18-25); ventral sucker length, 18.7 (18-21); ventral sucker breadth, 17 (14-19). Cercariae from *Amerianna*:—body length, 127 (93-153); body breadth, 37 (30-35); tail-stem length, 88 (72-100); tail-stem breadth, 35 (28-45); furca length, 116 (95-139); furca breadth, 21 (19-23); anterior organ length, 32 (27-37); anterior organ breadth, 25.5 (25-27); ventral sucker length, 18.7 (18-21); ventral sucker breadth, 19 (18-21).

The spines are restricted to the anterior organ and ventral sucker. In front of the mouth are three rows of forwardly directed spines, ten to twelve in all.

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with usually only one or two in the most anterior row (fig. 1) and four to five in the most posterior. A short spineless area succeeds the pre-oral spines, followed by a band of five or six irregular rows of spines around the front part of the anterior organ. The portion of the anterior organ anterior to the first row of spines may be completely withdrawn, or pushed forward. The ventral sucker bears three rows of rather irregularly arranged spines, approximately 50 in number, and these, too, can be withdrawn into the cavity of the sucker.

The digestive system consists of mouth, surrounded by the pear-shaped, highly contractile, anterior organ; a short pre-pharynx; well-developed pharynx; very short oesophagus; and a short knob-like caecum, all in the anterior third of the body. The caecum is at times partly lobulated in a manner suggestive of incipient division into two caeca (fig. 1).

There is a group of six rather small penetration gland cells posterior to the ventral sucker, arranged in two groups overlapping anteriorly. The ducts of these pass forward and open each side of the mouth. There is a group of probably four pairs of very small "head-glands" in the region of the anterior organ, which stain very deeply with neutral red used *intra-vitam*, and are hence conspicuous features in such a preparation. The genital primordium is a triangular mass of undifferentiated cells between the bladder and the two sets of penetration gland-cells. The nervous system was not observed. A large number of very small, highly refringent granules are scattered throughout the body. Whether these are part of the developing excretory system is uncertain.

The stem of the longifurcate tail contains six pairs of caudal bodies, the first rather smaller than the others. The usual stalked cells line the borders of the tail-stem. Both tail-stem and furcae are spineless. Transverse and longitudinal muscle fibres are present. A unique feature of this cercaria is the curious cuticular thickening halfway along the furca, opposite the opening of the excretory canal. This is knob-like in some, in others more spur-like, and is invariably present (fig. 2).

The bladder is trilobed, consisting of a central portion with an antero-lateral lobe on each side (fig. 1). Into this lateral lobe on either side opens the main collecting duct, which receives two secondary ducts at the level of the ventral sucker. The most anterior of these ducts drains the capillaries of two flame-cells, while the posterior, which is greatly coiled proximally, receives the capillaries of two further flame-cells in the body, and one in the tail at the level of the second pair of caudal bodies. Hence the excretory formula is $2[(2) + (2 + (1))] = 10$. In the region where the main ducts receive the secondaries a transverse commissure connects the two sides of the excretory system, passing across the body posterior to the ventral sucker. From the posterior part of the bladder a wide duct leads back, dividing to surround a small island of Cort, then continuing centrally along the tail-stem (fig. 3) and branching at the base of the furcae into two vessels which open halfway along the furcae, opposite the cuticular "spurs."

In one specimen a variation in the number of flame-cells on one side was observed. A third flame-cell in the hinder part of the body was connected with the posterior secondary duct on one side only, making the formula for that side $[(2) + (1 + 2 + (1))] = 6$ (fig. 1). This was apparently a precociously developed flame-cell of the metacercarial stage.

SPOROCAST

The sporocysts (fig. 3) occur in the digestive gland in both hosts. They are slender tubular structures, usually tangled together in masses. Much of the liver

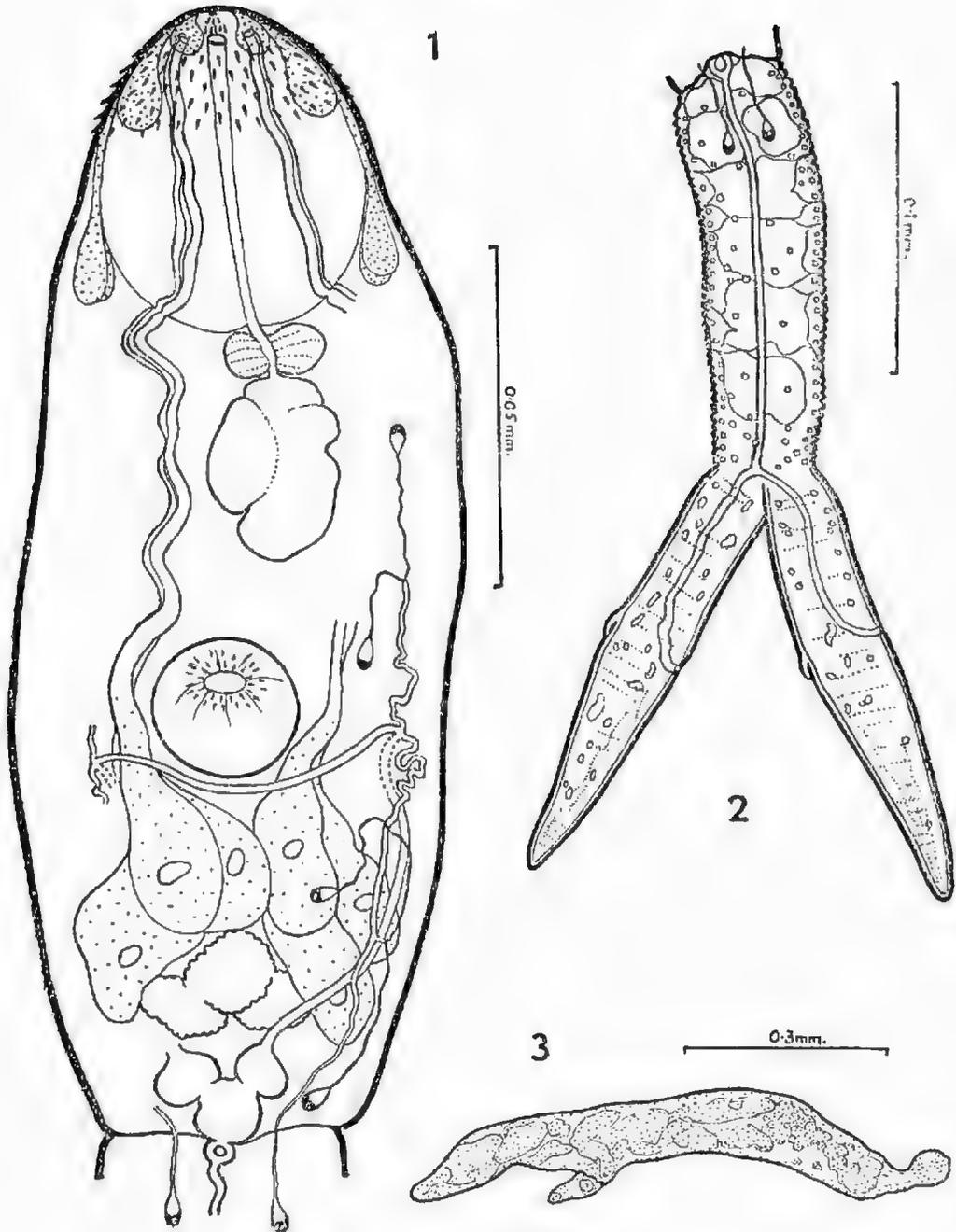


Fig. 1-3, *C. ancylus*

1, body, showing spines, digestive system, glands, excretory system, genital primordium; 2, tail; 3, sporocyst, showing cercaria emerging from tear in wall. Fig. 1 and 2 drawn from living specimens, outlines with camera lucida; fig. 3 from Canada balsam mount, also with camera lucida.

tissue of the host may be destroyed. The living sporocyst is capable of slow waving movements. Several sporocysts contained numbers of mature cercariae at the time when the first host (*Ancylus*) died, and some of the cercariae were observed pushing their way out through the walls of the sporocysts, but there is

apparently no birth-pore. Characteristically, a number of constrictions divides each sporocyst into several lobes, and the end may be marked by a small knob. Length is very variable—a fairly long one measured 3 mm. There are no very marked differences between sporocysts from the two hosts, but those from *Amerianna* tend to be slightly stouter and more coiled than those from the smaller host, *Ancylus*.

EXPERIMENTAL INFECTIONS

The second intermediate host of *C. ancyli* has not been ascertained. Attempts were made to infect experimentally with the cercaria the gastropods *Lymnaea lessona*, *Amerianna pyramidata* and *Planorbis isingi*; the fish *Gambusia affinis*, and mosquito larvae; but results were in every case negative.

RELATIONSHIPS

As far as has been possible to ascertain, *C. ancyli* is the first cercaria from a fresh-water limpet to be described fully. Fielder, in 1896, mentioned the presence of cercariae and of pigmented distome cysts in *Ancylus tasmaniensis*; while Cherry, in 1895, reported having seen cercariae from the same species, and in 1917 from *A. australicus*. As these cercariae were not described, it is impossible to know whether any of them could have been *C. ancyli*. The occurrence of this cercaria in *Amerianna* as well, indicates that its nearest relatives need not necessarily be parasites of fresh-water limpets.

One local cercaria, *C. angelae*, Johnston and Simpson 1944, also from *Amerianna*, resembles *C. ancyli* closely enough to make identification troublesome in routine examinations. The two species are distinguished, however, by a number of features, namely, size—*C. angelae* is considerably larger; number of gland-cells—eight in *C. angelae*, six in *C. ancyli*; number of flame-cells—ten in *C. ancyli*, sixteen in *C. angelae*; and absence of "preacetabular bodies" in *C. ancyli*. They are also distinguished by the form of the alimentary canal, the spination, and by the fact that the tail excretory tubules in *C. ancyli* open half-way along the furcae, but in *C. angelae* at the tips.

Several well-defined groups of cercariae can be eliminated immediately from close relationship with *C. ancyli*, although possessing some features in common with the latter. The *Elvae* group of furcocercariae (Miller 1923) all possess a single pair of caudal flame-cells high in the tail-stem, apparently a group characteristic rather than a species characteristic, and common to several groups of furcocercariae; but they differ from *C. ancyli* in various fundamental features, such as the possession of a brevifurcate tail. Probably much more closely related, though still distinct, is the *Apatemon* group, again with one pair of flame-cells in the tail-stem, and also resembling our larva in size, general proportions and spination, but differing in having four pairs of gland-cells, seven pairs of flame-cells, and well-developed caeca. *C. multicellulata* Miller (1923) and its allies possess six gland cells posteriorly placed, but are quite distinct from *C. ancyli* as a group, as they have two pairs of flame-cells in the tail-stem, a larger number of flame-cells in the body, and differ greatly in size, spine equipment and other features.

The cercaria mostly closely resembling ours is *C. dohema* Cort and Brackett (1937), a parasite of *Lymnaea* and *Stagnicola*. Of the relationships of this cercaria, Cort and Brackett said (p. 278) that they could find in the literature no other strigeid larva resembling theirs. *C. ancyli* has exactly the same excretory arrangement, similar type of gut and glandular equipment, similar pre-oral spines, six caudal bodies in the tailstem and somewhat similar body proportions. In actual size, however, *C. dohema* is rather larger (body 156 μ long, tail-stem 179 μ

long, furca 196 μ long); it also differs in having spines back to the level of the pharynx, unpigmented "eyespot," a pair of caudal bodies in the furcae, no head-glands and no furcal spur, and its sporocyst possesses a birth-pore. *C. dohema* is said to penetrate into a minnow (*Fundulus* sp.), and metacercariae (undescribed) recovered from the liver were considered to belong to that species, but investigations of the life-cycle were not completed.

C. riponi Brackett (1939) resembles *C. ancyli* somewhat less closely. The glandular equipment is very similar, and the excretory system differs only in the presence of an additional pair of flame-cells in the posterior body; but it has no pre-oral spines, more extensive body spination, well-developed gut, eyespots and no head-glands. *C. sincera* Olivier (1941) has an excretory formula identical with that of *C. ancyli*, and is very similar in size, but has only two pairs of glands, a heavily spinose body, and long caeca. *C. granula* Miller (1927) and *C. hirsuta* Miller (1927) are two more species with exactly the same excretory arrangements as *C. ancyli*; in *C. granula* there are also occasional variations in the number of flame-cells in the posterior part of the body, as in our larva. Both of Miller's cercariae have, in addition, very short caeca, and six caudal bodies, but differ from our larva in size, and markedly in their penetration gland equipment, although in both this is mainly posterior to the ventral sucker. Both have setae on the tail-stem.

Two other cercariae with six post-acetabular gland-cells, *C. higginsi* Olivier (1942) and *C. walloomi* Olivier (1941), are quite distinct from *C. ancyli*; both are considerably larger larvae than ours, and both have sixteen flame-cells, two of which are in the tail-stem.

***Cercaria lophosoma* n. sp.**

(Fig. 4-8)

In the course of examination of 2,920 specimens of the gastropod, *Notopala hanleyi*, for trematode infestation, a minute new lophocercaria, *Cercaria lophosoma*, has been recovered from two snails. These two infected specimens were collected in May 1945 and March 1946 respectively at Swan Reach on the River Murray; ten other collections of this mollusc made at the same place between April 1942 and March 1947, and two collections made at Renmark and Morgan respectively, yielded no further specimens infected with the same cercaria. It is possible that the cercariae at times escape notice because of their small size.

C. lophosoma is emitted mainly in the middle of the day. A few appear by 10.30 a.m., but large numbers are not emitted until between 12 noon and 2.30 p.m. When sufficient numbers are present, they tend to form a swarm in the tube. They are planktonic organisms and swim very little, but will respond to vibration of their tube with a few jerky bending movements of the tail. They float in various positions (fig. 6). The length of life is about 48 hours.

Cercariae, fixed by adding an equal quantity of boiling 10% formalin to the water in which they were swimming, were measured in a water mount with an ocular micrometer. The measurement of the breadth of the furcae excludes the fins, which in preserved material are often bent or shrunk. The averages of ten measurements are given in micra, with the ranges in brackets: body length, 95 (82-108); body breadth at widest part, 27 (21-32); tail-stem length, 196 (180-213); tail-stem breadth, 19 (16-21); furca length, 63 (54-73); furca breadth, 7 (5-9); anterior organ length, 18 (16-19); anterior organ breadth, 16 (14-19).

A difficulty encountered in studying this cercaria was the impossibility of making a ventral mount during life, partly because of the lateral compression of the body, and partly because of the stiff cuticular crest. Hence the measurement given as "body breadth" is more exactly "body depth."

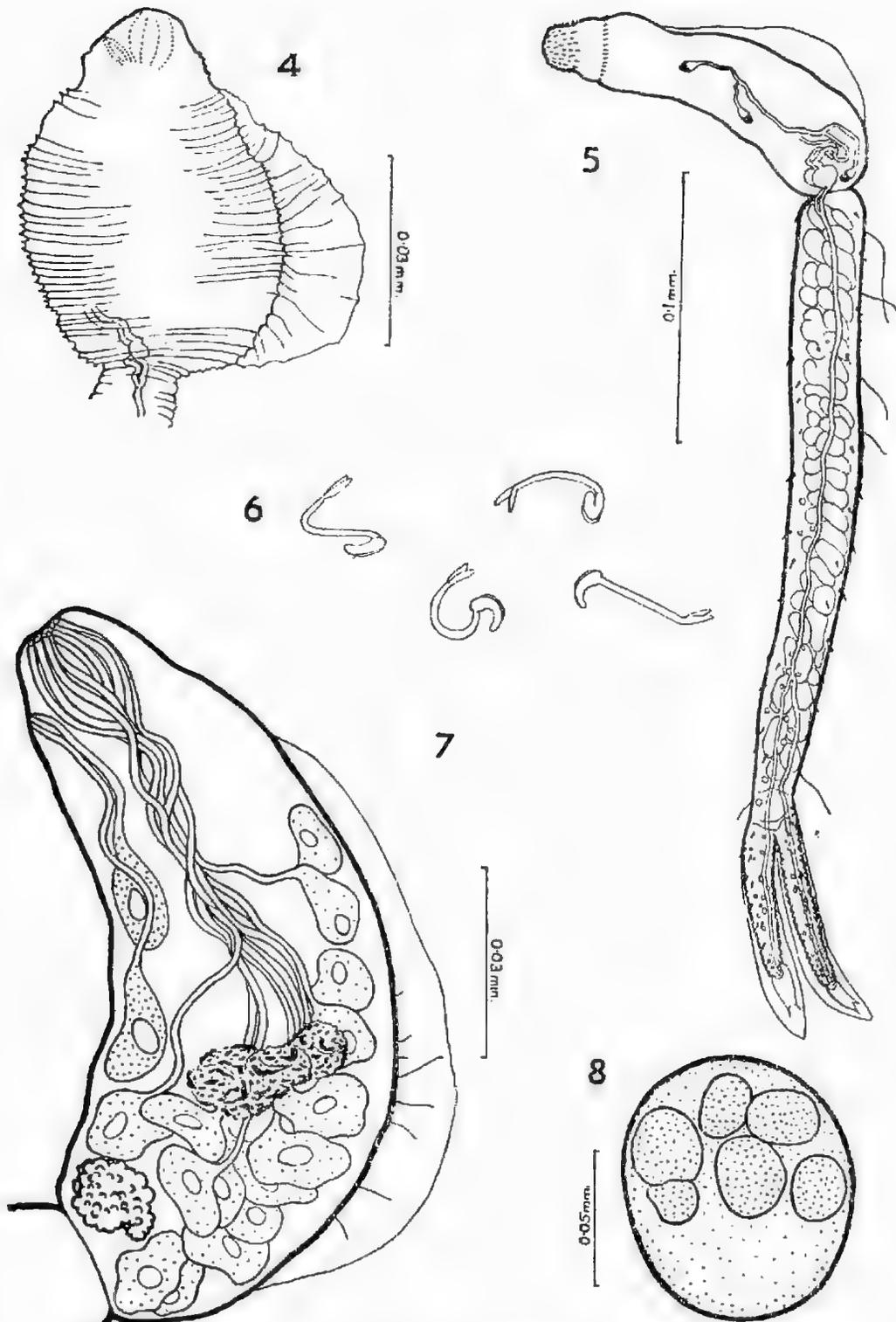


Fig. 4-8; *C. laphosoma*

4, body greatly contracted; 5, general features of body and tail, and excretory system; 6, various positions assumed when floating; 7, body in extended position, showing glands, central granular mass, and genital primordium; 8, sporocyst. Fig. 4, 5, and 7 drawn from living specimens, outlines with camera lucida; fig. 6 drawn freehand from living specimens in a drop of water without coverslip; fig. 8 drawn with camera lucida from Canada balsam mount.

The body of the cercaria is, like that of *C. helvetica xvi* (Dubois 1927, p. 27) highly contractile. There are five to six rows of fine straight spines round the front of the anterior organ. There are no further spines on the body, although when greatly contracted it has a spiny appearance, due to the intense wrinkling of the rather stiff cuticle (fig. 4). Small spines are scattered along the borders of the tail-stem, and more thickly on the fleshy part of the furcae.

The anterior organ is highly contractile and, as in Sewell's Indian *Lophocercariae* (1922, p. 46), definitely snout-like. There are no "hollow, conical spines" on the tip of this snout, as described for several *Lophocercariae*, but at times drops of secretion from the gland-ducts which open on the anterior surface of this organ, and which are highly refractive, may be seen. There is no ventral sucker. There are no eyes, though they have been described for some *Lophocercariae*.

The glands (fig. 7) are numerous, mainly in the middle and posterior regions of the body. Neutral red and Nile blue sulphate were used as intra-vitam stains, Delafield's haematoxylin and acetic acid alum carmine for permanent preparations. Two unicellular glands in tandem are situated ventrally, their ducts passing forward to open on the ventral surface of the anterior organ, separate from the other ducts. These two glands stain deeply with both neutral red and Nile blue sulphate, while a large group of glands dorsal to, and extending posterior to them, stain more lightly with neutral red, but just as deeply with Nile blue sulphate. These glands could not be accurately counted, but number more than twelve. Their ducts pass forward together centrally, to open on the apex of the snout. In the middle part of the body is a group of deeply-staining granules surrounded by a granular mass. It could not be determined whether these were the rudiments of the ventral sucker, or part of the genital primordium. A triangular-shaped mass of cells, staining deeply with acid alum carmine and with Delafield, situated just in front of the bladder, is certainly part of the genital primordium.

No trace of a digestive system is present; not even a mouth-opening was observed. The nervous system could not be distinguished.

The dorsal crest is a conspicuous feature of this cercaria. It is fine, transparent and slightly yellow, and is apparently formed of an extension of the cuticle. Its shape varies with the extension and contraction of the body (fig. 4 and 7).

The long slender tail is, together with the furcae, two to three times as long as the body (fig. 5). It is provided with a few very fine, hair-like structures dorsally, as well as the minute spines mentioned above. There are numerous small rounded caudal bodies grouped round the central axis of the tail; these disintegrate readily under pressure. A few scattered nuclei in the tail-stem stain deeply with neutral red in life. The tail-musculature is well developed. The principal fibres run obliquely in two directions, and hence in two sets, one dorsal and one ventral; when viewed from the side they appear to be arranged in herring-bone fashion, the apices of the one set directed forward, those of the other backward. Longitudinal fibres also are present.

Each short slender furca is provided with a fine cuticular flange or fin, extending round the whole furca. Longitudinal muscle fibres are present. At the end of the furca the flange forms a pocket-like or flask-like fold, open posteriorly, as is characteristic for this type of cercaria. At the base of this pocket, on the tip of the furca, opens an excretory pore.

As far as could be determined before the host died, the excretory system is of the usual pattern, i.e., $2(2 + 1) = 6$. The two sides of the excretory system,

if it be bilateral, were, however, never seen simultaneously in one specimen. The bladder (fig. 5) is bilobed, and from each side a duct passes forward. From this point, presumably owing to the fact that a ventral view was never obtained, only one set of tubules could be seen. The main duct branches into two, one passing forward to receive the capillaries of two flame-cells, the other passing back to receive a single flame-cell at the level of the bladder. There are no flame-cells in the tail. There is a long island of Cort, from which a single duct passes back through the clusters of caudal bodies, to divide into two tubules about three-quarters of the way back along the tail-stem (fig. 5). One tubule passes into each furca, opening at the tip into the flask-like extension of the flange.

EXPERIMENTAL INFECTIONS

Unsuccessful attempts have been made to infect the fish, *Gambusia affinis* and *Carassius auratus*, and a tortoise, *Emydura macquarii*, with the cercaria.

SPORO CYST

The sporocysts are very small, round, or oval bodies (fig. 8), and at the time of examination, after the death of the host, contained only germ-balls, which stained more deeply with acid alum carmine than did the rest of the sporocyst. Large masses of these parthenitae were packed together in the liver. They vary somewhat in size, and also in shape, according to the pressure of the surrounding tissue. The average length of ten, measured with an ocular micrometer from a canada balsam mount of a stained fragment of liver, was 101 μ , varying between 84 μ and 120 μ .

RELATIONSHIPS

The "Lophocerca" group of furcocercariae, so named by Lühe in 1909 to include *C. cristata* La Valette and *C. microcristata* Ereolani, was defined fully by Sewell in his "Cercariae Indicae" (1922); the essential features of cercariae of his "Lophocerca" group being the very small size, the relatively long, brevifurcate tail with furcae provided with a fin-fold; body with a crest; eyes (in many); gland cells in mid-body; anterior organ snout-like rather than sucker-like; no mouth, alimentary canal or ventral sucker; excretory formula, $2(2+1)=6$; development in small oval or rounded sporocysts. Sewell himself added four cercariae to this group (*Cercariae indicae IX, XIII, XX, XIX, and LV*), and since then a number of other Lophocercariae have been described.

Odhaer (1911), Scheuring (1922), and Ejsmont (1925), have shown that certain forms belonging to this group develop in the blood of Cyprinid fish into species of the genus *Sanguinicola*. Wall (1939; 1940), on the other hand, described a cercaria possessing the characteristic dorsal crest, which developed into *Spirorchis parvus* Stunkard, a blood-fluke of American freshwater tortoises. However, the life-history of another species of *Spirorchis*, *S. elephantis* Cort, was described by Wall in 1941, and its cercaria possesses no dorsal crest. Thus, if the possession of a dorsal crest be the only characteristic necessary for inclusion of a cercaria in the Lophocerca group, it would at once become a highly artificial group, closely related forms being separated, and unrelated forms being grouped together. Under Sewell's more limiting definition the presence of a dorsal crest is only one of several distinguishing features, and the cercaria of *Spirorchis parvus* is excluded from the group by the possession of an alimentary canal (pharyngeal) and a ventral sucker, and by its excretory formula of $2[(1+1+1)+(1+1+(1))]=12$. Furthermore, Wall's description of the crest of the cercaria of *S. parvus* indicates that its structure is somewhat different from that of the true Lophocercariae.

C. lophosoma is a Lophocercaria belonging to Sewell's group, but distinct from all other members. In size it is closest to *C. helvetica* XVI Dubois (1929), which, like our cercaria, has numerous gland cells and no eyes. Complete comparison is not possible because Dubois' description is very brief; the host of Dubois' larva is a very different gastropod, however, *vis.*, *Lymnaea*. *C. lophosoma* differs from Sewell's *Cercaria indica* IX (from *Indoplanorbis* and *Gyraulus*), XXXIX (from *Annicola*), and LV (from *Annicola*), in having no hollow spines on the tip of the snout, no eyes (pigmented or otherwise), a greater number of glands cells distributed differently, and finally, in size—being slightly larger than *C. indica* IX, and somewhat smaller than either *C. indica* XXXIX or *C. indica* LV. *C. indica* XIII (from *Annicola* and *Melanoides*) has no apical spines, but is larger than *C. lophosoma*, possesses non-pigmented eyespots, fewer gland cells, no spines on the furcae, and a papilla-like structure ventrally, thought to be a rudimentary genital papilla. The body of Scheuring's *C. Sanguinicolae inermis* (from *Lymnaea*) is slightly larger, according to Ejsmont's figures, and the tail is larger in proportion to the body than in our cercaria. The measurements Ejsmont gives for his *C. Sanguinicolae* spp. from *Bithynia* and from *Lymnaea* are both somewhat larger than those of *C. lophosoma*; he shows two excretory canals in the tail-stem, and though the large number of gland cells is suggestive of our cercaria, Ejsmont figures also a short, blindly-ending gut, in a somewhat similar position to the two special gland cells of *C. lophosoma*.

C. cristata La Valette (1852), from *Lymnaea*, which Sewell considered (p. 53) might be the same organism as his *C. indica* XIII, is a larger cercaria than ours, according to Ejsmont's figures; the cercaria which Wesenberg-Lund (1934) describes as *C. cristata* has the same body measurement as *C. lophosoma*, but the tail-stem is longer and the furcae very much longer; there are special apical spines, two excretory canals in the tail-stem, and the sporocysts are long and provided with a sucking disc. *C. microcristata* (from *Bithynia*) is, according to figures given by Ejsmont, smaller than *C. lophosoma* and all other known Lophocercariae.

Martin (1944) redescribed a marine Lophocercaria, previously described by Linton (1915), and named *C. loossi* by Stunkard (1929). This larva is remarkable for having as its host an annelid worm, *Hydroides*. In all other respects it is closely allied to the Lophocerca group, and the sporocysts are apparently of the characteristic type. Both Linton and Martin consider it closely related to cercariae of the genus *Sanguinicola*. It is, however, quite distinct from *C. lophosoma* in being larger, but with furcae shorter, and in having twelve to thirteen rows of spines around the snout, and fewer glands, arranged differently.

C. lophosoma is distinct from *C. sewelli* Faust (1926), from *Burnupia*, which is larger, has only two pairs of glands, a pair of partly-pigmented eyes, and as far as can be seen from the figure, no fin-folds on the furcae. Three other dorsally-crested cercariae, *C. whitentoni* Croft 1933, *C. brevifurca* McCoy (1926) from *Planorbis*, and *C. bombayensis* No. 8 Soparkar (1921) from *Planorbis* and *Lymnaea*, show somewhat dubious affinities with true Lophocercariae, because all possess simple, apharyngeal alimentary canals, and fin-less furcae, and they develop in rediae. *C. bombayensis* No. 8 and *C. whitentoni* possess also a rudimentary ventral sucker, and the excretory systems are more complex than that of the true Lophocerca type. It is possible that these three cercariae may be more closely related to *Spirorchis* or perhaps to *Clinostomum*, since the cercaria of *Clinostomum marginatum* has a dorsal crest, finless furcae, alimentary canal, ventral sucker rudiment, and five pairs of flame cells, and develops in rediae (Krull 1934).

SUMMARY

Cercaria ancyli n. sp., a parasite of *Ancylus australicus* and *Amerianna pyramidata*, is a longifurcate pharyngeal strigeid distome cercaria with six penetration glands, head glands, ten flame cells, an excretory commissure behind the ventral sucker, very short gut, and a furcal spur. Metacercaria and life cycle are unknown.

Cercaria lophosoma n. sp., a parasite of *Notopala hanleyi*, is a dorsally-crested brevifurcate, non-ocellate cercaria with numerous unicellular glands, but without a ventral sucker or alimentary canal. It belongs to Sewell's group, Lophocercaria, and is closely related to the cercaria of *Sanguinicola*.

LITERATURE

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ROYAL SOCIETY OF SOUTH AUSTRALIA (INCORPORATED)
Receipts and Payments for the Year ended 30 September 1947

RECEIPTS				PAYMENTS			
	£	s.	d.	£	s.	d.	
To Balance, 1 October 1946	113	11	4				By Transactions (Vol. 70, Pt. 2)
Less Endowment Fund	15	15	0				(Vol. 71, Pt. 1)
				97	16	4	Printing
„ Subscriptions				159	12	0	451 6 5
„ Government Grant for Printing, etc.				299	10	8	Illustrating
„ Sale of Publications and Reprints:—							81 11 0
University of Adelaide	56	19	9				Publishing
Sundries	48	3	2				47 10 0
				105	2	11	„ Reprints
„ Use of Room				8	11	0	„ Librarian
„ Miscellaneous				0	15	11	„ Sundries—
„ Interest: Transferred from Endowment Fund				202	3	2	Lighting
							Printing, Postages and Stationery
							Petties, Cheque Book, etc.
							Insurances
							Cleaning Rooms
							63 6 9
							„ Balances—30 Sept. 1947—
							Savings Bank of S. A.
							Bank of Aus- tralia ..
							Less Out- standing Cheques ..
							106 15 8
				£873	12	0	
							£873 12 0

ENDOWMENT FUND as at 30 September 1947
(Capital—Stock, etc., Face Value, £6,042 18s. 7d.; Cost, £6,041 8s. 7d.)

1946—October 1				1947—September 30			
	£	s.	d.	£	s.	d.	
To Balance—							By Revenue Account
Aust. Incribed Stock 6,008	10	0					202 3 2
Savings Bank of S.A.	17	3	7				„ Balance—
Bank of Australasia	15	15	0				Aust. Incribed Stock 6,008
				6,041	8	7	Savings Bank of S.A.
„ Interest—							6,041 8 7
Incribed Stock	200	9	6				
Savings Bank of S.A.	1	13	8				
				202	3	2	
				£6,243	11	9	
							£6,243 11 9

Audited and found correct. The Stock and Bank Balances have been verified by certificates from the respective institutions.

O. GLASTONBURY, F.A.I.S., A.F.I.A. }
F. M. ANGEL } Hon. Auditors

HERBERT M. HALE,
Hon. Treasurer

Adelaide, October 1947

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. MANIGAN, M.A., B.E., D.Sc., F.G.S.
 1946 HERBERT M. HALE

LIST OF FELLOWS, MEMBERS, ETC.

AS AT 30 SEPTEMBER 1947

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 Secretary.

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., 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.

FELLOWS.

1945. ARNIE, 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., Box 4331, G.P.O., Melbourne, Victoria—Council, 1937-42.
 1931. ANDREW, REV. J. R., c/o 212 Young Street, North Unley.
 1935. *ANDREWARTHA, H. G., M.Agr.Sc., D.Sc., Waite Institute (Private Mail Bag), Adelaide.
 1935. *ANDREWARTHA, Mrs. H. V., B.Agr.Sc., M.S., (nec 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 2 Moore Street, Toorak, Adelaide.
 1945. BARTLETT, H. K., L.Th., Burra, S.A.
 1932. BEGG, P. R., D.D.Sc., L.D.S., Shell House, 170 North Terrace, Adelaide.
 1928. BEST, R. J., M.Sc., F.A.C.I., Waite Institute (Private Mail Bag), Adelaide.
 1934. BLACK, E. C., M.B., B.S., Magill Road, Tranmere, Adelaide.
 1945. BONYTHON, C. W., B.Sc., A.A.C.I., 269 Domain Road, South Yarra, S.E. 1, Vict.
 1940. BONYTHON, SIR J. LAVINGTON, 263 East Terrace, Adelaide.
 1945. BOOMSMA, C. D., B.Sc.For., 2 Celtic Avenue, South Road Park, S.A.
 1945. BROUGHTON, A. C., Mt. Sella Station, via Copley, S.A.
 1947. BOWES, D. R., B.Sc., 51 Eton Street, Malvern.
 1939. BROOKMAN, Mrs. R. (nec A. Harvey), R.A., Meadows, S.A.
 1944. BURRIDGE, MISS N. T., M.Sc., C.S.I.R. Div. Plant Industry, P.O. Box 109, Canberra, A.C.T.
 1923. BURDON, R. S., D.Sc., University of Adelaide.
 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.), Dept. For., Mount Crawford Forest, S.A.

Date of Election.

1929. CHRISTIE, W., M.B., B.S., Education Department, Social Services, 51 Pirie Street, Adelaide—*Treasurer*, 1933-38.
1925. *CLELAND, PROF. J. B., M.D., University of Adelaide—*Verco Medal*, 1933; *Council*, 1921-26, 1932-37; *President*, 1927-28; 1940-41; *Vice-President*, 1926-27, 1941-42.
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., University, Adelaide—*Council*, 1933-41, *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.
1924. DE CRESIGNY, SIR C. T. C., D.S.O., M.D., F.R.C.P., 219 North Terrace, Adelaide.
1937. *CROCKER, R. L., M.Sc., Waite Institute (Private Mail Bag), Adelaide—*Secretary*, 1943-45; *Council*, 1945-47.
1941. *DICKINSON, S. B., M.Sc., Govt. Geologist, Mines Department, Flinders Street, Adelaide.
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., 11 Cross Road, Kingswood, S.A.
1933. †EARDLEY, Miss C. M., B.Sc., Waite Institute (Private Mail Bag), 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.
1944. FERRIS, MISS H. M., B.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., B.Sc., 297 Cross Roads, Clarence Gardens, Adelaide.
1935. *GLASTONBURY, J. O. G., B.A., M.Sc., Dip.Ed., Beatty Terrace, Murray Bridge, S.A.
1919. †GLASTONBURY, O. A., Adelaide Cement Co., Grenfell Street, Adelaide.
1927. GODFREY, F. K., Robert Street, Payneham, S.A.
1935. †GOLDSACK, H., Coromandel Valley, S.A.
1939. GOODE, J. R., B.Agr.Sc., P.O. Box 180, Whyalla, S.A.
1925. †GOSSE, SIR JAMES H., Gilbert House, Gilbert Place, Adelaide.
1910. *GRANT, PROF. SIR KERR, M.Sc., F.I.P., University of Adelaide.
1930. GRAY, J. T., Orrooro, S.A.
1933. †GREAVES, H., Director, Botanic Gardens, Adelaide.
1904. GRIFFITH, H. B., Dunrobin Road, Brighton, S.A.
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*, 1931-31; *Vice-President*, 1934-35, 1937-38; *President*, 1936-37; *Treasurer*, 1938-.
1946. *HADBY, MRS. J. E. (nee A. C. Beckwith), M.Sc., 59 Greenhill Road, Toorak Gardens, S.A.
1944. HARRIS, J. R., B.Sc., 94 Archer Street, North Adelaide, S.A.
1947. HENDERSON, D. L. W., Craigstone, Woodford, N.S.W.
1944. HERRIOT, R. L., B.Agr.Sc., Soil Conservator, Dept of Agriculture, S.A.
1924. *HOSSFELD, P. S., M.Sc., 132 Fisher Street, Fullarton, S.A.
1944. HUMBLE, D. S. W., 238 Payneham Road, Payneham, S.A.
1947. HUTTON, J. T., B.Sc., 13 Sherbourne Road, Medindie Gardens, S.A.
1928. IFOULD, P., Kurralla, 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, Adelaide.
1945. *JESSUP, R. W., B.Sc., 3 Alma Road, Fullarton, S.A.
1910. *JOHNSON, E. A., M.D., M.R.C.S., "Tarni Warra," Port Noarlunga, 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*, 1933-40; *Rep. Fauna and Flora Board*, 1932-39; *Editor*, 1943-45.
1939. †KHAKHAR, H. M., Ph.D., M.B., F.R.G.S., Khakar Buildings, C.P. Tank Road, Bombay, India.
1933. *KLEEMAN, A. W., M.Sc., University of Adelaide; *Secretary*, 1945-.
1945. LAYTON, E. E. T., Colonial Sugar Refinery Co., King William Street, Adelaide.
1922. LONDON, G. A., M.D., B.S., F.R.C.P. AM.P. Building, King William Street, Adelaide.
1931. LUDBROOK, MRS. W. V., (nee N. H. Woods), M.A., Elimatta Street, Reid, A.C.T.
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.

Date of
Election.

1929. MARTIN, F. C., M.A., Technical High School, Thebarton, S.A.
 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.
 1920. MAYO, THE HON. MR. JUSTICE, LL.B., K.C., Supreme Court, Adelaide.
 1943. MCCARTHY, MISS D. F., B.A., B.Sc., 70 Halton Terrace, Kensington Park.
 1944. MCGILP, L. K., Ramsgate Hotel, Henley Beach, S.A.
 1944. *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.
 1940. MORLOCK, J. A. T., 37 Currie Street, Adelaide.
 1936. *MOUNTFORD, C. P., 25 First Avenue, St. Peters, Adelaide.
 1944. MURKELL, J. W., Engineering and Water Supply Dept., Port Road, Thebarton, S.A.
 1944. NINNES, A. R., B.A., 62 Sheffield Street, Malvern, S.A.
 1945. *NORTHCOTE, K. H., B.Agr.Sc., A.I.A.S., 16 Carlton Street, Rosefield, S.A.
 1930. OCKENDEN, G. P., Primary School, Woodville, 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., B.Sc., c/o Mines Department, Flinders Street, Adelaide.
 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.
 1947. POYNTON, J. O., M.D., M.A., Ch.B., M.R.C.S., L.R.C.P., University of Adelaide.
 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.Por., 32 La Perouse Street, Griffith, N.S.W.
 1937. *RAIT, W. L., M.Sc., Medical School, University of Melbourne, Carlton N. 3, Victoria.
 1944. RICKMAN, D. S., B.Agr.Sc., C.S.I.R., Division of Nutrition, Adelaide.
 1925. RICHARDSON, A. E. V., C.M.G., M.A., D.Sc., 314 Albert Street, East Melbourne.
 1947. RIEDEL, W. R., B.Sc., St. Mark's College, Pennington Terrace, North Adelaide.
 1947. RIX, C. E., 42 Waimouth Avenue, Glandore, S.A.
 1946. ROBINSON, E. G., B.Sc., 42 Riverside Drive, Sudbury, Ontario, Canada.
 1945. RYMIILL, J. R., Old Penola Estate, Penola, S.A.
 1944. *SANDARS, MISS D. F., University of Queensland, Brisbane, Queensland.
 1933. SCHNEIDER, M., M.B., B.S., 175 North Ter., Adelaide.
 1924. *SEGNI, 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.
 1946. *SEIGNIT, E. R., M.Sc., C.S.I.R., Division of Industrial Chemistry, Box 4331, G.P.O., Melbourne, Victoria.
 1925. *SHEARD, H., Port Elliot, S.A.
 1936. *SHEARD, K., Fisheries Research Div. C.S.I.R., c/o Institute of Agriculture, Univ., W.A.
 1945. SHEPHERD, J. H., B.Sc., B.A., c/o Zinc Corporation, Broken Hill, N.S.W.
 1934. SILKFIELD, R. C., Salisbury, S.A.
 1942. SIMONOVIS, H. W., 130 Fisher Street, Fullarton, S.A.
 1938. *SIMPSON, MRS. E. R., M.Sc., Warland Road, Burnside.
 1924. SIMPSON, F. N., Pirie Street, Adelaide.
 1944. SMITH, C. A. N., B.Agr.Sc., Waite Institute (Private Mail Bag), Adelaide, S.A.
 1941. SMITH, T. LANGFORD, B.Sc., Department of Post War Reconstruction, Canberra, A.C.T.
 1941. SOUTHCOIT, 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., Woottona Ter., Glen Osmond, S.A.
 1947. SPEIGHT, R. L., B.Sc., 15 Main Road, Richmond, S.A.
 1936. *SPRIGG, R. C., M.Sc., Mines Department, Flinders Street, Adelaide.
 1947. SPURLING, M. B., B.Sc., Department of Agriculture, Adelaide.
 1938. *STEPHENS, C., G., M.Sc., Waite Institute (Private Mail Bag), Adelaide.
 1935. STRICKLAND, A. G., M.Agr.Sc., 11 Woottona 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; *President*, 1947-.

Date of
Election.

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.
1938. *THOMAS, MRS. I. M., (nee P. M. Mawson), M.Sc., 12 Broadway, Glenelg.
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*, 1947-.
1945. TIVER, N. S., 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; *President*, 1946-47.
1894. *TURNER, A. J., M.D., F.R.E.S., Dauphin Terr., Brisbane, Qld.
1925. TURNER, D. C., Brookman Buildings, Grenfell Street, Adelaide.
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., Canberra, A.C.T.
1936. WATERHOUSE, MISS L. M., 35 King Street, Brighton, S.A.
1942. WATSON, R. H., Central Wool Committee Testing House, 572 Flinders Lane, Melb., Cl.
1939. *WEEDING, REV. B. J., P.O. Box 51, Minlaton, S.A.
1946. WHITTLE, A. W. G. B.Sc., Bridgewater, S.A.
1931. WILSON, C. E. C., M.B., B.S., "Woodfield," Fisher Street, Fullarton, Adelaide.
1946. WILSON, A. F., M.Sc., University of Adelaide.
1944. WILSON, E. C., M.A., B.Sc., High School, Renmark, S.A.
1938. *WILSON, J. O., C.S.I.R. 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., 43 Carlisle Road, Westbourne Park, S.A.
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-.
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