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THE ECOLOGY OF THE AREA ADJACENT TO LAKES ALEXANDRINA AND ALBERT

BY R. W. JESSUP, DEPARTMENT OF BOTANY, UNIVERSITY OF ADELAIDE

Summary

This paper is concerned with the ecology of the area which links the Savannah Woodlands communities of the eastern Mount Lofty Ranges with the communities of the South-East of South Australia on the one hand and the mallee communities of the Murray Mallee on the other. More specifically the survey embraces the Hundreds of Manarto, Mobilong, Freeling and Brinkley of County Sturt and Malcolm, Seymour, Coolinong, Jeffries and Bonney of County Russell, representing a total of 1,100 square miles. Fig. 1 shows the relationship of the area to the rest of the State. On account a lack of development, due to comparatively low rainfall and poor natural conditions of soil, much of it is relatively inaccessible.

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By R. W. JESSUP, Department of Botany, University of Adelaide

[Read 15 November 1945]

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INTRODUCTION

This paper is concerned with the ecology of the area which links the Savannah Woodland communities of the eastern Mount Lofty Ranges with the communities of the South-East of South Australia on the one hand and the mallee communities of the Murray Mallee on the other. More specifically the survey embraces the Hundreds of Monarto, Mobiling, Freeling and Brinkley of County Sturt and Malcolm, Seymour, Coolinong, Jeffries and Bonney of County Russell, representing a total of 1,100 square miles. Fig. 1 shows the relationship of the area to the rest of the State. On account of a lack of development, due to comparatively low rainfall and poor natural conditions of soil, much of it is relatively inaccessible.

With regard to previous literature, Wood's "Vegetation of South Australia" (21) gives a good general account, while Crocker (5) has adequately dealt with the ecology of the lower South-East. The soils of the mallee have been investigated by Prescott and Piper (15), while soils related to some of those considered in this paper have been described by Taylor (19) in the upper South-East and Stevens *et alia* (18) in the lower South-East.

CLIMATE

The greater part of the area lies within Davidson's (6) warm temperate semi-arid zone with P/E greater than 0.5 for five months of the year, but in the western and south-easterly portions P/E exceeds 0.5 for seven months of the year. This is within the warm temperate semi-humid zone.

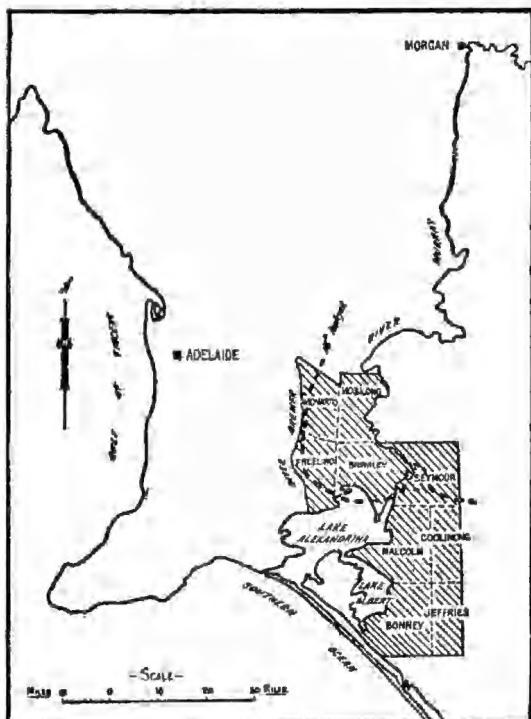


Fig. 1 Map showing the locality of the area surveyed

The influential rains fall in the winter and spring, with June the month of highest rainfall (fig. 2). Murray Bridge has a secondary maximum in September. Figures for temperature and relative humidity are only available for Strathalbyn, which lies just outside the western limits of the area. Relative humidity is low, particularly in the summer.

GEOLOGY AND PHYSIOGRAPHY

Broadly the surface deposits consist of level-bedded Miocene limestones overlain by much wind-blown sand of Pleistocene to Recent origin (7). Interposed between the light grey wind-blown sands of the southern portion of the area and the consolidated Miocene limestone is a layer of mixed calcareous and siliceous sands unconsolidated except for an indurated capping. The calcareous and siliceous sands form both dune sheets and dunes, the system being related to the Pleistocene coastal dunes of the lower South-East. This period of oscillating land and sea level has also resulted in the formation of limited areas of raised Pleistocene shell beds. According to Howchin (8) the Coorong, which may represent to some extent a former outlet of the River Murray in a more southerly direction, was formed during these times. The presence of lacustrine deposits overlying the wind-blown sands adjacent to Lakes Alexandrina and Albert indicates inundations following the arid Recent.

Topographically the area consists of gently undulating plains, but to the west of the mallee plains the land rises fairly rapidly to the Bremer Range, which is the

eastern-most block of the Mount Lofty Ranges. Underlying the Miocene limestone and occasionally outcropping is a granite batholith of Palaeozoic or Pre-Cambrian age (10). According to Fenner (7) these hard, older rocks may have influenced the course of the lower Murray, causing it to swing westerly from Chucka Bend, carrying it to Tailem Bend instead of following the normal fall of the land.

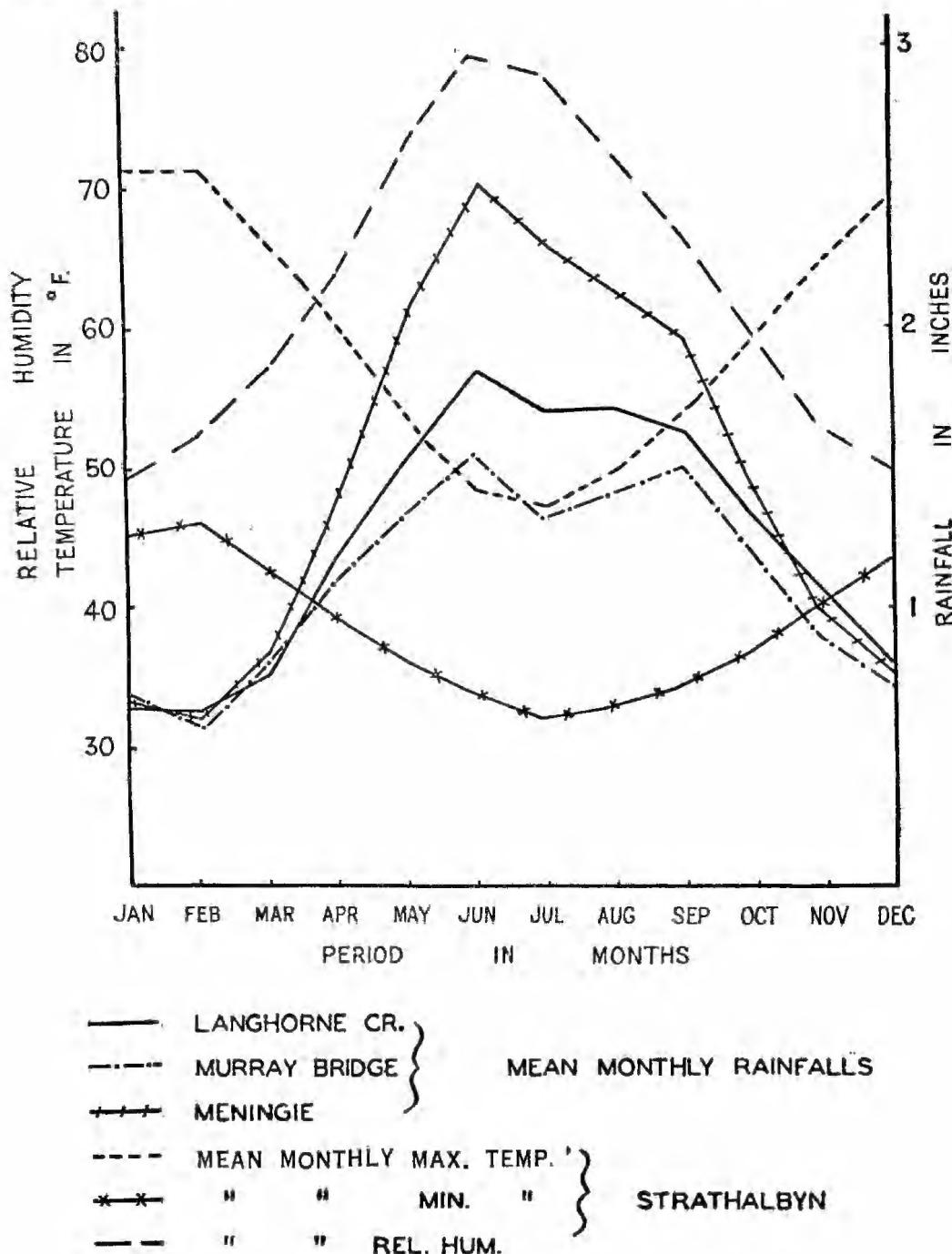


Fig. 2

THE SOILS

The soils are very closely related to the geology, so much so that certain difficulties are encountered in their classification. They can, however, be grouped as follows:

- 1 Soils derived from underlying sedimentaries (red-brown earths).
- 2 Podzols with solonized subsoils.
- 3 Weakly solonized brown soils.
- 4 Soils of intermediate nature.
- 5 Soils of partly lacustrine origin.
- 6 Soils derived from igneous parent materials.

1 RED-BROWN EARTHS

These soils have been derived from the underlying sedimentaries of the Adelaide Series (Proterozoic), which have undergone various degrees of metamorphism due to intrusion of igneous material. They are closely related to, if not identical with, red-brown earths and carry an *E. odorata*-*E. leucoxylon*-*E. fasciculosa* association, which is replaced by *C. stricta* on shallow skeletal soils which are common on the steeper hills. Some profiles show an accumulation of lime above the sedimentaries. To the east, with decreasing rainfall, these red-brown earths are replaced by brown weakly solonized soil. The transition zone is rather broad and Table I gives the results of laboratory analyses of a profile from this zone. In this case no horizons are developed and there is considerable lime accumulation above the underlying rock. The reaction is that of a brown weakly solonized soil.

2 PODZOLS WITH SOLONIZED SUBSOILS

These soils were formed under high rainfall conditions in the Pleistocene from the calcareous and siliceous sands of the old coastal dunes and dune sheets, probable accession of cyclic salt at the time of leaching accelerating the downward movement of the clay fraction while under arid conditions in the Recent the surface sands were subjected to aeolian redistribution (Crocker—paper unpublished.) The pedogenetically related podsolized sands of the lower South-East have their podsol characters more pronounced, while in the area discussed in this paper with conditions of much lower rainfall the solonetz characters are more prominent. Thus the pH values are higher and the subsoils which are faintly mottled show fairly well-developed columnar structure, sand from the A horizons penetrating the B horizon to a depth of 7" and the tops of the columns varying in diameter from 3 to 9 inches. Beneath the columns the subsoils show a nutty structure.

Soils of this group are widespread in the region surveyed and are associated with three major types of vegetation: (a) mallee-heath and heath; (b) *E. diversifolia*-*E. angulosa* association; and (c) *E. angulosa*-*M. mucinata* association. The profiles correspond to descriptions given by Taylor (19) of light and normal phases of the Laffer sand, and others to the Hill Country suite. For convenience the soils are discussed in three sections:

(a) *Mallee-heath and heath soils*—Over the greater part of the area shown on the vegetation map as mallee-heath and heath the soil is a Laffer sand. There are two phases: (a) light phase, lacking a sandy clay loam subsoil, and (b) normal phase (pl. iii, fig. 2). On sandy rises the soil profile corresponds to descriptions given for the low sandy rise type of the Hill Country suite. The soils occupy a gently undulating plain which is not subject to water-logging, although the water table, which is usually at a depth of 10-15', may come to within 6' of the surface. Analyses of the ground water have shown a variation of from 1-6% total soluble salts. Outcrops of limestone are not infrequent.

PROFILE CHARACTERISTICS OF THE PODSOLS WITH SOLONIZED SUBSOILS

(1) Heath and mallee-heath soils

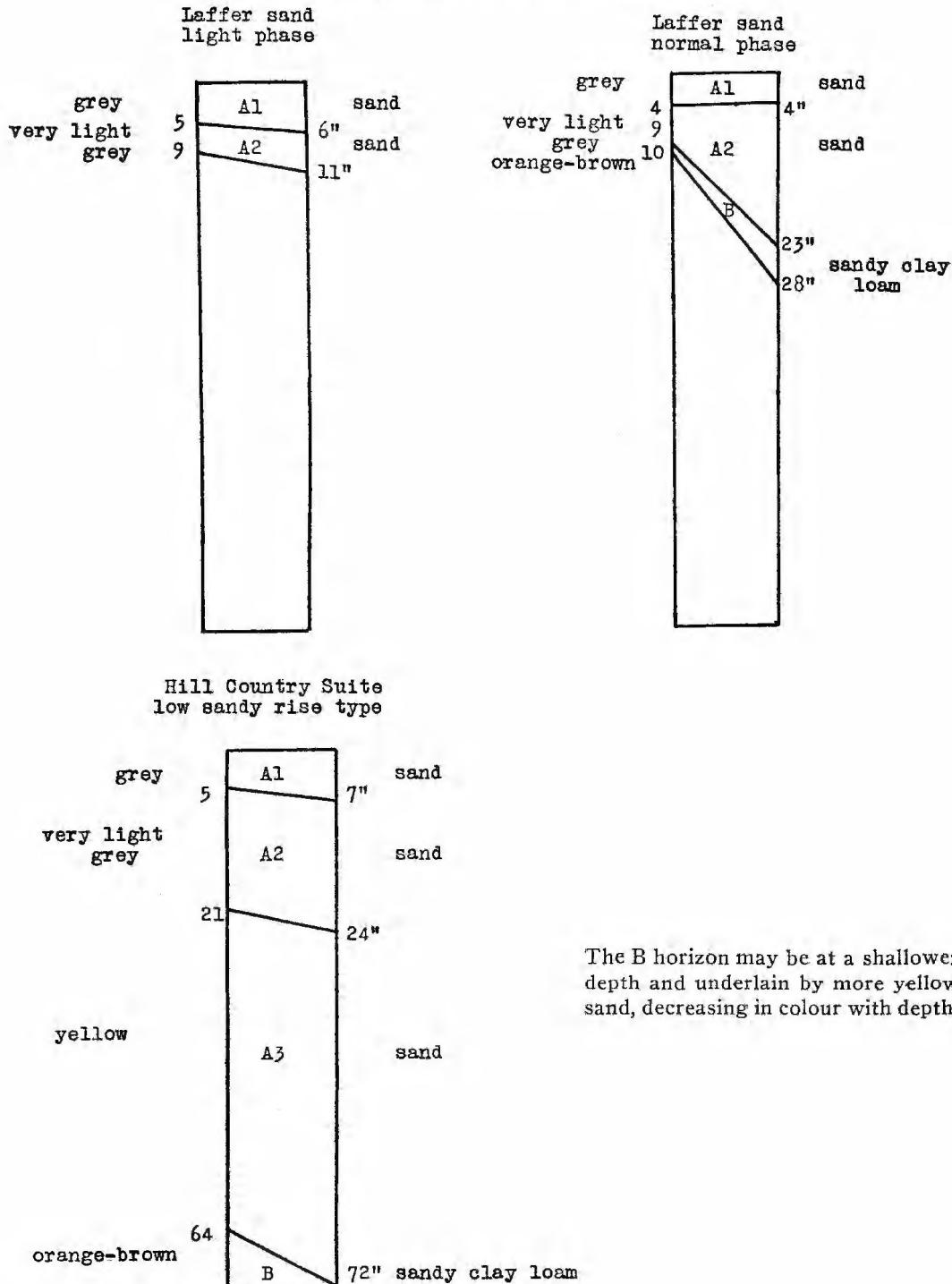


Fig. 3a

PROFILE CHARACTERISTICS OF THE PODSOLS WITH SOLONIZED SUBSOILS

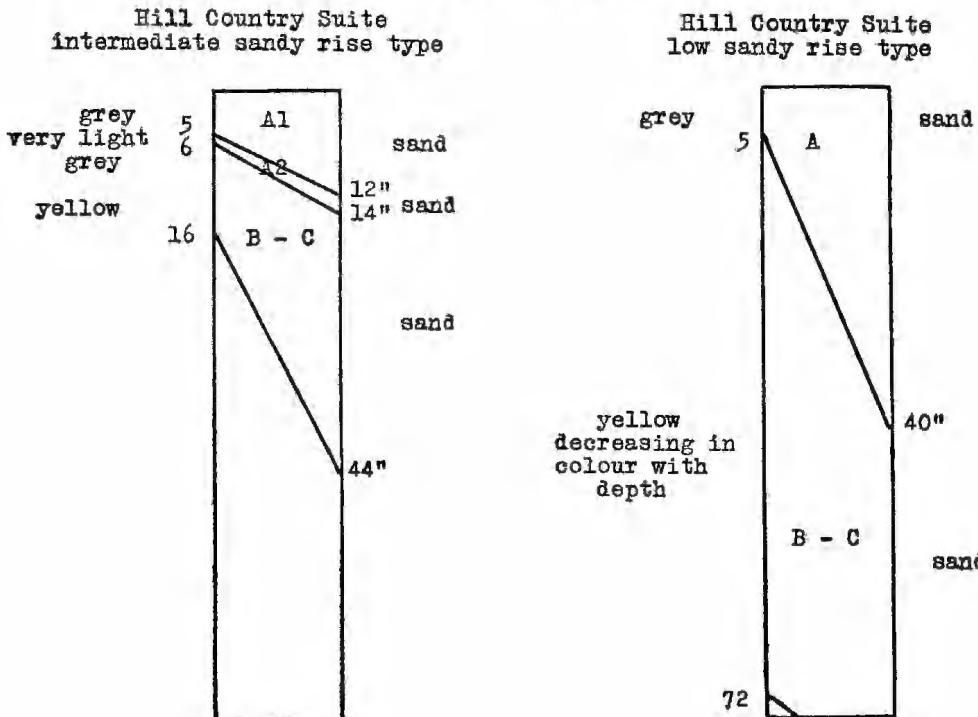
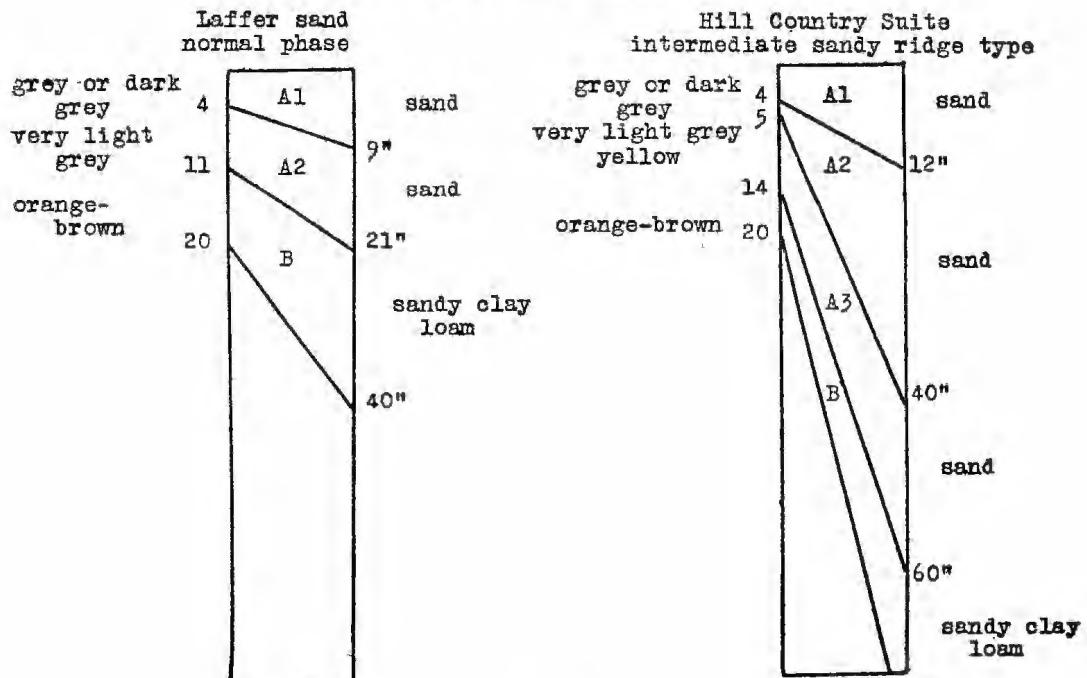
(2) *E. diversifolia*-*E. angulosa* soils.(3) *E. angulosa*-*M. uncinata* soils.

Fig. 3b

Table II gives the results of laboratory analyses of these soils. Mechanical analysis shows that the surface horizons contain a preponderance of coarse over fine sand and that the amount of coarse sand decreases with depth. As with brown weakly solonized soils, the silt content is low and the amount decreases through the surface horizons. Outstanding among the chemical data are the very low figures for phosphoric acid (.005% P₂O₅) and acid soluble manganese (30 parts Mn₂O₄ per million). The parent material of the soil itself is deficient in phosphorus. Prescott (14) has shown the nitrogen content of these soils to be strictly proportional to the phosphate level. In connection with the nitrogen estimations, it should be noted that a considerable proportion of the organic matter is very resistant to decomposition and therefore of little immediate use to the plant as a source of nitrogen. In addition to deficiencies in the major plant foods, various minor elements, notably copper and zinc, are lacking [Riceman and Anderson (17)]. The pouness of the soil is reflected in both the native vegetation and the stock grazing upon it.

(b) *Soils associated with the E. diversifolia - E. angulosa association*—The area indicated on the vegetation map as *E. diversifolia - E. angulosa* association is topographically one of low sand dunes (in the coastal region) and low limestone hills. The soils belong to the Hill Country suite. There is only a limited extent of Taylor's low sandy rise soil type, since it is found only in some of the hollows between the crests of the coastal dunes. It is usually associated with *E. leucoxylon* var. *pauperila*. Outstanding features of the profiles are the great depths of yellow sand whose intensity of colour decreases with depth, and the complete absence of a subsoil.

It is noteworthy that the reaction of a sample taken in the coastal *E. diversifolia - E. angulosa* association (Table III) is higher than that indicated in Table II, where the sample was taken further inland from the coast.

(c) *Soils associated with the E. angulosa - Melaleuca uncinata association*.—Here again the profiles correspond to descriptions given for the normal phase of the Laffer sand and the intermediate sandy ridge type of the Hill Country suite. There is, however, a greater depth of sandy clay loam subsoil. Throughout the area shown on the vegetation map as alternating *E. oleosa - E. dumosa* and *E. angulosa - M. uncinata* associations, the leached sands which support the latter community are present as sandridges showing parallelism and running approximately east-west. Between these ridges is brown weakly solonized soil supporting the *E. oleosa - E. dumosa* association (pl. ii, fig. 4). The sandridges are of variable width and distance apart. In parts the leached sands predominate, while elsewhere there is a greater proportion of brown weakly solonized soil. Near Murray Bridge the soil profile is underlain by granitic material.

3. WEAKLY SOLONIZED BROWN SOILS ("MALLEE" SOILS)

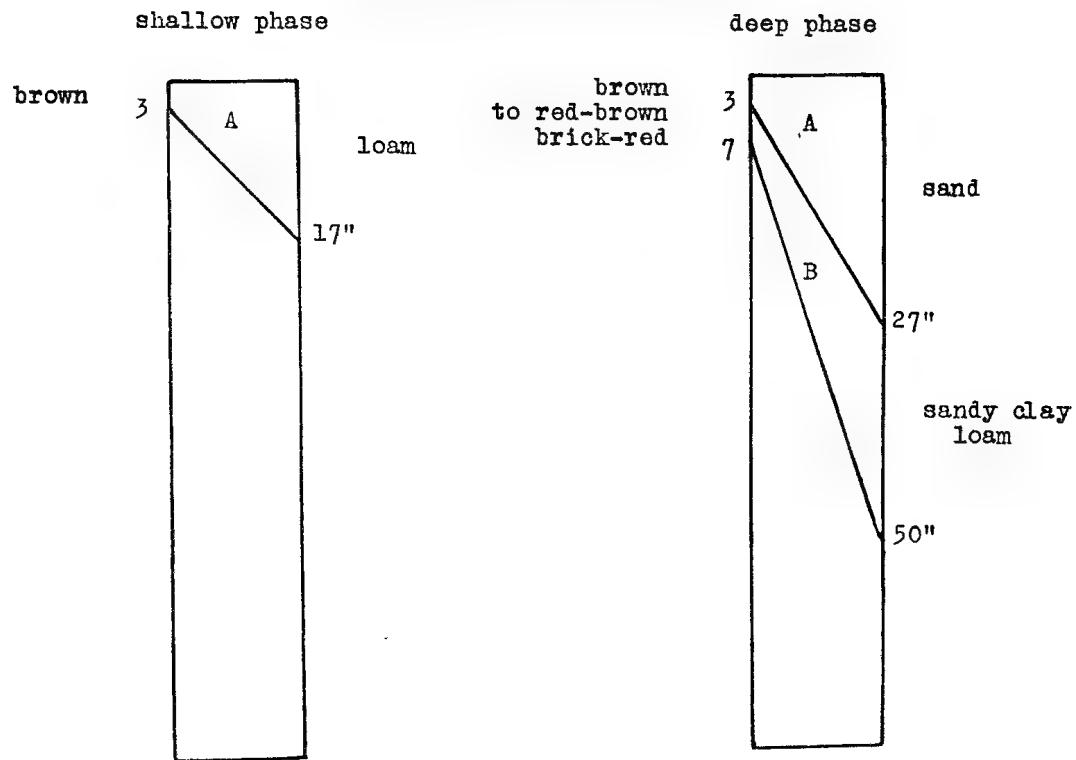
Movement of clay has occurred by the process of solonization [Prescott (13)]. The most outstanding feature is an accumulation of lime in the subsoil, either in the form of limestone rubble or as limestone hardpan which may be structureless or may consist of limestone nodules which have been cemented together by calcium carbonate. The hardpan may be 20" in thickness (pl. iii, fig. 1). Beneath this zone of maximum lime accumulation is a layer which varies in character with the nature of the underlying rock but always containing much fine-grained calcium carbonate, the amount of which decreases with depth.

Two phases may be distinguished:

(a) A shallow phase, very common in the interdune areas. Where "scalding" has occurred, limestone appears at or near the surface. Its shallow nature is its chief agricultural disadvantage.

PROFILE CHARACTERISTICS OF THE SOILS

(1) Weakly solonized brown soils



(2) Red-brown earths

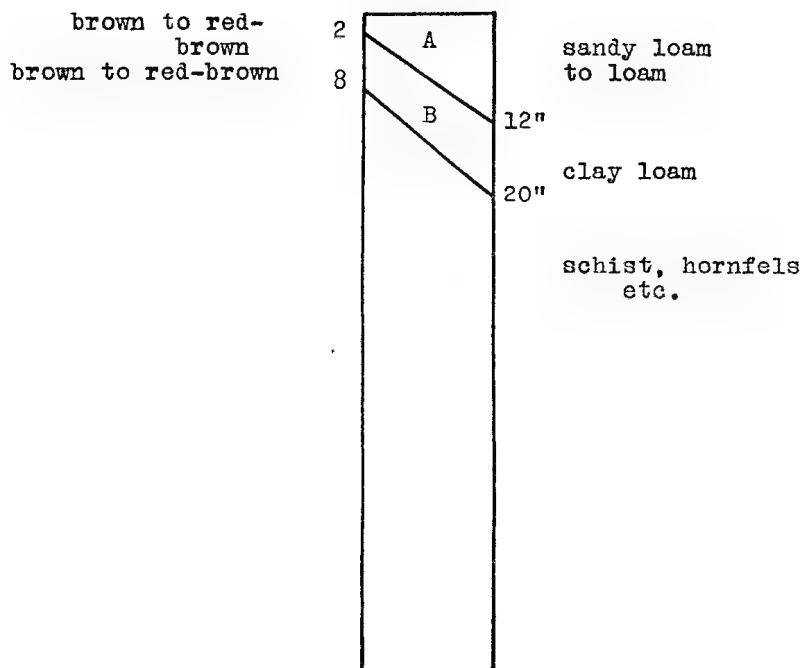


Fig. 4a

(b) A deep phase—In the deep profiles the B horizon becomes lighter in colour with depth. It has been divided into a B_1 and B_2 for analysis. Sometimes the A horizon is a dark-brown sand, and in any case the brown or red-brown sand becomes lighter in colour with depth. More rarely the lower levels of the A horizon may be a sandy loam. The deep sands often support *E. angulosa* with or without *E. oleosa*, *E. dumosa* or *E. leptophylla*.

No evidence of columnar structure is seen in the phases described above, but nutty structure may be shown by the subsoil.

Of interest is the occurrence of some localized areas in the mallee where the soil will not wet under rain. Locally these are known as "grease-spots." An examination of one such area following a rain showed that the surface soil particles had, under the influence of the drops, formed a thin crust beneath which the soil was quite dry. Even the crust was not wetted, but rather was due to compaction and rearrangement of the particles. A field estimate of texture revealed no differences from the surrounding soil. Other writers mention similar cases which are attributed to waxy or fatty substances in the soil (15).

Table V gives the results of analyses of a deep phase profile. The phosphate status of this soil is not much higher than that shown in Table IV, although potash is very much higher. Fertility in regard to nitrogen is low. There is a greater preponderance of coarse sand than in any of the podsolts with solonized subsoils.

Near Tailem Bend, on both the eastern and western side of the River Murray and in the vicinity of Ashville, are some very shallow soils having affinities with terra rossas developed on exposed limestone hardpan. The soils may be up to 6" in depth but are usually less, and are red-brown or brown sandy loams. They support *C. stricta*, *M. pubescens*, and towards their margins *E. odorata*.

4 SOILS OF INTERMEDIATE NATURE

In the Hundreds of Coolinong and Malcolm, where the brown weakly solonized soils reach the limits of their range in a southerly direction, are other soils intermediate in character between brown weakly solonized soils and podsolts with solonized subsoils. Representative profiles are shown in fig. 4 b.

Type (a) supports a small area of *E. leucoxylon* var. *pauperita*. The pH values of 7.4, 7.1 and 7.1 for the A_1 , A_2 and B_1 horizons are lower than those obtained for "mallee" soil. The percentages of total soluble salts of .02, .05 and .05 were obtained for the A_1 , A_2 and B_1 horizons respectively.

Type (b) has surface horizons similar to the Laffer sand, while the subsoil resembles that of a "mallee" profile. The values of 7.4, 6.9 and 7.3 were obtained for pH of the A_1 , A_2 and B_1 horizons respectively, and .053% and .023% for total nitrogen of the A_1 and A_2 horizons.

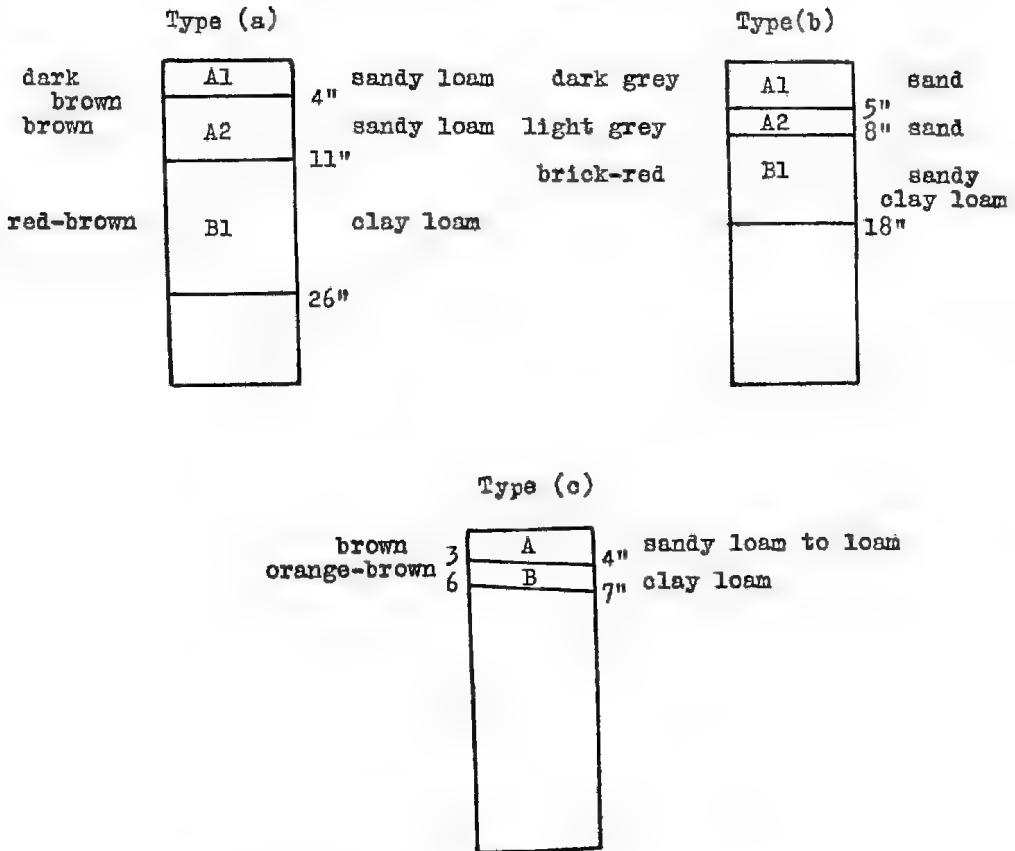
In Type (c) the values of 7.6 for the A horizon and 7.8 for the B horizon were obtained for the reaction. These are lower than corresponding reactions given by "mallee" soil. The subsoil shows strongly-developed nutty structure. The salt concentration is moderately high, as shown by the values .08% for the A horizon and .04% for the B horizon of total soluble salts.

5 SOILS OF PARTLY LACUSTRINE ORIGIN

Here two distinct types may be recognised: on the one hand the soil formed as a result of deposition of material of predominantly silty and calcareous nature, and on the other, the one formed from deposits in which sand and clay predominate. Each soil has its own distinctive associated vegetation, and in both cases the lacustrine deposits overlie an older soil profile of the Laffer sand type.

PROFILE CHARACTERISTICS OF THE SOILS

(1) Soils of intermediate nature



(2) Soils derived from igneous parent material

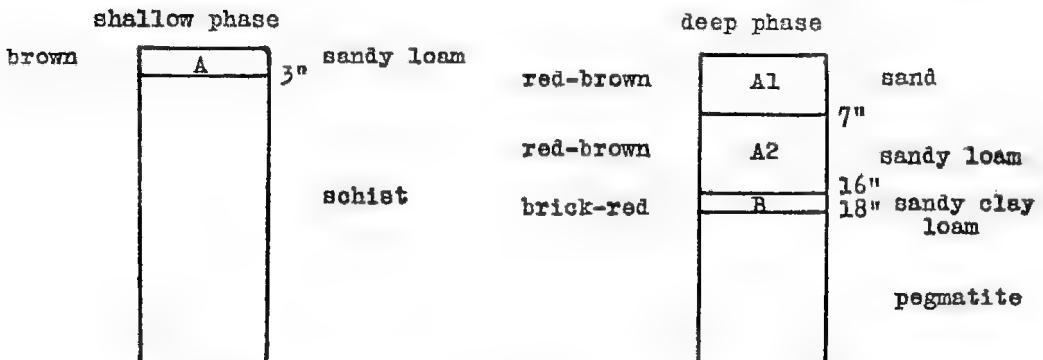


Fig. 4b

(a) *Soil developed in swampy areas of local internal drainage.*—In some swamps there is simply a considerable depth of unconsolidated calcareous material incorporated with which may be some sand and sub-fossils of the gasteropod *Coxiella confusa*. More usually, however, there is a layer of black silt loam overlying the calcareous layer. These two horizons are superimposed upon a narrow

PROFILE CHARACTERISTICS OF SOILS OF PARTLY LACUSTRINE ORIGIN
 (Due to retreat of lakes)

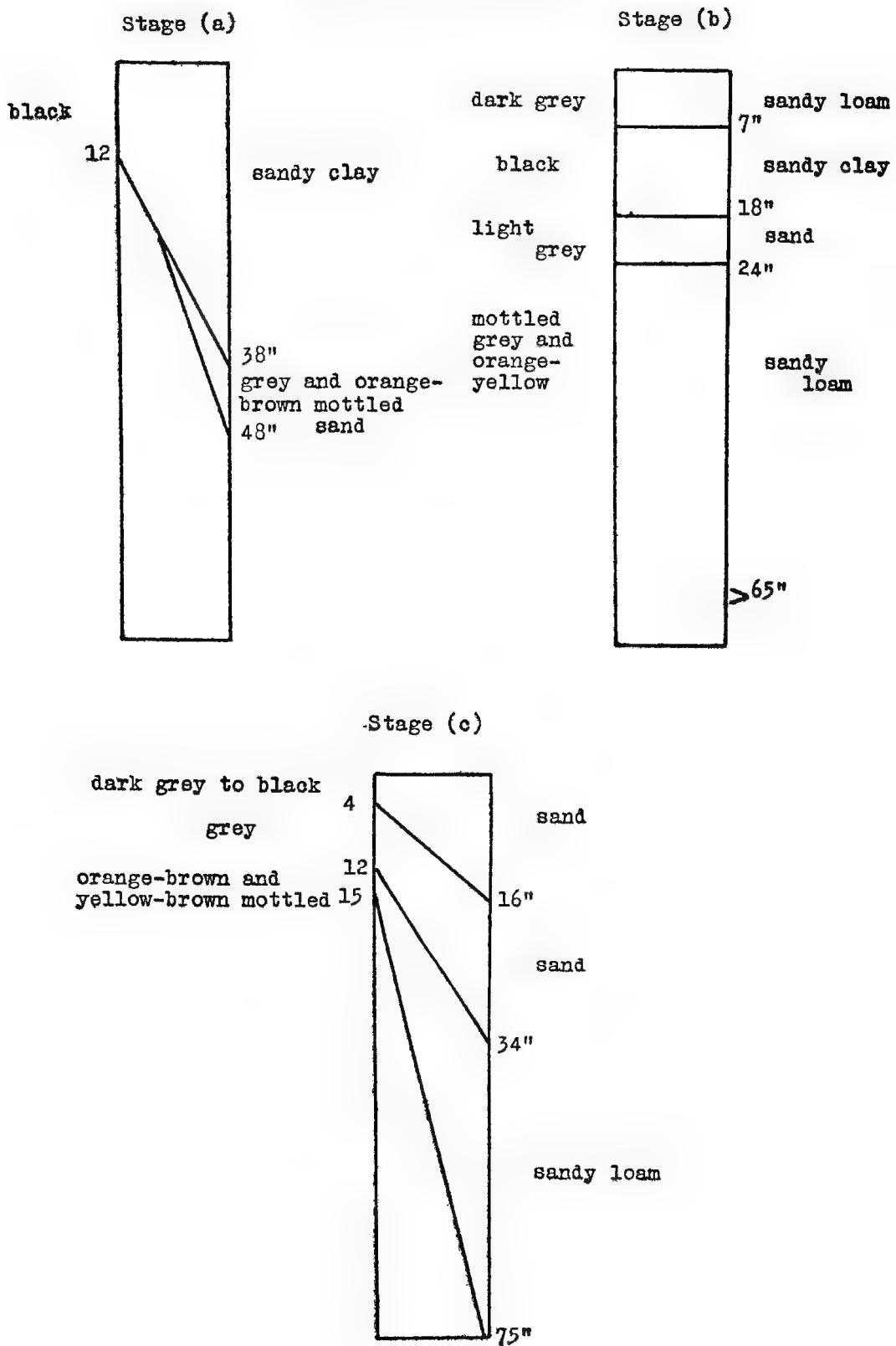


Fig. 5

grey siliceous sand layer, the A₁ horizon of the old soil profile. The old A₂ horizon is now strongly mottled, showing grey, orange and red-brown colourations due to conditions of intermittent waterlogging. Mechanical analysis reveals that this horizon contains more coarse sand than the old A₁. This is not typical of an ordinary Laffer profile.

The remaining two horizons show a marked increase in clay content. Sodium is obviously important in the base exchange complex, since in addition to pronounced plasticity and stickiness on wetting, the subsoil is impervious to water. Small limestone pebbles and fossils of *Coxiella confusa* are found in the B₂ horizon, which is a mottled green-blue and orange-brown. On the margins of the swamp the calcareous and/or sand layers do not occur. Instead, the black silt loam which may be up to 7" in depth is followed by the sand or clay layers. Of interest is the widespread occurrence beneath the silt loam of a narrow layer ($\frac{1}{2}$ - $\frac{2}{3}$ " thick) of consolidated limestone containing *Coxiella confusa* fossils.

Table VI gives the results of laboratory analyses. Outstanding features of the mechanical analysis are the figures of 35.3% obtained for silt in the silt loam horizon, and the 97% loss on acid treatment of the unconsolidated calcareous layer. Clay has been rendered mobile by solonization and has accumulated in the B horizon. Results for loss on ignition are correlated with organic and colloid contents. Organic matter is responsible for the black colouration of the silt loam which is high in nitrogen, phosphorus and potash, but the total soluble salt content (mainly chloride) precludes plants other than extreme halophytes. The chloride concentration of the surface horizon fluctuates according to the amount of water in the swamp.

That this type of swamp has never been connected with the lakes or the Coorong is evidenced by the presence of the surrounding hills with their podsolized sands, which in the swamps themselves underlie the lacustrine deposits.

(b) Soils directly associated with advance and retreat of the Lakes—Here again the lacustrine deposits overlie the old podsol profile, but they are of predominantly sandy and clayey nature. The typical immature profile has a black sandy clay with pronounced nutty structure overlying the sands which are now strongly mottled. Thus the inundation of the lakes over the land and their subsequent retreat took place later than the arid Recent geological period. A series of developmental stages can be traced in the soil profiles. These are shown in fig. 5. Table VII shows the results of analysis of a Stage (b) profile. Comparing these results with those given in Table VI, it is seen that again there is an increase of coarse sand with depth in the A horizons of the old Laffer profile. However, in the present case, the amounts of coarse and fine sands in the old A₁ horizon are about equal, whereas fine sand predominates in the old A₁ of Table VI.

The presence of a greater proportion of this somewhat more mature soil and of more grassland than samphire swamp in the Malcolm Plains, indicates that the lake retreated earlier from this region than from the Waltowa area or, at least, the retreat was more complete.

The final stage of maturation [Stage (c), fig. 5] can be seen in a narrow zone fringing the Coorong and the lakes (in part). These soils carry *Casuarina stricta*. Apparently this area has been longer exposed. Table VIII gives the results of laboratory analysis of the mature soil. The surface horizon shown in this table has more coarse sand and less silt and clay than the surface horizon of Table VII. This has resulted from increased separation of the finer particles. Greater removal of silt and clay has also reduced the amount of potash and phosphoric acid.

Summing up, then, three stages of maturation of these soils have been distinguished. As a result, it is possible to trace serial stages in the associated vegetation.

6 THE SOILS DERIVED FROM IGNEOUS PARENT MATERIALS

In the vicinity of Rocky Gully is a small area of soils derived from pegmatite, schist, etc., and containing visible fragments of quartz, felspar and mica. The soils have affinities with brown weakly solonized soil.

Two phases have been distinguished, but the shallow phase is more common. This type has been taken for analysis (Table IX). No subsoil is developed in the profile analysed.

MECHANICAL AND CHEMICAL ANALYSES OF THE SOILS

| Loc. of Sample: | Hd. of Monarto Sect. 472 | Hd. of Bonney Section 173 | Hd. of Bonney Section Y's | Hd. of Brinkley, Section 88 |
|---|--|---|---|---|
| Pedogenic type: | Transit. "mallee" and red- brown earth | Podsol with solon- ized subsoil; Laffer sand (normal phase) | Hill Country suite, low sandy rises | Podsol with solonized sub- soil. Hill Country suite (inter. sandy ridge type) |
| Horizon | A | TABLE II | TABLE III | TABLE IV |
| Depth | 0-8" | A ₁ 0-5" | A ₁ 0-5" | A ₁ 0-4" |
| Reaction | 8.4 | 5-17" | 5-20" | 4-24" |
| % | % | % | % | % |
| Coarse sand | 20.6 | 57.0 | 53.0 | 56.2 |
| Fine sand | 42.6 | 39.8 | 45.4 | 40.3 |
| Silt | 29.7 | 1.5 | 0.3 | 2.1 |
| Clay | 9.9 | 2.1 | 0.4 | 1.3 |
| Loss on acid treatm. | 0.9 | — | — | — |
| Loss on ignition | 7.3 | 1.3 | 0.3 | 0.4 |
| Nitrogen, N | .183 | .026 | .015 | .095 |
| Phos. Acid, P ₂ O ₅ | .054 | .005 | .007 | .011 |
| Potash, K ₂ O | 1.29 | .06 | — | .07 |
| Mangan., Mn ₂ O ₃ | — | 30 p.p.m. | — | 30 p.p.m. |
| Chlorides, as NaCl | — | .005 | — | .002 |
| Total Sol. Salts | .06 | .02 | .01 | .04 |
| | | .12 | .02 | .03 |
| | | | .02 | .01 |
| | | | | .04 |
| | | | | .07 |

| Loc. of Sample: | Hd. of Mobilong, Section 27 | | | | Hd. of Bonney, Section 171 | | | | | | | |
|---|-----------------------------|----------------|----------------|----------------|---|-------|--------|--------|--------|--------|--|--|
| Pedogenic type: | Brown weakly solonized soil | | | | Lacustrine origin (Internal drainage swamp) | | | | | | | |
| Horizon | TABLE V | | | | TABLE VI | | | | | | | |
| Horizon | A ₁ | A ₂ | B ₁ | B ₂ | 0-3" | 3-24" | 24-27" | 27-39" | 39-61" | 61-72" | | |
| Depth | 0-15" | 15-27" | 27-33" | 33-51" | 7.8 | 8.7 | 8.8 | 8.6 | 8.4 | 8.7 | | |
| Reaction | 8.6 | 8.6 | 8.4 | 8.6 | % | % | % | % | % | % | | |
| % | % | % | % | % | % | % | % | % | % | % | | |
| Coarse sand | 60.2 | 70.0 | 52.8 | 54.4 | 16.1 | 0.2 | 23.9 | 45.1 | 17.0 | 12.9 | | |
| Fine sand | 35.6 | 26.5 | 33.0 | 28.9 | 18.2 | 2.0 | 55.5 | 42.2 | 43.5 | 21.3 | | |
| Silt | 2.3 | 0.4 | 0.5 | 0.2 | 35.3 | 2.0 | 9.6 | 1.0 | 8.8 | 6.2 | | |
| Clay | 0.6 | 2.3 | 12.7 | 15.0 | 8.4 | 0.3 | 2.5 | 5.5 | 28.0 | 49.2 | | |
| Loss on acid treatm. | — | — | — | — | 22.7 | 97.0 | 7.9 | 5.4 | 4.0 | 9.0 | | |
| Loss on ignition | 1.3 | 0.8 | 2.0 | 1.8 | 21.2 | — | — | 1.5 | 3.9 | 13.1 | | |
| Nitrogen, N | .023 | — | — | — | .436 | .071 | — | — | — | — | | |
| Phos. Acid, P ₂ O ₅ | .018 | .012 | — | — | .112 | .034 | — | — | — | — | | |
| Potash, K ₂ O | .18 | .14 | .48 | — | .94 | .46 | — | — | — | — | | |
| Mangan., Mn ₂ O ₃ | — | — | — | — | — | — | — | — | — | — | | |
| Chlorides, as NaCl | .008 | .007 | — | — | 12.040 | 2.192 | — | — | — | — | | |
| Total Sol. Salts | .04 | .04 | .02 | .04 | 12.23 | 3.51 | 1.64 | 4.90 | 1.67 | 0.19 | | |

| Locality of Sample: | Hd. of Malcolm, Section 600 | Hd. of Bonney, Sect. 368 | Hd. Mobilong Section 535 |
|--|--|---|---------------------------------|
| Pedogenic type: | Lacustrine origin due to retreat of lakes. Stage (b) | Lacustrine origin due to retreat of lakes Stage (c) | Derived igneous parent material |
| TABLE VII | | | |
| Horizon | 0-7" | 7-18" | 18-24" |
| Depth | 0-7" | 7-18" | 18-24" |
| Reaction | 6.0 | 7.7 | 8.3 |
| | % | % | % |
| Coarse sand | 45.3 | 34.8 | 49.3 |
| Fine sand | 42.9 | 30.6 | 48.3 |
| Silt | 4.7 | 4.2 | 0.3 |
| Clay | 6.2 | 31.1 | 1.2 |
| Loss on acid treatment | — | — | — |
| Loss on ignition | 2.9 | 4.7 | 0.5 |
| Nitrogen, N | .116 | .096 | — |
| Phosphoric acid, P ₂ O ₅ | .030 | .041 | — |
| Potash, K ₂ O | .29 | 1.16 | — |
| Mangan., Mn ₂ O ₃ | — | — | — |
| Chlorides, as NaCl | .007 | .011 | — |
| Total soluble salts | .03 | .04 | 0.06 |
| | | | 20 |
| TABLE VIII | | | |
| | 0-10" | 10-34" | 34-75" |
| | 6.8 | 8.5 | 9.0 |
| | % | % | % |
| | 65.4 | 57.6 | 33.4 |
| | 31.8 | 42.2 | 56.6 |
| | 1.1 | 1.0 | 9.0 |
| | 0.2 | — | — |
| TABLE IX | | | |
| A | 0.3" | 8.2 | % |
| | | | 51.4 |
| | | | 36.4 |
| | | | 8.2 |
| | | | 2.7 |
| | | | — |
| | | | 2.8 |
| | | | .081 |
| | | | .047 |
| | | | .66 |
| | | | .002 |
| | | | .02 |

TABLE X

| Sample | % Silica | % Other Insol. Residue | % CaCO ₃ |
|--------|----------|------------------------|---------------------|
| 1 | 20 | 8 | 72 |
| 2 | 30 | 5 | 65 |
| 3 | 45 | 0 | 55 |
| 4 | 51 | 3 | 46 |
| 5 | 37 | 28 | 35 |
| 6 | 34 | 20 | 46 |
| 7 | 36 | — | 63 |
| 8 | 32 | — | 68 |
| 9 | 47 | — | 53 |

THE ORIGIN OF THE SOILS

The geological history of any area is of prime importance in a consideration of the origin of the soils. Climatic factors are largely responsible for the development of the mature soil profile from the parent material.

In the South-East of South Australia the outstanding physiographic feature is the ancient dune system parallel to the existing coastline and connected with successive stages in the retreat of the sea in the Pleistocene (7). The fluctuation in relative position of land and sea level is attributed to glacial and interglacial conditions. These dunes are superimposed upon level-bedded Miocene marine limestones which are usually overlain by more recent calcareous deposits and in part by siliceous sands. The consolidated dunes have arisen from unconsolidated dunes similar to those present along the coastline at the present time. Thomas (20) gives an analysis of the coastal dunes at Robe as about 65% calcium carbonate and 25% silica. At Discovery Bay, Victoria (3), they consist of 75% calcium carbonate, while the finer sands of Portland Bay have up to 93% calcium carbonate. The latter is derived from the remains of marine organisms comminuted by wave action, while the quartzite fragments have survived a previous katamorphic cycle and are probably Oligocene in origin. In addition, Thomas has shown that the sands contain small amounts of iron and aluminium which

decrease in amount from the surface downwards. Since ferruginous and aluminous materials are absent from the original shell remains, their presence is attributed to continued accumulation of atmospheric dusts containing ferromagnesian minerals.

The Pleistocene dunes of the South-East have consolidated cores which are commonly overlain by leached siliceous sands. There are extensive interdune sandplains, the soils being podsols derived from yellow sands which probably represent the remains of the A horizons formed from the calcareous and siliceous sands of the dunes by leaching under high rainfall conditions in the Pleistocene and which were resorted by aeolian agencies under arid conditions in the Recent as suggested by Crocker (paper un-

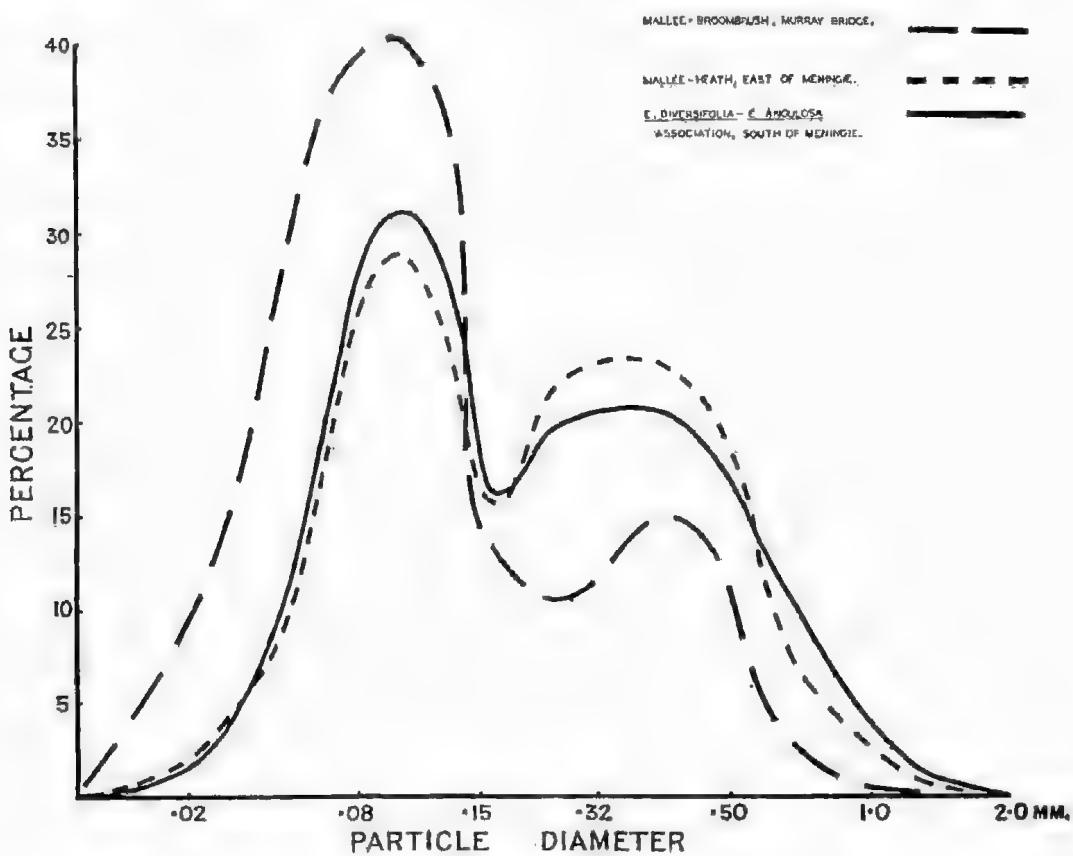


Fig. 6 Distribution curves for particle size of the surface sands

published). Evidence of such resorting results from a comparison of the distribution curves for particle size of the dune sands and the interdune plain sands. Many of the podsols have structured subsoils, and the Riddoch sand (18) which is a meadow podsol has a columnar-structured solonetzic B horizon. Where the limestone hardpan capping of the dunes was exposed by removal of the overlying sands, terra rossa soils have developed.

Some of the soils of the area considered in this paper are closely related pedogenetically to those of the South-East. However, instead of a system of old dunes running parallel to the existing coastline, there is an extensive dune sheet beginning somewhere about the latitude of Wellington and extending beyond the

southern boundary of the area surveyed. Its northern margin is not clearly defined, since there is a gradual increase in the proportion of calcium carbonate and decrease in siliceous sand proceeding north from its approximate margin. The calcareous and siliceous sands of the dune sheet are unconsolidated except for an indurated capping, while the old dunes of the lower South-East are more consolidated. Furthermore, the soils developed on this dune sheet have higher pH values than might be expected. Thus in the Hundreds of Laffer and Willalooka, where the rainfall is about 18" per annum, the Laffer sand has a pH value of 6.5, in the surface horizons, and 7.8 in the subsoil (19); while in the vicinity of Meningie, with a rainfall of about 20" per annum and a similar soil profile, the subsoil has the same pH value of 7.8 but the surface sands have a pH value of 7.3. Soils of the Hill Country suite in the Hundred of Bonney have a pH value about 2 units higher than similar soils in Laffer and Willalooka.

Examination of the sands of the dune sheet reveals some macroscopically visible fragments of marine organisms, but generally the comminution of their remains has been fairly complete. Fragments of Bryozoa, foraminifera and molluscs, can be distinguished by washing and examining the material under a microscope. Since the podsols with solonized subsoils have a low phosphate status, and in the surface horizons low potash, the parent material was analysed for these constituents, using the ordinary hydrochloric acid method of extraction. The values of .009% for phosphoric acid and 1.30% for potash were obtained. A number of samples were also treated with hydrochloric acid to determine the proportions of calcium carbonate and silica present. The results are presented in Table X. Crocker (paper unpublished) has suggested that much fine-grained calcium carbonate was winnowed out of the coastal dunes and dune sheets. Differential winnowing would explain the variations indicated in the analyses.

The redistribution of the surface sands in the Recent resulted in the exposure of limestone hardpan near Tailem Bend, Ashville and Waltowa, and at the same time gypsum dunes which are now usually overlain by a thin covering of "mallee" soil were built up at Cooke Plains. Shallow soils having affinities with terra rossas have developed on the limestone. The northerly as well as easterly scarp faces on some of the sandhills show that both southern and western winds played a part in the redistribution. Distribution curves for particle size of the surface sands (fig. 6) show the same general trends in the three cases. The sands associated with the *E. angulosa*—*M. uncinata* association have undergone the greatest amount of resorting, while there is no significant difference between the other two curves. Thus the soils of the sandplain were largely developed *in situ*. The relative amount of resorting as indicated by the sievings is supported by an examination of the sand grains under a microscope. Thus the larger grains of a sample taken in the *E. angulosa*—*M. uncinata* association near Murray Bridge are more highly polished than grains of similar size from the mallee-heath at Meningie. The small grains do not show the effect to the same extent.

It has been pointed out in the section dealing with the soils that the deep yellow sands have a zone of maximum colour intensity in their upper levels, and that at greater depths the sand becomes light yellow and finally light grey in colour. In this connection there is an occurrence in the Hundred of Bonney of a series of low hills, all of which are about the same level above the surrounding plain and which have fragments of ferruginous sandstone from the size of gravel up to 1' across embedded in the grey sand of the surface, which is about 6" in depth. Beneath this surface horizon is the orange-brown sandy clay loam subsoil, which gradually decreases in colour and texture to a light yellow sand with depth. Somewhat consolidated mixed calcareous and siliceous sand is encountered at about 4'

THE VEGETATION

There is a close relationship between the soil and its associated vegetation; climate is also important, but in the area considered in this paper climatic changes are not so clear cut so that their effect is less obvious.

THE CLASSIFICATION OF THE COMMUNITIES

At the beginning it should be pointed out that the term community is used in a general sense to mean an assemblage of plants. The basis of classification is the association as defined by Wood (24). All the associations herein considered are climax communities with the exception of the *Hordeum-Danthonia* association, which is a stage in the sere samphire swamp-grassland—*Casuarina stricta*.

The concept of succession is restricted to those seres where the development is due to the influence, partly or wholly, of the plants themselves.

Ecologically the area is a very complex one. The soils are closely related, topography plays a large part and transitions between associations are frequent and not always clearly marked. Thus heath, mallee-heath (ecotone), *C. stricta*—*X. australis* (ecotone), *E. diversifolia*—*E. angulosa* association and *E. angulosa*—*M. uncinata* associations all occur on soils belonging to the group podsols with solonized subsoil.

For the sake of clarity in discussion Table XI sets out the plant communities and the factors determining their distribution.

Hordeum murinum—*Danthonia semiannularis* association

As with most Savannah communities there has been considerable invasion by introduced species. Most likely *D. semiannularis* and *Stipa setacea* were the original dominants. Pryor (16) describes a similar community in the Australian Capital Territory (*S. setacea*—*D. auriculata* association). Selective grazing by stock would doubtless have been of importance in altering the botanical composition of the sward.

In addition to *H. murinum* and *D. semiannularis*, other plants practically as important are *H. maritimum*, *Bromus madritensis*, *Avena barbata* and *Erodium cygnorum*. Common plants are *Medicago tribuloides*, *Stipa setacea*, *Cryptostemma calendulaceum* (Cape dandelion), *Trifolium glomeratum*, *T. tomentosum* and *Moraea xerospatha* var. *monophylla*. Less commonly *Salsola Kali* and *Kochia brevifolia* are found. *Marrubium vulgare* (horehound), *Carduus tenuiflorus* (Scotch thistle), and occasionally *Lycium ferocissimum* (African boxthorn), and *Asphodelus fistulosus* (onion weed) are present along roadsides. *Distichlis spicata* is present in the earlier stages of the sere but is later largely replaced by the other species. The plants form a continuous ground cover. Of the 19 described species only 6 are natives. The most important family is the Gramineae with 7 species.

The community occurs on soil derived from lacustrine deposits. (Stages a and b, fig. 5.) Strong westerly and southerly winds are an important feature of the habitat.

Casuarina stricta association

(Pl. ii, fig. 2)

This community is found on soils belonging to several different pedological groups in the same climatic zone in the area surveyed. A comparison of floristic lists shows some differences, but in addition to the dominant species, many others are shared in common.

TABLE XI

| Community | Topography | Complex | Remarks | Formation | Popular Name | Soil | Origin of Soil |
|---|--------------------------------------|--|---|-----------------------------|------------------|---|---|
| <i>X. australis-</i> <i>C. pusilla</i> association | plain, well drained; low sandy rises | <i>E. diversifolia-</i> <i>E. angulosa-</i> <i>E. leptophylla</i> | | Heath | heath | Laffer suite, Hill Country suite | |
| <i>X. australis-</i> <i>C. pusilla</i> ; <i>E.</i> <i>diversifolia-</i> <i>E. angulosa</i> ecotone | low rises | <i>E. diversifolia-</i> <i>E. angulosa-</i> <i>E. leptophylla</i> | much | <i>E. leptophylla</i> | mallee-heath | as above | |
| <i>E. diversifolia-</i> <i>E. angulosa</i> association | sandhills, low limestone hills | <i>E. diversifolia</i> dominant on shallow soils | | Sclerophyllous mallee scrub | | Hill Country suite | dune sheet and aeolian redistribution |
| <i>E. angulosa-</i> <i>M. uncinata</i> association | undulating | <i>E. angulosa-</i> <i>E. cneorifolia-</i> <i>M. uncinata-</i> <i>B. Behrii</i> | lower rainfall than mallee-heath <i>B. Behrii</i> requires more moisture than <i>M. uncinata</i> | <i>E. leptophylla</i> | mallee-broombush | Laffer sand (normal phase) Hill Country suite (intermediate sandy ridge) | |
| <i>E. oleosa-</i> <i>E. dumosa</i> association | plain | <i>E. oleosa-</i> <i>E. dumosa</i> | | mallee scrub | mallee | brown weekly solonized soil | underlying rock and loess from dune sheet |
| <i>C. stricta</i> association | undulating to hilly | | | sheoak | | shallow red-brown earth, soils affin. terra rossas, brown weakly solonized soil | Adelaide Series (Proterozoic) exposed limestone hardpan |
| <i>E. odorata-</i> <i>E. leucoxylon-</i> <i>E. gracilis</i> association | undulating to hilly | | | Savannah Woodland | | peppermint-blue-pink gum | Adelaide Series |
| <i>H. marinum-</i> <i>D. semianularis</i> association | old lake bed | | | Savannah | | barley and wallaby grass | lacustrine sediments overlying Laffer sand |

In the Hundred of Monarto the associated soil is largely a shallow red-brown earth, but some "mallee" soil is included. Physiographically the area is steep and hilly. The community occurs as two separate patches in a locality otherwise occupied by Savannah Woodland of *E. odorata*, *E. leucoxylon* and *E. fasciculosa*. In addition a few isolated groups of sheoak occur scattered through the eucalypts. Edaphically there is little difference between the two habitats, but the *Casuarina* tends to be found on shallower soils. The differentiation is due largely to microclimatic influence, sheoak replacing the eucalypts where there is a rainshadow effect. The association has all the characteristics of a typical Savannah Woodland with the dominant trees scattered, shrubs not abundant and a continuous ground layer.

The only seral phases recognised are *Scirpus nodosus* along sandy creeks which flow irregularly, and crustose and foliose lichens (including species of *Acarospora* and *Pormelia*) and xeric mosses on outcropping rocks. *Parmelia australiensis* is occasionally present on the ground.

The most common shrubs are *Acacia brachybotrya*, *Pimelia glauca*, *Bursaria spinosa*, *A. pycnantha*, *Cassia eremophila*, *C. eremophila* var. *platypoda*, *Kochia brevifolia* and *Nicotiana glauca*; less common are *A. armata*, *Hakea leucoptera* and *A. Menscelii*. *A. ligulata*, *Olearia floribunda*, *Dodonaea viscosa*, *H. rugosa*, *Beyeria opaca*, and *Halorrhagis elata* are rare. *Callitris propinqua* and *Myoporum platycarpum* are trees of fairly common occurrence, while *Eremophila longifolia* (only recorded along watercourses) and *Pittosporum phillyreoides* are rare. Common undershrubs are *Rhugodia crassifolia*, *Enchylaena tomentosa* and the prostrate *Atriplex semibaccatum*. *Vittadinia triloba* is not common, while *Comesperma volubile* and *Dampiera rosmarinifolia* (Wild Rosemary) are very rare.

Common associated herbaceous plants (frequently of seasonal aspect) are *Lomandra leucocephala*, *Helichrysum apiculatum* (including a dwarf form), *Velleia paradoxa*, *Bulbine bulbosa*, *Microseris scapigera*, *Trichinium spathulatum*, *Helipterum Jessenii*, *Helichrysum obtusifolium*, *Erodium cicutarium*, *Lepidosperma laterale* and *Gahnia lanigera*. Rarer herbaceous plants are *Dianella revoluta*, *Lomandra dura*, *Kennedya prostrata*, *Halganea cynaea*, *Wahlenbergia gracilis*, *Thysanotus Patersonii*, *Salsola Kali* and occasionally *Acaena ovina*. *Convolvulus erubescens*, *Dichopogon strictus*, *Asphodelus fistulosus* and *Lomandra densiflora* occur. Many species are only present in grazed paddocks when protected by clumps of *Lomandra leucocephala*. This also applies to the taller grasses.

Many introduced species are common, especially along roadsides. These include *Plantago Bellardii* which is locally very abundant, *Salvia Verbenaca* (wild sage), *Erythraea Centaurium* (common Centaury), *Foeniculum vulgare* (fennel), *Plantago lanceolata* (ribgrass), *Moraea xerophthalma* var. *monophylla*, *Anagallis arvensis* (scarlet pimpernel), *Trifolium arvense* (hare's-foot clover), *T. procumbens* (hop clover), *Medicago minima*, *Hedypnois cretica* and *Cryptostemma calendulaceum* (Cape dandelion).

Native grasses present are *Stipa elegantissima*, *S. eremophila*, *Danthonia penicillata*, *D. carphoides* and less commonly *S. semibarbata*, *Neurachne alpinaeoides* and *Themeda australis*. The following introduced grasses are present in the community: *Avena barbata* (bearded oat), *Briza maxima* (large quaking grass), *Vulpia myuros* (rat's tail fescue), *Scleropogon rigidus* (*Festuca rigidus*), *Lolium subulatum* and *Lepturus cylindricus*.

Loranthus exocarpi (mistletoe) is a common parasite on the *Casuarina stricta*, and one specimen was recorded on *Eucarya persicarius*. *Cheilanthes tenerrima* (parsley fern) is found throughout most of the area, but in the southern portion is present only where protected by rocks or other plants.

Many of the recorded species are typical of the Savannah Woodland communities of the Mount Lofty Ranges as a whole, others of the *E. oleosa*—*E. dumosa* association. Among the 82 species the following families are represented: Gramineae 17, Leguminosae 11, Liliaceae 8, Compositae 8, and Chenopodiaceae 5. Comparing these with the most important South Australian families listed by Wood (21) as Compositae, Leguminosae, Gramineae, Chenopodiaceae, Orchidaceae, Cyperaceae, Myrtaceae (in order of importance), it is seen that four of the five most important for South Australia as a whole are well represented in this association. Twenty-two of the listed species are introduced plants. Of the native species four are endemic to South Australia—*Lomandra densiflora*, *Casuarina stricta*, *Gahnia lanigera* and *Acacia Mengelii*. The latter has a very limited distribution, being found in a small area north and north-east of Monarto South. An analysis of the rest of the flora shows that 21 species are shared in common with Temperate Australia, 14 with Australia as a whole, 12 with Eastern Australia, 2 with Western Australia and 7 with both Eastern Australia and Western Australia.

Where the *C. stricta* association occurs other than in the Hundred of Monarto in this survey, the soil either has affinities with terra rossas or is a brown weakly solonized soil or to a lesser extent the mature phase (Stage c. fig. 5) of the soil derived from lacustrine deposits. The topography is gently undulating. In these localities the community usually occurs adjacent to *E. oleosa*—*E. dumosa* association, but there is no evidence to indicate that it is a seral phase culminating in mallee. Rather, field evidence shows that it is an edaphic climax, the limiting factor being the shallow nature of the soils. Of interest in this connection is the tendency for the eucalypts in the adjacent mallee fringe to become more scattered or for the *E. oleosa* and *E. dumosa* to be replaced by *E. odorata*. On the very shallow terra rossas *Melaleuca pubescens* takes the place of *C. stricta* (pl. ii., fig. 3).

Plants present in the Hundred of Monarto but not recorded elsewhere in this association are *Acacia brachybotrys*, *A. armata*, *Pittosporum phillyreoides*, *Rhagodia crassifolia*, *Hakea rugosa*, *Myoporum platycarpum*, *Fremontia longifolia*, *Beyeria opaca*, *Dampiera rosmarinifolia*, *A. Menselii*, *Olearia floribunda*, *Dianella revoluta*, *Dichopogon strictus*, *Trifolium arvense*, *T. procumbens*, *Medicago minima*, *Wahlenbergia gracilis*, *Cheilanthes tenuifolia*, *Anagallis arvensis*, *Halganea cyanea*, *Plantago lanceolata*, *Foeniculum vulgare*, *Bulbina bulbosa*, *Microseris scapigera*, *Velleia furadouxii*, *Thysanotus Patersonii*, *Erythruca Centaurium*, *Acaena ovina*, *Exocarpus persicarius*, and the grasses *Briza maxima*, *Bromus madritensis*, *Themeda australis*, *Scleropoa rigidula*, *Stipa semibarbata*, *Vulpia myuros*, *Aira caryophyllea*, *Lepturus cylindricus*, *Lolium subulatum* and *Neurachne alopecuroides*.

Species recorded elsewhere but not in Monarto include *Melaleuca pubescens*, *Callitris Drummondii*, *Daviesia brevifolia*, *Hibbertia sericea*, *Marrubium vulgare*, *Lotus australis*, *Lepidosperma carphoides*, *Carduus tenuiflorus* (Scotch thistle), *Senecio lautus*, *S. picridifolia*, *Euphorbia terracina*, *Gahnia deusta* and *Callistemon rugulosus* which forms societies in low-lying areas of improved water relationships. *Callitris propinqua* is much more widespread. A distinctive appearance is given to the community by *Lepidosperma laterale*, *L. carphoides*, *Gahnia deusta* and *Lomandra leucocephala*. In Monarto the first three species are not prominent.

In the vicinity of Ashville an ecotone of *C. stricta* and *Xanthorrhoea australis* can be recognised between the *C. stricta* and the *E. diversifolia*—*E. angulosa* associations. The soil profile corresponds to the description given for the Hill Country low sandy rise type.

E. odorata – *E. leucoxylon* – *E. fasciculosa* association
 (Pl. ii, fig. 1)

Although these three eucalypts occur in constant combination throughout the area occupied by the community, the relative numbers are somewhat variable. *E. odorata* is most common, with an increasing proportion of *E. fasciculosa* in the northern and southern portions of the area. The *E. odorata* has a semi-mallee habit with commonly two or three main trunks arising from the lignotuber. Towards the east this habit is more pronounced, *E. odorata* at first mingling with *E. oleosa* and *E. dumosa*. *E. leucoxylon* and *E. fasciculosa* are trees with typical woodland form, having short boles and spreading round-headed crowns which are greater in depth than the length of the bole.

The physiography of the habitat is variable, being steep and hilly in parts and elsewhere gently undulating. The soil is a red-brown earth which is slightly podsolized in the extreme north.

With regard to the floristics of the association any species recorded for the *C. stricta* association of Monarto may be present, and in addition the following: shrubs commonly present are *Acacia obliqua* and *A. calamifolia* var. *cuthycarpa*; shrubs and undershrubs of rare occurrence are *A. spinescens*, *Goodenia primulacea*, *Helichrysum retusum*, *A. farinosa*, *Ulex europaeus* (gorse), *Hibbertia stricta* and *Thomosia petalocalyx*; very rare are *Asclepias fruticosa* and *Teuchrium racemosum*; *Lepidosperma carphoides* is widespread and abundant in the ground layer; *Xanthorrhoea semiplana*, *X. quadrangulata*, *E. camaldulensis* (red gum) and *Pteridium aquilinum* (bracken fern) are extremely rare in the far north of the area where there is an improved rainfall; herbaceous plants and plants of seasonal aspect are *Anguillaria dioica*, *Helipterum moschatum*, *Echium plantagineum* (Salvation Jane), *Rapistrum rugosum* (wild turnip), *Oxalis corniculata*, *Picris echioides*, *Sonchus oleraceous*, *Asparagus officinalis*, *Silene gallica*, *Bartsia latifolia*, *Hypochaeris radicata*, *Stellaria media*, *Senecio lautus*, *Caladenia cardiochila*, *C. dilatata* and *Diurus maculata*; *Loranthus Miquelianus* is rarely present on *E. odorata*.

E. oleosa – *E. dumosa* edaphic complex

E. oleosa – *E. dumosa* association

(Pl. iii, fig. 3)

The mallee communities in South Australia are found within the area bounded by the 20" and 8" annual rainfall isohyets (22). Near Ashville, where the rainfall approaches 19" per annum, *E. oleosa*, *E. dumosa* and less commonly *E. gracilis* occur, but many of the associated plants are typical of the *E. diversifolia* – *E. angulosa* association. Wood and Baas Becking (23) have pointed out that the mallee is really a vast ecotone connecting the sclerophyll communities of the south with the arid communities of the north of the State.

The habitat in the area considered here is in general gently undulating and, as can be seen by reference to the vegetation map, interspersed throughout the greater part of it are sandhills which carry *E. angulosa* – *M. uncinata* association. This is a transition area between the communities of the South-East of the State and the mallee proper. No seral phases are present, the community being closed and mature and having the status of a climatic climax. The soil belongs to the brown weakly solonized group, although in the vicinity of Tailem Bend *E. odorata* occurs on shallow soils with terra rossa affinities.

The *E. oleosa* – *E. dumosa* association is the only association of the edaphic complex of the same name represented in this area. Throughout the association *E. dumosa* and *E. oleosa* occur in fairly constant combination, although locally

either may be absent. Associated with them are *E. leptophylla*, *E. calycogona* and *E. gracilis*, any of which may locally become co-dominant. In a few localities *E. odorata* is the dominant, the other mallees being partly or entirely lacking. Where the soil is deeper, such as on sandrises, *E. angulosa* may be found with or without *E. oleosa*, *E. dumosa* or *E. leptophylla*. However, *E. angulosa* is characteristic of the *E. angulosa*—*M. uncinata* and *E. diversifolia*—*E. angulosa* associations rather than the mallee proper. *E. calycogona* is restricted to the shallow phase of soil.

Thus seven eucalypts with mallee habit are present as co-dominants and many different combinations (vegetation types) occur through the area. The difficulties of classification are similar to those encountered in the Mixed Eucalypt Forests of New South Wales (12). There the different vegetation types are the result of varying topography which influences the microclimate. In the mallee the topography is uniform. Depth of soil with its effect on moisture relationships is probably the factor which controls the distribution of the mallee eucalypts. Chance distribution of seeds may play some part.

Callitris propinqua (native pine) is common, particularly in the Hundred of Seymour. In the area surveyed the southern-most limit of this pine corresponds fairly accurately with that of the *E. oleosa*—*E. dumosa* association. It is lacking in the *E. diversifolia*—*E. angulosa* association and the mallee-heath of the Hundred of Bonney. Edaphic factors controlling its distribution are obscure, since it forms societies on both deep sands and shallow soils with limestone near the surface. *C. Morissoni* also occurs on both deep and shallow soils, but *C. verrucosa* shows preference for deeper soils. *C. verrucosa* has previously been recorded for the eastern side of the River Murray, but is present also on the western side.

Melaleuca pubescens and *M. acuminata* are universally present. Common trees are *Myoporum platycarpum*, *Eucarya acuminatus* (native peach) and *E. persicarius* (bitter quandong); less common are *Pittosporum phillyreoides* and *Exocarpus cupressiformis* (native cherry). The following shrubs and undershrubs are commonly present: *Acacia Osvaldii*, *A. farinosa*, *A. microcarpa*, *Kochia brevifolia*, *Enchylaena tomentosa*, *Bassia uniflora*, *Rhagodia crassifolia*, *R. nutans* and *Hakea leucoptera*. Less commonly present are *Acacia spinescens*, *A. calomifolia*, *A. ligulata*, *A. rigens*, *Cassia cremophila*, *C. eremophila* var. *platypoda*, *C. Sturtii*, *Daviesia genistifolia*, *D. brevifolia*, *Olearia floribunda*, *O. pieridiifolia*, *Atriplex semibaccatum*, *Bassia biflora*, *Phebalium bullatum*, *Bursaria spinosa* and *Dodonaea bursariifolia*. Rarely present are *Pomaderris racemosa*, *Revera Leschenaultii*, *B. Leschenaultii* var. *rosmarinoides*, *Halgonea cyanea*, *Pimelea glauca*, *Exocarpus aphylla*, *Westringia rigida*, *Grevillea ilicifolia* (hollybush), *Dodonaea attenuata*, *D. stenosyga*, *Eremophila crassifolia*, *E. glabra* (tar bush), *Boronia inornata*, *Kunzea pomifera*, *Olearia pimeleoides* var. *minor*, *Helichrysum retusum* and *Acacia Menzelii*. *A. rhelinocarpa* is very rare. Previously it had been recorded for Monarto South, but the present specimens were collected south of Murray Bridge. *Callistemon rugulosus* (scarlet bottlebrush) forms pure societies in low-lying areas of improved water relations. The introduced plants *Nicotiana glauca* (native tobacco) and *Lycium ferocissimum* (African boxthorn) are occasionally found.

Herbaceous plants, apart from *Gahnia lanigera*, *G. deusta*, *Dianella revoluta*, *Lomandra leucocephala*, *Lepidosperma laterale* and *L. carphoides*, which are frequently plentiful, are not common, but *Helichrysum leucopsidium*, *H. apiculatum* (everlastings), *Mesembryanthemum aequilaterale* (angular-leaved pigface), *Lomandra dura*, *L. densiflora*, and *Goodenia primulacea* are found. Rarely present are *G. varia*, *Wahlenbergia gracilis*, *Mesembryanthemum australe* (roundly-leaved

pigface), *Cheiranthera linearis*, *Microseris scapigera* (yam), *Cucumis myriocarpus*, *Citrullus vulgaris*, *Convolvulus erubescens* and *Lavatera plebeja* (Australian hollyhock). *Thysanotus Patersonii*, *Mesembryanthemum crystallinum* (ice plant), *Echium plantagineum* (Salvation Jane), *Nicotiana suaveolens* (tobacco bush), *Swainsona Greyana* (Darling pea), *Papaver aculeatum*, *Oxalis corniculata*, and *Linum marginale* (native flax) are very rare. The parasites *Cassytha melantha* and *C. pubescens* are often abundant on shrubs and eucalypts. *Clematis microphylla* (old man's beard) and *Billardiera cymosa* are climbers which are occasionally present. On land from which the native vegetation has been removed but which is otherwise undeveloped, *Inula graveolens* (stinkwort) and *Salsola Kali* become abundant. *Marrubium vulgare* occurs along roadsides.

Grasses, apart from *Triodia irritans* which forms local societis, are not abundant but the following have been recorded: *Stipa semibarbata*, *E. elegans-sima*, *Donthonia semiannularis* and the introduced *Hordeum murinum* (barley grass). Xeric mosses are often conspicuous in the ground stratum. In concluding notes on the flora it should be pointed out that the seedlings of the eucalypts were not seen in this association.

There are 104 recorded species in the association, and of these only 7 are introduced. The most important families are Leguminosae 16 species and 2 varieties (genus *Acacia* 10 spp. and 1 variety), Myrtaceae 12 (genus *Eucalyptus* 7 spp.), Compositae 8, Chenopodiaceae 8, Gramineae 5, Liliaceae 5, Santalaceae 5 and Pittosporaceae 4. An analysis of the flora shows that 35 of the species are found in Temperate Australia, 32 in Eastern Australia, 13 in Australia as a whole, 10 in both Eastern Australia and Western Australia, and 3 in Western Australia. 6 species and 2 varieties of species are endemic to South Australia, and of these *Acacia Menzelii* and *A. rhetinocarpa* are restricted to the area considered in this paper.

Considering the genus *Acacia*, we see that of the 8 species not limited to South Australia, 7 are found also in Eastern Australia and 1 in Western Australia. It is obvious that the centre of origin of these species is mainly Eastern Australia. The other important genus is *Eucalyptus*, and of the 7 species, 3 are found also in Eastern Australia, 3 in Western Australia, and 1 is typical of Temperate Australia.

For a comparison of the floras of the *E. oleosa*—*E. dumosa* and the *E. angulosa*—*M. uncinata* associations see page 28.

In the extreme north of the area occupied by *E. odorata*—*E. leucoxylon*—*E. fasciculosa* association there are several small isolated mallee communities on ironstone capped hills, e.g., 1½ miles south-east of Mount Beevor in the Hundred of Monarto. The soil cover is extremely shallow, the underlying rock (schist) and ironstone nodules being exposed. Stunted *E. dumosa* and *E. leptophylla* have been recorded, as well as *Melaleuca pubescens*. The ground between is bare except for some clumps of *Schoenus deformis*. In addition occasional stunted yuccas (*Xanthorrhoea quadrangularis* and *X. semiplana*) are present. The areas are rather curious, since they might be expected to carry *Casuarina stricta*.

E. angulosa—*E. cneorifolia*—*Melaleuca uncinata*—*Baeckea Behrii*
edaphic complex

E. angulosa—*M. uncinata* association
(PL. iv, fig. 2)

Allied associations have been reported on Kangaroo Island by Cracker (4) as the *E. cneorifolia*—*M. uncinata* and *E. cosmophylla*—*M. uncinata* associations. Together, these form the *E. cneorifolia*—*M. uncinata* edaphic complex.

Baeckea Behrii is entirely lacking on Kangaroo Island. On the mainland, the *E. angulosa*—*M. uncinata* association extends from north of Kinchuna to the south of Bordertown. In addition, *M. uncinata* is found in the Southern Districts, Yorke and Eyre Peninsulas and westward to Kingoonya. *B. Behrii* is rare in the Southern Districts (2). Ising, Cleland and Black have listed the plants found between Monarto South and Kinchuna (9).

The habitat is undulating, while the associated soil is a podsol with solonized subsoil. Rarely the broombushes occur on "mallee" soil or soil derived from rock of igneous origin, but in these cases the community is modified by the presence of eucalypts of the *E. oleosa*—*E. dumosa* association.

The distributions of *M. uncinata* and *B. Behrii* are largely controlled by soil moisture content. In the area receiving from 13–15" rainfall per annum, *M. uncinata* is much more abundant than *B. Behrii* and occurs commonly on deeper sands than the latter, while both may be present on soils of intermediate depth. Under slightly higher rainfall conditions (16–18"), *B. Behrii* is more common and is found also on deep sands. Thus *B. Behrii* prefers slightly more favourable soil moisture conditions than *M. uncinata*. Supporting evidence is afforded by the recorded distribution of the two species in South Australia (Black 2). Both species are rather unusual in their local distribution, since there are often large areas of apparently suitable soil either sparsely colonized or completely unoccupied.

Edaphic control of the distribution of the eucalypts is marked. Thus, where the surface horizons are deep, *E. angulosa* is the only mallee present. *E. leptophylla* occurs where the profile is shallower. However, it does not follow that because the soil is shallow *E. leptophylla* will be present. The margins of the dunes have shallow sand horizons but do not necessarily carry a fringe of *E. leptophylla*. All that can be said regarding the edaphic requirement of these two species is that *E. leptophylla* prefers shallower soils than *E. angulosa*, which is not so limited in its requirements. Soil moisture content is again the determining factor.

The Hundreds of Coolinong and Malcolm are "critical" areas, because here four associations reach the limits of their range in the area surveyed. Thus here is the southern limit of the *E. angulosa*—*M. uncinata* and *E. oleosa*—*E. dumosa* associations and the northern limit of the *E. diversifolia*—*E. angulosa* and *Casuarina pusilla*—*Xanthorrhoea australis* associations. As a result, *B. Behrii* invades the surrounding heath and *X. australis* and *E. diversifolia* invade the mallee-broombush.

When limestone occurs near the surface, *Melaleuca pubescens* and *M. acuminata* may replace the broombushes. A gradation of broombush to teatree may be traced proceeding up a rise which has limestone exposed near the crest.

The following plants are usually present in addition to the dominants: *Lepidospermum coriaceum* (green tea-tree), *Calythrix tetragona*, *Lasiopetalum Behrii*, *L. Baueri*, *Hibbertia stricta*, *H. stricta* var. *glabriuscula* and *H. stricta* var. *canescens*. In addition the following are common: *Correa rubra*, *Boronia caerulescens*, *Brachyloma ericoides*, *Astroloma humifusum*, *A. conostephioides* (flame heath), *Acacia calamifolia* var. *euthycarpa*, *A. pycnantha*, *Baeckea crassifolia*, *Exocarpus cupressiformis*, *E. sparteo*, *Grevillea lavandulacea* var. *sericea*, *Hibbertia sericea* and *H. sericea* var. *seabrifolia*. Fairly common are *Acacia spinescens*, *Dillwynia uncinata*, *Olearia pieridifolia*, *Daviesia brevifolia*, *V. genistifolia*, *Eutaxia microphylla*, *Stackhousia monogyna*, *Olearia glutinosa*, *O. lepidophylla*, *O. floribunda*, *Helichrysum retusum*, *Dianella revoluta*, *Thomasia petalocalyx*, *Dodonaea hexandra*, *Prostanthera Behriana*, *Grevillea ilicifolia*, *Hibbertia virgata* var. *crassifolia*, *Hakea leucoptera*, *Spyridium vexilliferum*, *S. subochrea-*

tum, *Pomaderris racemosa*, *Beyeria Leschenaultii* var. *rosmarinoides* and *Casuarina Muelleriana*. Rarely present are *A. rigens*, *A. microcarpa*, *Phebalium bullatum*, *Eucarya persicarius* (bitter quandong), *Prostanthera microphylla*, *Pimelia flava*, *E. acuminatus* (native peach), *Dodonaea cuneata*, *Eremophila crassifolia*, *Myoporum platycarpum*, *Pomaderris obcordata*, *Rhagodia crassifolia*, *Pimelia glauca* and *Halganea cyanea*. Very rare are *Solanum nigrum*, *Acacia Menzelii*, *A. colletoides*, *A. rhigiophylla*, *A. ligulata*, *A. calamifolia*, *Kunzea pomifera*, *Pomaderris obcordata*, *Adriana Klotzschii*, *Lomandra densiflora*, *Prostanthera aspalathoides*, *L. dura*, *L. leucocephala*, *Zieria veronicae* (previously recorded for the Square Water-hole, Mount Lofty Ranges and Kangaroo Island, but collected and quite common around Harriet Hill), *Styphelia exarrhena*, *Dodonaea viscosa*, *D. attenuata*, *Psoralea patens*, *Westringia angustifolia* and *Bursaria spinosa*.

Callistemon rugulosus occasionally forms societies in low-lying areas of increased soil moisture content. The following grasses are present but are not common: *Tridia irritans* (porcupine grass), *Danthonia semiannularis*, *Stipa variabilis*, *S. setacea*, *S. eremophila* and the introduced species *Bromus madritensis* and *Aira caryophyllea* (silvery hair-grass). The three Gymnosperms, *Callitris propinqua*, *C. verrucosa* and *C. Drummondii* are of common occurrence. Additional herbaceous plants include the following: *Microseris scapigera* (yam), *Helichrysum Baxteri* (vicinity of Harriet Hill), *Wahlenbergia gracilis*, *Senecio lautus*, *H. leucopsidium*, *H. apiculatum*, *Ixodia achilleoides*, *Drosera glanduligera*, *D. Planchonii*, *D. Whittakeri*, *Goodenia viria*, *Loudonia Behrii*, *Mesembryanthemum acutilaterale*, *M. australe*, *Erodium cicutarium* (on cleared land only), *Emex australis* and *Anagallis femina* (blue pimpernel). Climbing plants include *Clematis microphylla* and more rarely *Billardiera cymosa* and *Mitchella adpressa*. The parasites *Cassytha melantha* and *C. pubescens* are commonly present on the eucalypts and shrubs, while *C. glabella* has been recorded on *B. Behrii* in the Hundred of Coolinong. Orchids which have been found include the following: *Pterostylis nona*, *P. mutica* and *Lyperanthus nigricans* in Coolinong and *Caladenia cardiochila* elsewhere. *Thelymitra azurea* was collected at Harriet Hill.

Lepidosperma laterale, *L. carphoides*, *Gahnia deusta* and *G. longirostris* are a conspicuous feature of the ground vegetation. The introduced plants *Inula graveolens* (stinkwort), *Cryptostemma calendulaceum* (Cape dandelion) and *Erecthites quadridentata* are present on land which has been cleared of native vegetation but which is otherwise undeveloped. *Lycium ferocissimum* (African boxthorn) is occasionally found.

As pointed out previously *Melaleuca pubescens* and *M. acuminata* may be present occasionally, but these species are more typical of the *E. oleosa*-*E. dumosa* association.

Out of a total of 130 recorded species only 7 are introduced plants. The most important families are Leguminosae 14 species and 1 variety, Compositae 14 species, Myrtaceae 11, Gramineae 7, and Orchidaceae 5. *Acacia* is the most important genus. An analysis of the flora shows that 52 of the species are shared in common with Eastern Australia, 29 with Temperate Australia, 13 with both Eastern and Western Australia, 12 are found throughout Australia and 2 are shared in common with Western Australia. Thus most of the species are of Eastern Australian origin. Nine species and 4 varieties endemic to South Australia are present. In addition the position with regard to *Acacia rhigiophylla* is rather doubtful. Apart from its occurrence in this area, where it is found over 7 square miles of country centred about Kinchuna, it was recorded in 1902 from West Wyalong, New South Wales. This is an unusual distribution and could well be confirmed by comparison of specimens from the two localities.

The following lists of species give the floristic differences between the present association and the *E. oleosa* - *E. dumosa* association. Present in the mallee but not in the mallee-broombush are *Acacia Oswaldii*, *A. farinosa*, *A. rhetinocarpa*, *Lavatera plebeja*, *Swainsona Greyana*, *Cassia Sturtii*, *C. eremophila*, *C. eremophila* var. *platypodo*, *Nicotiana suaveolens*, *Eucalyptus oleosa*, *E. dumosa*, *E. gracilis*, *E. odorata*, *Papaver aculeatum*, *Olearia pimuleoides* var. *minor*, *Salsola Kali*, *Citrullus vulgaris*, *Kochia brevifolia*, *Atriplex semibaccatum*, *Enchylaena tomentosa*, *Rhagodia nutans*, *Bassia uniflora*, *B. biflora*, *Stipa semibarbata*, *S. elegans-sima*, *Hordeum murinum*, *Thysanotus Patersonii*, *Cheiranthera linearis*, *Cucumis myriocarpus*, *Pittosporum phillyreoides*, *Eremophila glabra*, *Mesembryanthemum crystallinum*, *Dodonaea bursariifolia*, *D. stenozyga*, *Goodenia primulacea*, *Westringia rigida*, *Linum marginale*, and *Nicotiana glauca*. This is a total of 38 species.

Present in the mallee-broombush but not in the mallee are *Acacia rhigophylla*, *M. uncinata*, *B. Behrii*, *Leptospermum coriaceum*, *Calytrix tetragona*, *Baeckea crassifolia*, *Olearia glutinosa*, *Helichrysum Baxteri*, *Senecio lautus*, *Ixodia achilleoides*, *Prostanthera uspalthoides*, *Bromus modritensis*, *Aira caryophyllea*, *Boronia caeruleascens*, *Zieria veronicae*, *Dodonaea hexandra*, *D. viscosa*, *Hibbertia virgata* var. *crassifolia*, *A. colletoides* *Thomasiae petalocalyx*, *Grevillea lavandulacea* var. *sericea*, *Cassytha glabella*, *Prostanthera microphylla*, *Erectites quadridentata*, *P. Behriana*, *Westringia angustifolia*, *Stockhousia monogyna*, *Erodium cicutarium*, *Dodonaea cuneata*, *Anagallis femina*, *Casuarina Muelleriana*, *Loudonia Behrii*, *Pimelia flava*, *Psoralea patens*, *Muchlenbeckia adpressa*, *Spiridium vexilliferum*, *S. subochreatum*, *Pomaderris obcordata*, *Drosera peltata*, *D. glanduligera*, *D. Planchonii*, *Brachyloma ericoides*, *Astroloba humifusum*, *A. conostephioidea*, *Styphelia exarrhena*, *Pterostylis nana*, *P. mutica*, *Lyperanthus nigricans*, *Culadenia cardiochila*, *Thelymitra azurea*, *Stipa setacea*, *S. eremophila*, and *S. variabilis*. This represents a total of 53 species. The *E. oleosa* - *E. dumosa* association has more Acacias, eucalypts and Chenopods, while the *E. angulosa* - *M. uncinata* has exclusively Droseras, Epacrids and orchids. With more favourable seasonal conditions, orchids would have been recorded in the mallee.

The chief differences in the origin of the species of the two associations are that more species of the mallee-broombush are shared in common with Eastern Australia than is the case with the mallee which has more species in common with Temperate Australia.

Table XII gives the life-spectrum of the *E. angulosa* - *M. uncinata* association.

TABLE XII

| | spp. | MM | M | N | Ch | 11 | G | HH | Th | E | S |
|--|------|----|----|----|----|----|---|----|----|---|---|
| Normal spectrum | 400 | 6 | 17 | 20 | 9 | 27 | 3 | 1 | 13 | 3 | - |
| <i>E. angulosa</i> - <i>M. uncinata</i> assoc. | 126 | — | 24 | 41 | 13 | 11 | 7 | — | 1 | 1 | 2 |

The outstanding feature is the lack of tall trees and the prominence of the small shrub (25 cm. - 2 m.), and to a lesser extent of small trees and tall shrubs (2-8 m.). This, then, is predominantly a community of shrubs.

E. diversifolia - *E. angulosa* - *E. leptophylla* edaphic complex

This complex is a result of the influence of topography in a sandplain and sandhill region. An analysis of the vegetation shows that on the crests of the hills eucalypts are the dominants and give the characteristic appearance to the community, while shrubs and ground vegetation (consisting of species belonging to the families Cyperaceae and Restionaceae) are not important. This assemblage constitutes the *E. diversifolia* - *E. angulosa* association. Secondly, on hill slopes where shrubs give the facies, eucalypts are subordinate and the amount of ground

vegetation is intermediate between hill crests and flats-between-hills. This is the mallee-heath and is really an ecotone between the *E. diversifolia*—*E. angulosa* association and the heath. And thirdly, on flats-between-hills where shrubs and ground vegetation give the characteristic appearance, eucalypts are entirely absent. These heath patches are usually very localized. Scattered throughout various other associations in some localities in the area surveyed are deep sand-hills which also carry heath, but the community is dominated by somewhat different species to that of the heath plain. Finally, the blue gum (*E. leucoxylon* var. *pauperita*) forms societies in flats where there is increased moisture (pl. iv, fig. 1), c.f. *E. Baxteri* which is found only on the ranges where it reaches the limits of its range in the upper South-East (5).

The dividing line between the *E. diversifolia*—*E. angulosa* association and the mallee-heath with its small included patches of heath shown on the vegetation map is a relative one, since the three communities form a complex pattern. However, there is a marked tendency towards dominance by the *E. diversifolia*—*E. angulosa* association in the coastal fringe and by mallee-heath in the sandplain. The change is a gradual one, but the physiognomy of the vegetation in the two areas is distinct. Throughout the whole area the soil is of the Laffer and Hill Country types.

E. diversifolia—*E. angulosa* association

As pointed out above, this community occurs in the sandhills fringing the sandplain or on isolated hills scattered through it. The soil profile may be shallow with limestone near the surface. The dominants form a dense growth. *E. diversifolia* and *E. angulosa* are more abundant than *E. leptophylla*, which is prevalent in the mallee-heath. On shallow soils *E. diversifolia* occurs alone.

In hollows between the coastal sandhills there are isolated areas where eucalypts are lacking and shrubs are stunted (often less than 6' in height). Frequently the only plants present are mats of *Kunzea pomifera* with scattered *Banksia marginata*, *Astroloba humifusum* and *Hibbertia sericea*. Occasionally *A. conostephoides*, *Thomasia petalocalyx* and *Mesembryanthemum australe* may be present. These treeless areas are due to an accumulation of salts in the soil. A sample taken from the first few inches of soil where the shrubs grew to a height of 3' 6" but where mallees were lacking, gave a value for total soluble salts of .17%.

In addition to the dominants the following plants are usually present: *Melaleuca pubescens*, *M. fasciculiflora*, *Kunzea pomifera*, *Pullenaea tenuifolia*, *P. prostrata*, *Xanthorrhoea australis*, *Hakea vittata*, *Thomasia petalocalyx*, *Scirpus nodosus*, *Hibbertia sericea*, *H. sericea* var. *scabrifolia*, *Boronia caeruleascens*, *Dianella revoluta*, *Correa rubra*, *Exocarpus cupressiformis* and *E. sparte*. Fairly common are *Leptomeria aphylla*, *Casuarina Muelleriana*, *Aerantia cordata*, *Phyllospadix pleurandrodes*, *Eucarya persicarius*, *E. acuminatus* (the latter two species especially in the fringes of samphire swamps), *Lasiopetalum Behrii*, *L. Baueri*, *Hibbertia stricta*, *H. stricta* var. *glabriuscule*, *Hakea rostrata*, *Grevillea lavandulacea* var. *sericea*, *Isopogon ceratophyllum*, *H. leucoptera*, *H. rugosa*, *Brachyloma ericoides*, *Baeckea crassifolia*, *Astroloba humifusum*, *A. conostephoides*, *Leucopogon Clelandii*, *Calythrix tetragona*, *Melaleuca acuminata*, *Daviesia brevifolia*, *Acacia myrtifolia* var. *sophoreae*, *O. picridifolia*, *A. ligulata*, and *Dillwynia floribunda*. Fairly rare are *Helichrysum retusum*, *O. leptophylla*, *O. axillaris*, *A. pyrenantha*, *Euphrasia collina*, *Spyridium subochreatum*, *S. vexilliferum*, *Pomaderris racemosa*, *Hibbertia virgate* var. *crossifolia*, *Cryptandra tomentosa*, *Pimelia glauca* and *P. humilis*. The following plants are very rare: *Kennedya prostrata*, *A. spinescens*, *Leptospermum myrsinoides*, *Lomandra densiflora*, *L. leucocephala*, *Styphelia exarrecta*, *Conospermum*

patens, *Grevillea ilicifolia*, *Spiraea criocephalum*, *Pomaderris obcordata*, *Pimelia flava*, *Dampiera rosmarinifolia*, *Myoporum insulare*, *Leucopogon costatus*, *Bursaria spinosa*, *Dodonaea bursariifolia*, *D. attenuata*, *Rhagodia crassifolia* and *Adriana Kluitgeschi*.

The following additional herbaceous plants or species of seasonal aspect have been recorded as commonly occurring: *Stackhousia monogyna*, *Thelymitra aristata*, *Drosera peltata*, *D. glanduligera*, *Loudonia Beirii*, *Mesembryanthemum aequilaterale*, *Helichrysum leucopodium*, *Senecio lautus* and *Polygonum aviculare*. Less common are *Iridia achilleoides*, *Microseris scapigera*, *Wahlbergia gracilis*, *Goolenii varia*, *G. primulacea*, *Mesembryanthemum australe* and *Pimelia octophylla*. Ground vegetation consists of the following members of the Cyperaceae: *Gahnia deusta*, *G. lanigera*, *Cladium junceum*, *Lepidosperma laterale*, *L. carphoides* and *Schoenus deformis*. The Restionaceae is represented by *Isopogon fastigata*. Grasses are rare but several species have been recorded. These include *Stipa variabilis*, *S. eremophila*, *Danthonia setacea*, *Bromus madritensis*, *Neurachne alopecuroides*, *Themeda australis*, *Agrostis Billardieri*, *Deschampsia caespitosa* and *Bromus madritensis*. *Triodia irritans* is more common. Climbing plants include *Hardenbergia monophylla*, *Muehlenbeckia adpressa*, *Billardiera cymosa* and *Clematis microphylla*. *Cassytha melantha* and *C. pubescens* are present on shrubs and trees and *C. glabella* on shrubs only. The mistletoe *Loranthus microcarpus* var. *Melaleucae* is present on *Melaleuca pubescens* but has not been recorded on other *Melaleuca* spp.

Several introduced species are present along roadsides. These include *Carduus tenuiflorus*, *Cryptostemma calendulaceum* (Cape dandelion), *Rumex acetosella* (sheep sorrel), *Anagallis femina*, *Lycium ferocissimum* and *Marrubium vulgare*. The composites *Erechtites quadridentata* and *Inula graveolens* are abundant on land from which the native vegetation has been removed but which is otherwise undeveloped. *Banksia ornata* and *B. marginata* have both been recorded but are more typical of the mallee-heath and heath. *Callitris verrucosa* is not found in the Hundred of Bonney but is particularly abundant along the boundary of the Hundreds of Coolinong and Malcolm. Restricted to this area is a glaucous form of *C. verrucosa*. Mallee seedlings are found in some localities (pl. i, fig. 1 and 2).

The total number of recorded species is 130, and of these only 10 have been introduced. Most important families are Leguminosae with 12 spp., Compositae 12, Myrtaceae 11, Proteaceae 10, Gramineae 10, Epacridaceae 7, and Cyperaceae 7. Outstanding features are the importance of the families Proteaceae and Epacridaceae and the deficiency of members of the typical South Australian families Chenopodiaceae and Orchidaceae. An analysis of the flora shows that 51 species are shared with Eastern Australia, 3 with Western Australia, 12 are found in Australia as a whole and 30 are typical of Temperate Australia. Seven of the species and 4 varieties of species are endemic to South Australia.

It is of interest to compare the floristics of this association with that of the *E. angulosa* - *M. uncinata* association. The following list gives the species recorded here but not present in the mallee-broombush: *E. diversifolia*, *Acacia myrtifolia*, *Phyllota pleurandroides*, *Hardenbergia monophylla*, *A. longifolia* var. *sophoreae*, *Cryptandra tomentosa*, *Dillwynia floribunda*, *Kennedya prostrata*, *Pultenaea tenuifolia*, *P. prostrata*, *Carduus tenuiflorus*, *Olearia axillaris*, *Melaleuca fasciculiflora*, *Leptospermum myrsinoides*, *E. leuroxylon* var. *pauperita*, *Xanthorrhoea australis*, *Danthonia setacea*, *Neurachne alopecuroides*, *Themeda australis*, *Agrostis Billardieri*, *Deschampsia caespitosa*, *Thelymitra aristata*, *Leucopogon Celandrii*, *Acrotriche cordata*, *Leucopogon costatus*, *Leptomeria aphylla*, *Dodonaea bursariifolia*, *Marrubium vulgare*, *Scirpus nodosus*, *Cladium junceum*, *Hypolaena*

fastigata, *Schoenus deformis*, *Conospermum patens*, *Banksia ornata*, *B. marginata*, *Hakea vittata*, *H. rugosa*, *H. rostrata*, *Isopogon ceratophyllus*, *Myoporum insulare*, *Pomaderris obcordata*, *Spyridium eriocephalum*, *Stackhousia monogyna*, *Goodenia primulacea*, *Dampiera rosmarinifolia*, *Pimelia humilis*, *P. octophylla*, *P. flava*, *Rumex Acetosella*, *Adriana Klotzschii*, *Euphrasia collina* and *Loranthus miraculosus* var. *Melaleuca*. This is a total of 52 species.

Present in the *E. angulosa*-*M. uncinata* association, but not in the *E. diversifolia*-*E. angulosa* association, are: *Melaleuca uncinata*, *Acacia colletoides*, *Solanum nigrum*, *Psoralea patens*, *Dodonaea cuneata*, *Prostanthera aspalathoides*, *Pterostylis mutica*, *Stipa setacea*, *Baeckea Behrii*, *Eutaxia microphylla*, *Daviesia genistifolia*, *Dillwynia uncinata*, *A. microcarpa*, *A. calamifolia*, *A. rhigiophylla*, *A. Menzelii*, *A. rigens*, *A. calamifolia* var. *euthycarpa*, *Olearia glutinosa*, *Helichrysum Baxteri*, *H. apiculatum*, *Leptospermum coriaceum*, *Callistemon rugulosus*, *Lomandra dura*, *Danthonia semiannularis*, *Aira caryophyllea*, *Pterostylis nana*, *Lyperanthus nigricans*, *Caladenia cardiochila*, *Thelymitra azurea*, *Phebalium bullatum*, *Zieria veronicae*, *Dodonea hexandra*, *D. viscosa*, *Prostanthera microphylla*, *P. Behriana*, *Westringia angustifolia*, *Callitris Drummondii*, *Drosera Planchonii*, *Myoporum platycarpum*, *Eremophila crassifolia*, *Halganea cyanea*, *Beyeria Leschenaultii* var. *rosmarinoides* and *Erodium circutarium*. This is a total of 44 species.

The families Gramineae, Cyperaceae, Proteaceae and Epacridaceae are represented by more species in the *E. diversifolia*-*E. angulosa* association.

Mallee-heath

(Pl. iv, fig. 3)

This is an ecotone between the *E. diversifolia*-*E. angulosa* association and the heath, so that the species present are typical of both associations. A few are absent from the heath. *E. leptophylla* is more numerous than it is in the *E. diversifolia*-*E. angulosa* association, and again *E. diversifolia* can tolerate shallower soils.

Casuarina pusilla-*Xanthorrhoea australis* association

(Pl. iv, fig. 4)

Crocker has described a similar association in the South-East as the *X. australis*-*Hakea rostrata* association (5). The nomenclature of the community is difficult since many species are about equally abundant. Other very important perennial species which may locally become codominant are *Banksia marginata*, *B. ornata*, *Hakea vittata* and *Phyllota pleurandroides*. Many of the shrubs are about 2' high.

In addition to the species given above, the following are common: *Adenanthera terminalis*, *Leucopogon costatus*, *Euphrasia collina*, *Hibbertia stricta*, *Pultenaea tenuifolia*, *Boronia caerulescens*, *Hakea* spp. (difficult to determine because firing destroys the fruits), and *Acrotriche cordata*.

Fairly common are *Astrolobia humifusum*, *Leucopogon Clelandii*, *Correa rubra* and *Pimelia humilis*. Rarely present are *Lomandra densiflora*, *Isopogon ceratophyllus*, *Astrolobia conostephivides*, *Leptospermum myrsinoides*, *Daviesia brevisifolia*, *Hibbertia sericea*, *Pultenaea prostrata*, *Leucopogon Woodsii* and *H. virgata* var. *crassifolia*. *Lhatzkya alpestris*, which was not recorded for the mallee-heath, is very rare. *Helichrysum Baxteri*, *Drosera peltata*, *D. pygmaea* and *Thelymitra aristata* are of seasonal aspect. The ground vegetation is a conspicuous feature and consists of *Schoenus deformis*, *Lepidosperma carphoides*, *Hypolaena fastigata* and *L. laterale*. *Cassytha glabella* is parasitic on the shrubs.

As has been pointed out, the heath vegetation associated with some sandhills has a somewhat different floristic composition to the heath of the plains. Any of the following species may be dominant or several may be codominant: *Banksia ornata*, *Phyllota pleurandrodes*, *Casuarina pusilla*, *Leptospermum coriaceum* or *Baeckea Behrii*. The last two species occur where the heathy hill is adjacent to *E. angulosa* - *M. uncinata* association. Plants present which are not listed for the heath plain are *Brachyloma ericoides*, *Phebalium bullatum*, *Conospermum patens*, *Baeckea crassifolia*, *Thomasia petalocalyx*, *Spyridium subochreatum*, *S. vexilliferum*, *Kunzea pomifera*, *Clematis micraphylla*, *Mesembryanthemum aequilaterale*, *Casuarina Muelleriana*, *Beyeria Leschenaultii* var. *rosmarinoides* and *Helichrysum Blandowskianum*.

THE DEVELOPMENTAL COMMUNITIES

Primary succession is not evident in most of the area studied since colonisation has proceeded to a stage where the communities are mature. There are, however, two important exceptions, the governing factors being in both instances the salt and moisture contents of the soil.

SUCCESSION IN AREAS FROM WHICH THE LAKES OR COORONG HAVE RETREATED

Here the sere is samphire swamp—grassland—*Casuarina stricta*.

The samphire swamp is a practically pure community of *Salicornia australis* (?) Although the plants themselves are somewhat scattered, the community is a closed one through the spreading of the root systems (11). Locally *Atriplex paludosum*, *Nitraria Schoberi*, *Kochia oppositifolia* and *Mesembryanthemum australe* are present. *Cotula coronopifolia* is abundant along drainage channels, but is never present when the salt content of the soil is high. *Melilotus indica* and *Spergularia rubra* are sometimes found in the early stages, but they are later replaced by other species as the sere progresses.

With reduced salt and water content of the soil other species begin to appear. *Hordeum maritimum* is one of the first, and also at an early stage *Distichlis spicata*. Initially they are found around the raised columns of samphire, but later spread to form a continuous sward. The mature grassland is considered with the climax communities, although it is really a subclimax. Relic samphires are common in the grassland (pl. iii, fig. 4).

The climax community consists of *Casuarina stricta* with scattered clumps of *Scirpus nodosus*. *Cladium juncinum* is a conspicuous associate, and also *Distichlis spicata*. *Bursaria spinosa* is rare. There is no evidence of any further development.

The percentages of total soluble salts in the surface few inches of soil are:

| | | | | |
|----------------------------------|---|---|---|------|
| <i>Salicornia australis</i> zone | - | - | - | 4·13 |
| Mature grassland | - | - | - | ·04 |
| <i>C. stricta</i> | - | - | - | ·03 |

Osborn and Wood (11) give the following figures:

| | | | |
|-------------------------------|---|---|-----------|
| <i>Arthrocnemum arbustula</i> | - | - | 16·9-17·5 |
| <i>A. halocnemoides</i> | - | - | 2·9- 4·9 |

SUCCESSION IN SWAMPS DUE TO LOCAL INTERNAL DRAINAGE

Here the sere is samphire swamp—*Cladium filum*—tea-tree thicket. No further stages can be discerned. It is not, however, an example of simple zonation, since there is definite evidence of biotic succession. Again the samphire swamp consists of rather open dwarf shrubland of *Salicornia australis* (?).

Frankenia pauciflora, *Plagianthus microphyllus* and *Nitraria Schoberi* are sometimes present. Fringing this is a sedge zone consisting of the cutting grass *Cladium filum*. The outermost zone is a tea-tree thicket of *Melaleuca fasciculiflora* and *M. pubescens*. Either may be locally absent. Occasionally the *Cladium filum* sedge meadow is more extensive, in which case the tea-trees are included either as a discrete zone or dispersed throughout. *Nicotiana glauca* and *Inula graveolens* are found around the margins.

These swamps are fringed by *E. diversifolia* - *E. angulosa* association, which begins abruptly. *Eucarya* spp. are conspicuous in the fringe, and often also *E. leucoxylon* var. *pauperita*.

The following gives the percentage of total soluble salts in the different zones:

| | | | | |
|--|---|---|---|---------|
| <i>Salicornis australis</i> | - | - | - | 4-13 |
| <i>Cladium filum</i> | - | - | - | { |
| <i>M. fasciculiflora</i> and <i>M. pubescens</i> | - | | | ·15-·76 |

A sample taken at the margin of the *E. diversifolia* - *E. angulosa* association showed only ·02%.

SUMMARY

This paper deals with the soils and vegetation of the area adjacent to Lakes Alexandrina and Albert. Undulating plains with much wind-blown sand overlying Miocene limestone are characteristic of the area.

The soils are classified and described and mechanical and chemical analyses given of representative profiles. In one instance the maturation of an immature soil is traced. The most widespread soils are the podsols with solonized subsoils. Their origin is discussed.

The plant communities and the factors responsible for their maintenance are set out together with detailed floristic lists. Two areas in which biotic succession may be traced are described.

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The writer wishes especially to acknowledge the advice given by Professor J. G. Wood and Mr. R. L. Crocker. To Mr. B. S. Glasgow who was responsible for the drawing of the vegetation map and the figures for reproduction, those who accompanied me in the more inaccessible parts, and my friends at Willingale and Coolinong with whom I stayed while doing some of the field work my thanks are due.

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EXPLANATION OF PLATES I-IV

PLATE I

Stages in the development of the lignotuber of the mallees. *E. diversifolia*, *E. angulosa*, and *E. leptophylla*.

PLATE II

- Fig. 1 Mallee habit. *E. odorata*, with *E. leucoxylon* in the centre of the photograph. *Lomandra leucocephala* in the foreground. Callington.
 Fig. 2. *Casuarina stricta* and *Lomandra leucocephala* on skeletal soil. Callington.
 Fig. 3 *Melaleuca pubescens* on shallow soil with terra rossa affinities. Ashville.
 Fig. 4 Transition between podsol with solonized subsoil of the dune and brown weakly solonized soil of the interdune areas.

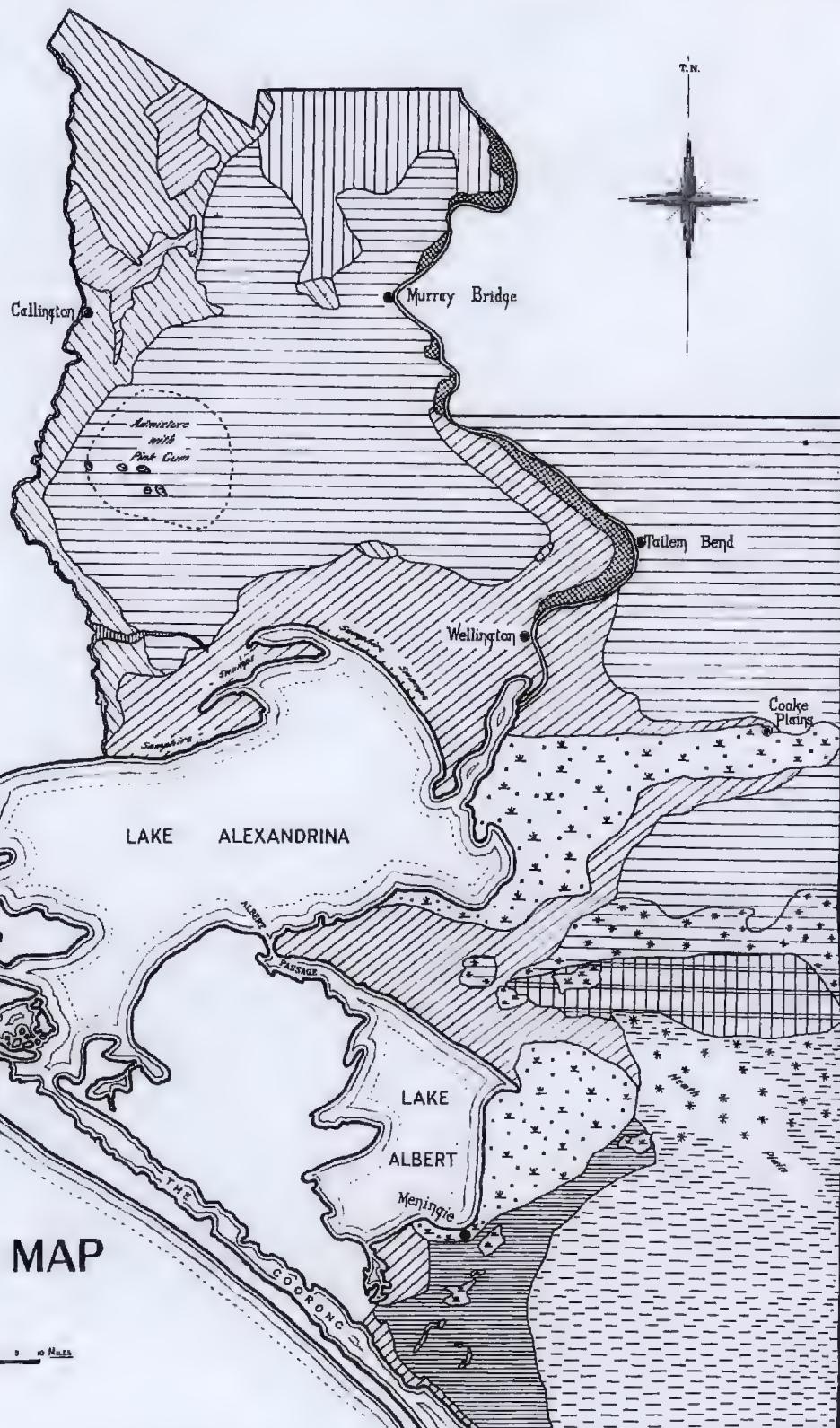
PLATE III

- Fig. 1 Great thickness of limestone hardpan in the B horizon of a "mallee" soil profile. Near Murray Bridge.
 Fig. 2 Profile of the normal phase of the Laffer sand.
 Fig. 3 *E. oleosa*—*E. dumosa* association. Murray Bridge.
 Fig. 4 Relic samphires in grassland. Malcolm Plains.

PLATE IV

- Fig. 1 Society of *E. leucoxylon* v. *pauperita* with *Kunzea pomifera* and *Scirpus nodosus*. Meningie.
 Fig. 2 *E. angulosa*—*M. uncinata* association. Murray Bridge.
 Fig. 3 Mallee-heath plain.
 Fig. 4 *Casuarina pusilla*—*Xanthorrhoea australis* association.

-  SERIAL AREA OF SAMPHIRE SWAMP AND GRASSLAND
-  INTERNAL DRAINAGE SWAMP
-  RIVER SWAMPS (IRRIGATION AREAS)
-  E. CAMALDULensis
-  E. CAGUARIA STRICta ASSOCIATION
-  E. ODDORA - E. LEUCOTYPO - E. FASCICULOSA ASSOCIATION
-  E. OLEOSA - E. DUMOSA ASSOCIATION
-  E. DIVERSIFOLIA - E. ANGULOSA ASSOCIATION
-  COMPLEX OF E. DIVERSIFOLIA - E. ANGULOSA AND E. OLEOSA - E. DUMOSA ASSOCIATIONS
-  ALTERNATING E. OLEOSA - E. DUMOSA AND E. ANGULOSA - M. VINCIGUERA ASSOCIATIONS
-  MALLEE - HEATH
-  SCATTERED HEATH SANDHILLS



VEGETATION MAP

- SCALE -

1:250,000 0 1 2 3 4 5 6 7 8 Miles

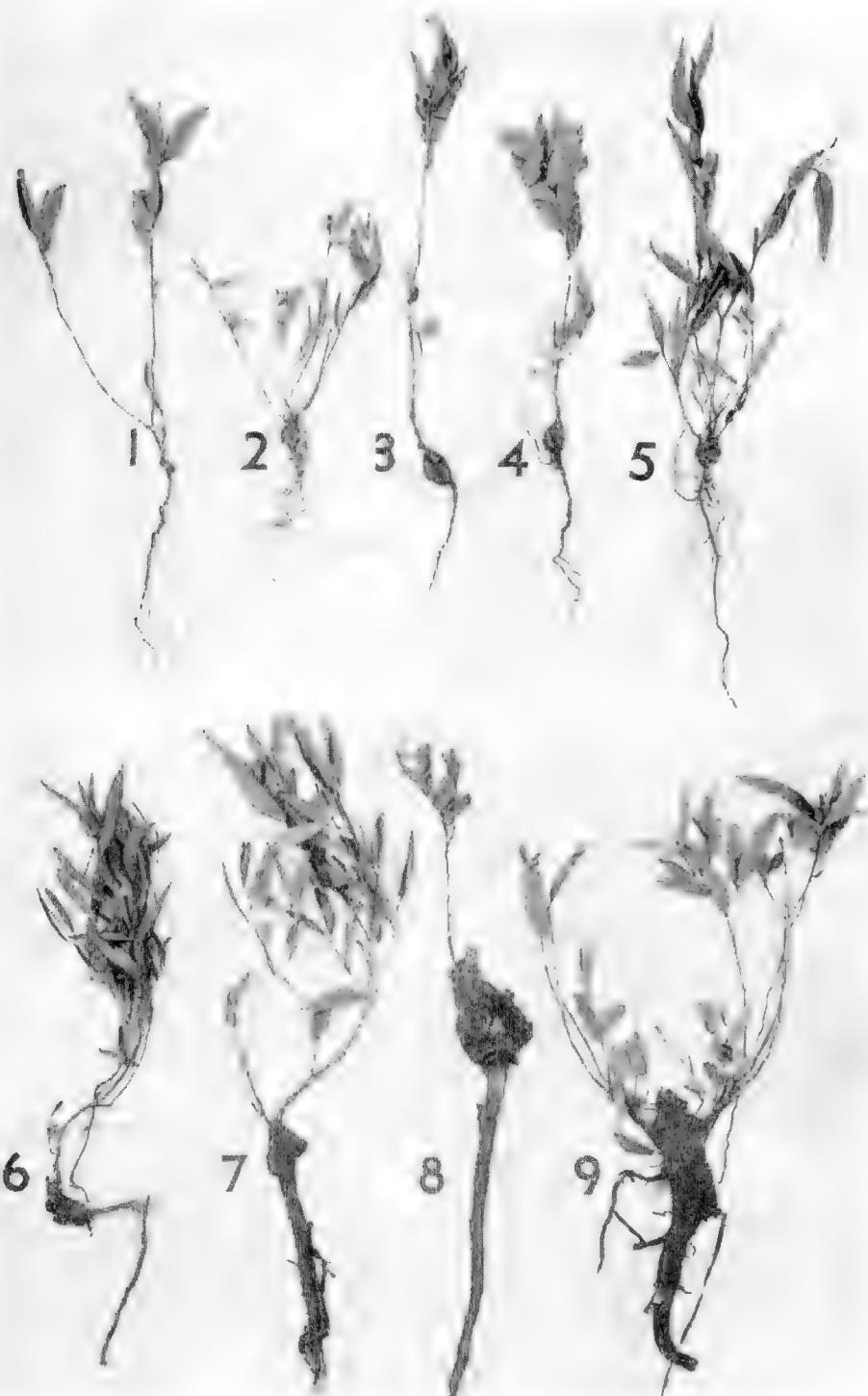




Fig. 1

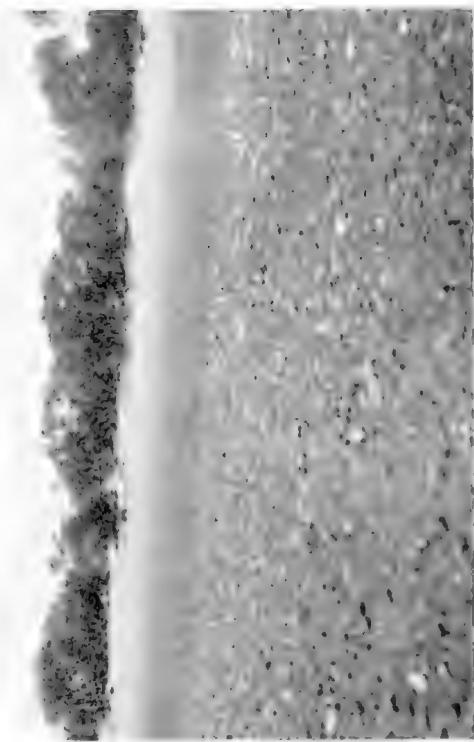


Fig. 2



Fig. 3



Fig. 4



Fig. 2

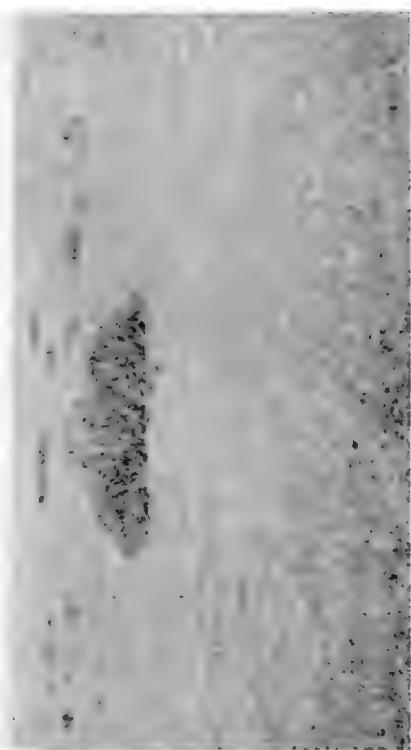


Fig. 4



Fig. 1



Fig. 3



Fig. 1

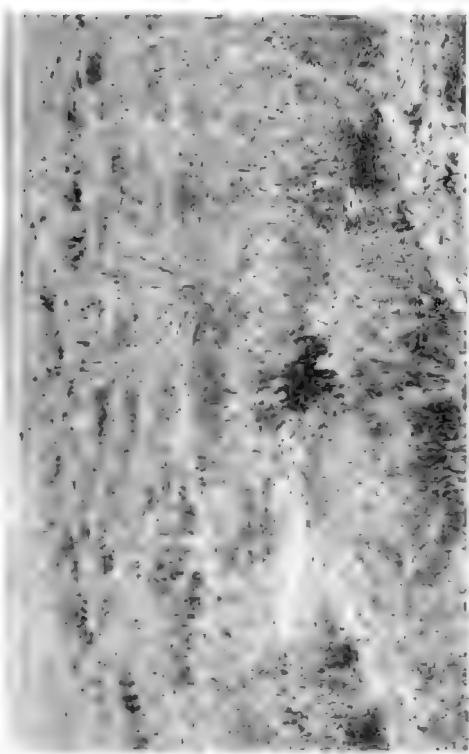


Fig. 2

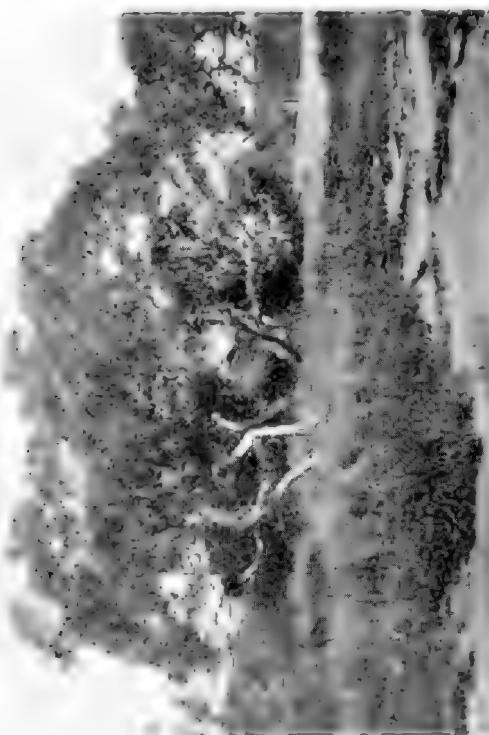


Fig. 1

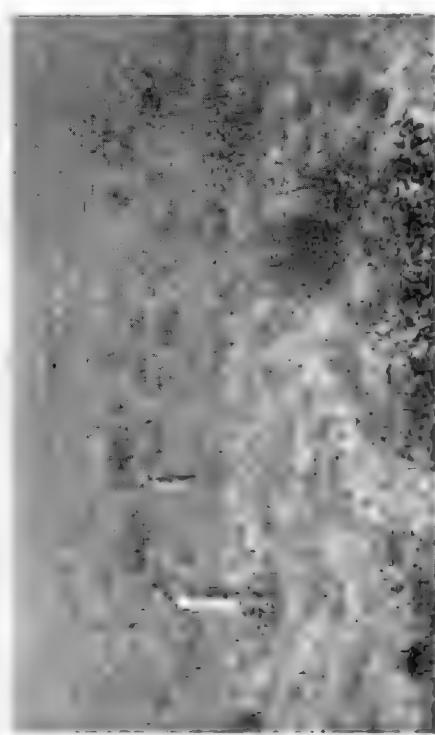


Fig. 2

SINGING SAND

BY E. S. H. GIBSON, M.Sc., A.INST. PHYS.

Summary

Roaring or singing sand dunes have for many centuries been known to exist in desert regions, but were not recorded as existing elsewhere than in waterless regions until Hugh Miller discovered a beach of musical sand on the Island of Eigg in the Hebrides in 1884. Following the publication of his finding the existence of many similar deposits has been noted. Although only two occurrences of squeaking sand in Australia have been reported, one at Phillip Island, Victoria, and the other at Botany Bay, New South Wales, many of our beaches contain sand which to some extent possesses peculiar acoustical properties.

SINGING SAND

By E. S. H. GIBSON, M.Sc., A.Inst.Phys.

[Read 11 April 1946]

INTRODUCTION

Roaring or singing sand dunes have for many centuries been known to exist in desert regions (6), but were not recorded as existing elsewhere than in waterless regions until Hugh Miller discovered a beach of musical sand on the Island of Eigg in the Hebrides in 1884. Following the publication of his finding the existence of many similar deposits has been noted. Although only two occurrences of squeaking sand in Australia have been reported, one at Phillip Island (7), Victoria, and the other at Botany Bay (5), New South Wales, many of our beaches contain sand which to some extent possesses peculiar acoustical properties.

The number of singing sandhills which produce a sound when the sand is set running down the slope is relatively small, in spite of the fact that they have been known to exist for so long. Beaches which produce a musical noise when disturbed by being walked upon or by stroking the dry surface appear to be fairly common. The present paper deals with further Australian deposits of singing sand, and with some physical properties of the sand.

SOME AUSTRALIAN MUSICAL SANDS

On the eastern side of the north arm of Boston Island, Port Lincoln, there is about half a mile of ocean beach which has been known to local residents for many years for its sonorous properties. The sound which accompanies normal walking on the dry sand announces that the beach is peculiar. By sweeping the surface with the hand or shuffling and scraping the surface, quite a loud note of high pitch is obtained. It is rather like that heard when a roughened rubber sole is swept across the pile of a carpet, more of a swish and not very musical, and it differs only in intensity from that sometimes heard when the sand on the Adelaide beaches is vigorously disturbed.

Sand possessing this peculiar property to some degree has been collected on occasions at many sites from Cape Jervis to the Semaphore. When conditions have been favourable, sand from at least Port Noarlunga, Hallett Cove, Glenelg and the Grange has appeared to be almost as musical as that from Boston Island. On Boston Island the dry sand always appears to be ready to emit a note when disturbed, even if only driven by a strong wind. The conditions frequently prevailing at the other beaches prevent the sand singing *in situ*, although with treatment it can often be made to produce a sound.

According to reports received, many other deposits of sand with some acoustic properties exist on Australian beaches, but so far no reliable evidence has been found indicating the presence of musical sand in Australia away from the coast.

INVESTIGATION AND EXPERIMENTAL OBSERVATIONS

GRADING AND GRAIN SIZE

In a number of reports dealing with the musical properties of sand it has been stated, without experimental evidence, that the grains appeared to be uniform in size. Samples of approximately 3 kilos of sand have been reduced to 250 grammes in a Jones sample splitter, and the specimen obtained placed in a

Rot-tap Automatic Shaking Machine on a set of standard sieves. The results obtained in grading the sand have been represented in a series of graphs, where the percentage of sand passing through them has been plotted against the size of the holes in the sieves. The steepness of the curves gives an indication of the uniformity of the size of the grains in the sample considered. Although the sands taken range from excellent types of musical sand, like that from the Island of Eigg, to sand which is silent under all circumstances like that from Moana, no outstanding difference is apparent from these curves.

Sand which is musical on the beach also emits a note when a pestle is rapidly pressed into a mortar containing some of it. Certain sands which appear to be silent on the beach will emit a note in a mortar, although not as readily, nor with the same intensity as the sand which is musical on the foreshore.

In grading sand some form of uniformity coefficient is often adopted, this coefficient sometimes being the ratio of the largest size of the smallest grains, which constitute 60% of the sand, to the size of the smallest grain which would be included in 90% of the larger particles. The more uniform the sand the smaller is this coefficient, its value being unity when all the grains are of the same size. Table I, giving the explanation of the grading curves, also gives the value of the uniformity coefficients. The value of the uniformity coefficients calculated in this manner have been tabulated with the key to the graphs.

TABLE I

| No. | Sand | Uniformity Coefficient |
|-----|---|------------------------|
| 1 | Moana sand hills, South Australia, silent - | - - 1.6 |
| 2 | Arno Bay, South Australia, fair in mortar | - - 1.8 |
| 3 | Port Noarlunga, South Australia, (A), feeble | - - 1.4 |
| 4 | Boston Island, South Australia, (B), excellent | - - 1.4 |
| 5 | Island of Eigg, Hebrides, excellent - | - - 1.3 |
| 6 | Second Valley, South Australia, fair in mortar | - - 1.6 |
| 7 | Glenelg North, South Australia, feeble on beach | - - 1.5 |
| 8 | Cape Jervis, South Australia, good - | - - 1.4 |
| 9 | Simpson Desert, Central Australia, dead | - - 1.5 |
| 10 | Warrnambool, Victoria, silent - | - - 1.7 |
| 11 | Port Noarlunga, South Australia, (B), good | - - 1.3 |
| 12 | Boston Island, South Australia, (A), excellent | - - 1.7 |
| 13 | Glenelg South, South Australia, (B), good - | - - 1.5 |
| 14 | Bundoona, Central Australia, dead - | - - 1.8 |
| 15 | Brighton-le-Sands, New South Wales, silent | - - 1.3 |
| 16 | Glenelg South, South Australia, (A), fair - | - - 1.6 |
| 17 | Brighton-le-Sands, New South Wales, good | - - 1.2 |
| 18 | Palm Beach, New South Wales, good in mortar | - - 1.4 |
| 19 | Wollongong, New South Wales, dead - | - - 1.5 |

The results obtained by sieving the samples of sand do not support the contention that for sand to be musical it must be more uniform in size. On the other hand, the size of the grains does play some part in determining the character of the sound produced, if any, in a mortar. A large sample of Boston Island sand was graded into fractions according to size and tested separately in a mortar with the following results:

| Size of grain | Results obtained in mortar |
|------------------------|-------------------------------------|
| Less than 0.251 mm. | - Very poor sample of musical sand |
| 0.0251 - 0.295 mm. | - Just a feeble squeak |
| 0.295 - 0.353 mm. | - Good musical sand |
| 0.353 - 0.422 mm. | - Better than mixture, higher pitch |
| Greater than 0.422 mm. | - Better than mixture, lower pitch |

Except in one case, where the size of the grains was about 1 millimetre, all musical sands which have been described seem to be less than half a millimetre in size. Most musical sands measured appear to be in between 0·3 mm. and 0·5 mm., a range in which practically all the sand examined here would fall.

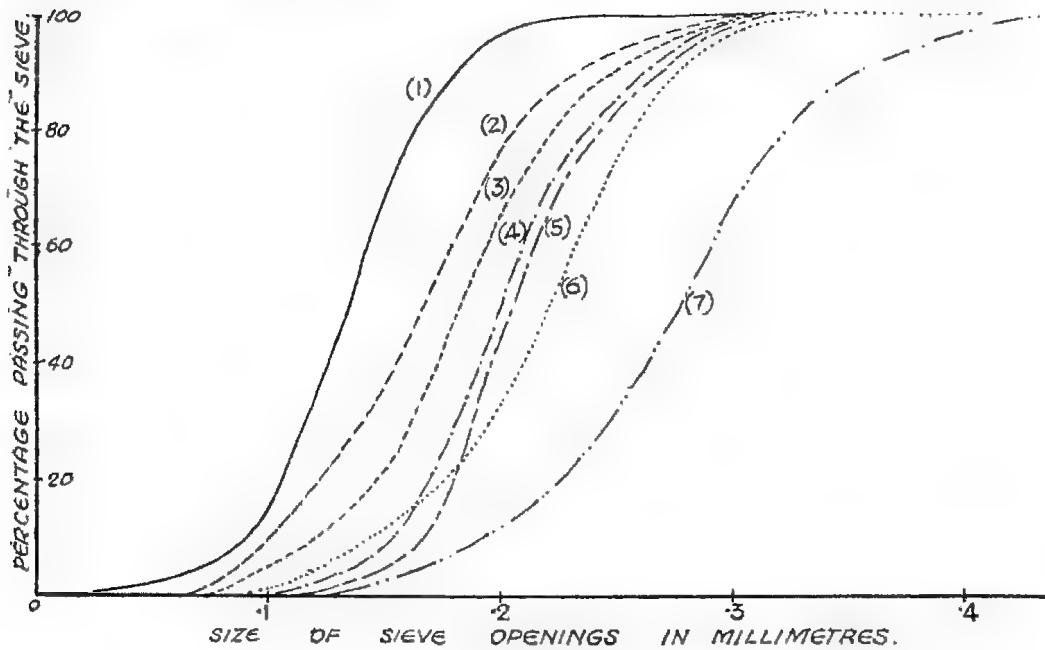


Fig. 1

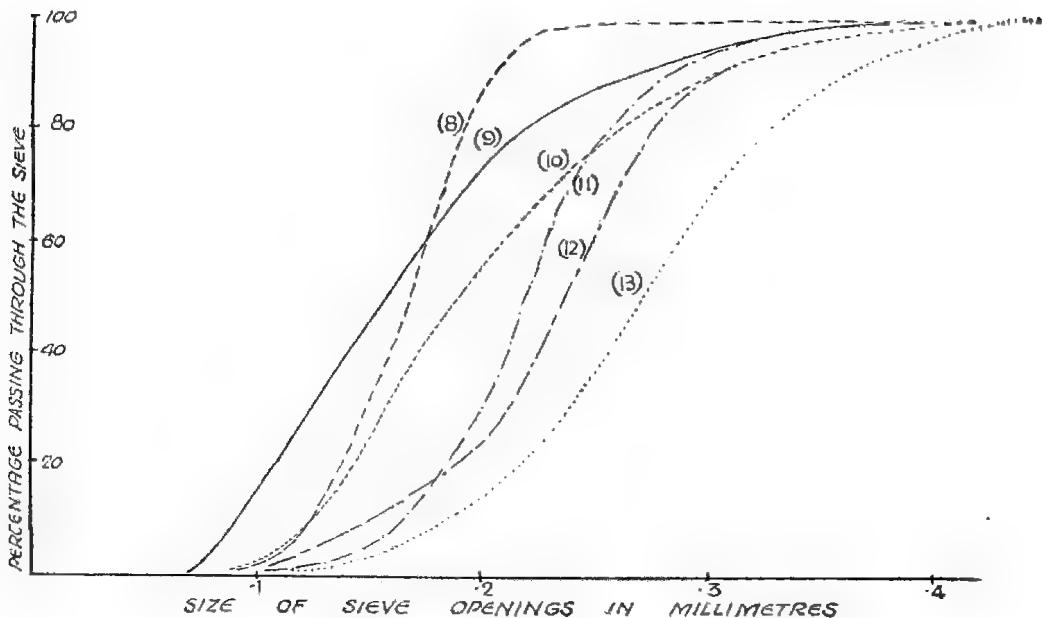


Fig. 2

"KILLING" SINGING SAND

It has been reported that singing sand can only be made to respond to treatment on the beach, and that even careful transport appears to rob the sand of

its peculiar power. However, sand carried from Port Lincoln by motor car and stored for nine years still appears to be quite normal. Some evidence to support the belief that musical sand will gradually lose its musical properties has been found. For example, a quantity of excellent singing sand from Hallett Cove, stored in a sack on the floor, lost its power to sing in just over a year. By the treatment to be described it could be restored. On the other hand, if the material is kept in a metal container where the risk of contamination by dust and moisture is considerably reduced the time limit seems to be indefinite. Many samples, including one from the Island of Eigg, have been stored in tins for over nine years without any apparent change.

Wilson (4) found that sand shaken in a tin gradually lost its power of producing a note in a mortar. After a great many demonstrations with Boston Island sand it similarly began to lose its power of creating a note. If a pestle is continually pressed into the sand for about half an hour it becomes quite dead.

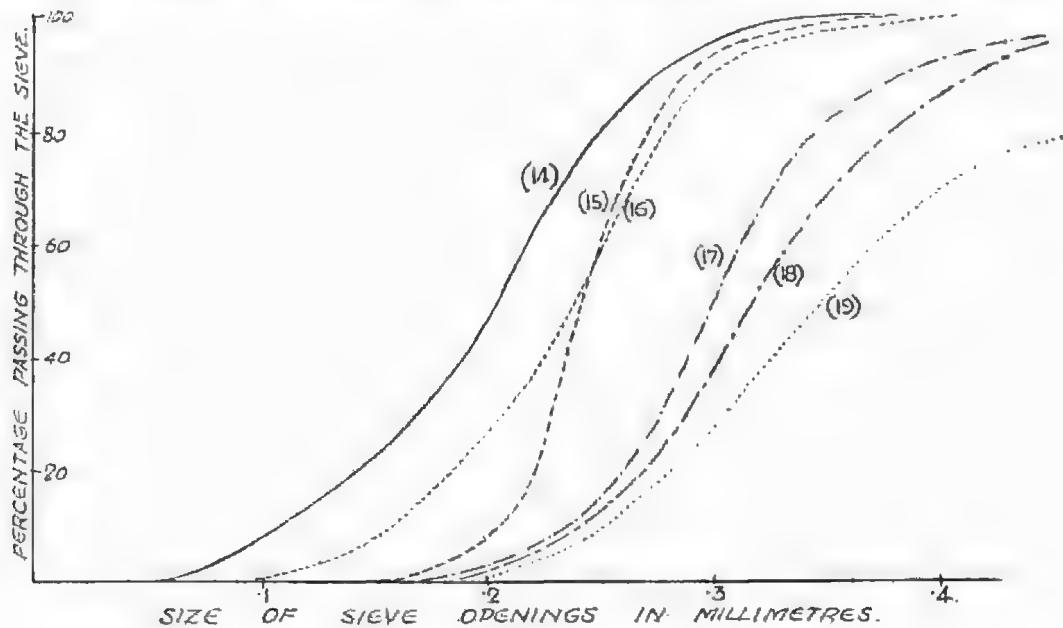


Fig. 3

Similarly, if a sample of musical sand is placed in a glass bottle, and rolled mechanically while in a horizontal position, the musical property is gradually destroyed. Every sample of musical sand which has been submitted to this treatment has lost its peculiar property. However, if the sand is well covered with water during the rolling process, and afterwards dried out, even after rolling for four hours, the dried sand is still able to emit a note when suitably disturbed. The water evidently protects the grains from the rough treatment sustained when the dry sand is rolled.

Although rolling or continual hammering in the mortar appears to make a difference to the acoustic property of the sand, the actual change appears to be very small. A quantity of Boston Island sand was split into four samples, one of which was pounded for an hour, another rolled for two hours, the third rolled with water for four hours and dried, and the fourth left untreated. A sieve analysis with each fraction failed to indicate any change brought about by the treatment.

REVIVING SAND

If musical sand which has been killed is thoroughly mixed with water, and the liquid poured off before all the particles have settled, and the process repeated several times, the sand when dried appears to regain its power to sing in the mortar. Most samples which have been rolled and thus treated have regained their musical powers, while sands which did not exhibit the musical property to any degree have been improved by this procedure. Although this washing treatment has been successful in reviving the musical properties of many parcels of sand, it is not always efficacious. Evidently some sands, like that from Moana sandhills, are definitely dead, and no treatment as yet devised will make this type of sand utter a note in the mortar. Some investigators have found that singing sands are more effective after a shower. Although washing has been found to definitely improve the acoustic properties of the sand, it cannot be the important factor in desert regions.

Rolling and washing can be continued alternately with satisfactory results. One sample of sand from Port Noarlunga, which did not sing on the beach, but which did give a good note in the mortar, has been rolled and revived five times. After rolling for 15 hours in all, it is still capable of emitting a sound. The washing and drying treatment does not always give back to the killed sand its acoustic properties, and at times the process has to be repeated to be effective.

If the finer particles are separated by sieving from sand which has been killed, the residue on the sieve does not regain its power to emit a note. The agitation of the grains during a vigorous separation on a sieve would tend to silence the sand. A gentle movement of the sieve might be expected to separate the sand without deterioration, but on attempting to restore sands from various sources by this method no success has been attained.

MOISTURE AND SINGING SAND

Most writers agree that sand is silenced by the addition of moisture, although on some occasions singing sands have been investigated after rain with satisfactory results. It seems to make no difference if 0·05% of water by weight is added to sand in the mortar, 0·1% makes a marked difference, while the addition of 1% only allowed a very feeble note. On the Adelaide beaches sounds can often be produced by sweeping the dry surface sand over the damp sand below. As a rule the sand must be dry, and in a number of cases, local sand which responded in a feeble manner on the beach, has given quite a satisfactory note in the mortar when thoroughly dried.

It has been frequently stated that musical sand cannot be transported any great distance or kept for any length of time if it is to retain its powers. Lewis (8) found that when the roaring sand of the Kalahari desert was left exposed to the air away from the dry interior it absorbed up to 0·2% of moisture and became dead. On the other hand, Bolton (2) attributed the deterioration of musical sand on exposure to the loss of moisture. Both accounts give details which cannot be dismissed lightly. To further complicate matters, Bolton (3) found that from his collection of 600 varieties of sand only two produced a squeak when wetted. The local musical sands examined seem to belong to the larger group which only produces a note when suitably disturbed in the dry state.

IMPURITIES IN SAND

Regularly shaped grains free from any adhering matter have been observed in all but one deposit of musical sand, and from the work described above it appears that some small quantity of fine material produced by abrasion between

the grains might be able to prevent the production of sound. In the case of beach sand it is to be expected that any fragments of shells and other calcareous fragments would be the first to be broken up by the rolling process. One per cent. of finely divided calcium carbonate added to musical sand interfered very seriously with its peculiar property, but it was still more musical than sand which had been tumbled about in the bottle. Two per cent. of French chalk considerably reduced the intensity of the sound, but slightly raised its pitch. When finely divided pipe clay was added, 1% reduced the intensity and raised the pitch, while 3% rendered the sand silent. One per cent. of finely divided pumice stone reduced the intensity and raised the pitch, while 1% of powdered resin prevented the production of a note. A further sample of musical sand mixed with 1% of pipe clay, which had been ground up with water in order to obtain a more uniform distribution of the clay, upon drying was still feeble in its powers to produce a note. Three per cent. of Moana sand, which is quite dead, appears to have very little effect on Boston Island sand, but 6% or more greatly reduces the intensity of the note produced in the mortar. Thus it appears that, by addition, quite a considerable amount of foreign matter is necessary to prevent the production of sound, yet the sand appears to be killed by some slight change brought about by rough treatment.

Although an absence of contamination may be a contributing factor, under some circumstances determining whether the sand will sing or not, it does not appear to be a necessary condition, for Bagnold (1) found in Libya that the vocal sands contained considerable quantities of fine material mixed with the grains, and the grains were coated with oxide.

The roundness of the grains might also be expected to be a contributing factor towards the production of sound, but most beach sands appear to be well rounded. With suitable treatment sand which can produce a note may be "killed" and "restored" alternately. Hence it is unlikely that the actual shape of the grains could be altered during the treatment which has been found to produce the reversal of the acoustic properties of the sand.

VIBRATING AIR POCKETS

Although the air between the grains must be affected by the emission of the sound when the sand is set moving, it does not appear to play an essential role in the production of sound, for it has been found that musical sand will emit a note when agitated in a vacuum.

The mortar was placed under a bell jar on the plate of a vacuum pump, and a pestle with a very long handle was made to pass through a rubber tube and protrude through an opening at the top of the jar. The upper end of the rubber tube was closed on the handle of the pestle and the lower end fastened to the neck of the bell jar. When the air was removed the rubber tube allowed the pestle to be moved up and down into the sand. The note was still produced, although reduced in intensity, when the sand was disturbed in the mortar, the sound passing through the metal plate on which the apparatus was arranged.

It has been suggested that the air spaces between the grains of sand, acting as resonators, were responsible, the cumulative effect giving rise to an audible note. This demonstration shows that neither the air between the grains of sand, nor that in the tiny hollows in the grains themselves, can be responsible. Barking sand from Hawaii consists almost wholly of fragments of coral, and the grains on grinding displayed hollows. The presence of these air cells has been used to explain the origin of the sound produced when the sand is disturbed. If such microscopic air pockets did vibrate, the pitch of the note would be extremely high, well above the range of human audibility.

ULTRA SONICS

The note emitted by a single oscillating sand particle would be well above the range of audibility. In order to detect any such high frequency tones, if produced, a microphone attached to an amplifier designed to handle high frequencies was placed near the mortar, while the pestle was forced into the sand. A filter incorporated in the circuit prevented the passage of tones lower than 15,000 cycles per second. With several samples of good singing sand no high frequency tones could be detected. The apparatus was checked, using a beat frequency oscillator giving a minimum frequency of 16,000 cycles per second. I am greatly indebted to Mr. D. W. Cox, of the School of Mines, Adelaide, for his assistance in carrying out this particular investigation.

As the sound made by the sand was quite loud, the high frequency components required to give this audible note by interference would have to be of considerable intensity, and no difficulty should be encountered in detecting their presence if they did exist. It appears that no such high frequency tones were produced, at least when the sand was disturbed in the mortar.

THE NOISE OF MOVING SAND

To determine the character of the sound produced when sand moves down an incline the following procedure was adopted. The sand was placed in a triangularly-shaped hopper with a slot 9 cm. long and 0·3 cm. wide. An incline 10 cm. wide and 53 cm. long caught the sand as it fell from the hopper at the rate of 250 grammes per second. A barrier at the base of the incline held back a layer of sand 2·5 cm. thick, and by adjusting the inclination of the trough the tumbling sand grains were kept moving over the stationary sand retained in the apparatus. A sensitive moving coil microphone was employed to pick up the sounds created by the sand, and a five-stage amplifier, capable of a million-fold amplification arranged to magnify the sound. With smaller apparatus great difficulty was encountered in obtaining any sound that could be heard distinctly from the background noises present, even in an otherwise empty and well insulated room. In the final trial the whole apparatus was placed in a large carton and surrounded with a layer of 12 cm. of finely divided wood flour. The apparatus was placed in a well insulated studio and covered with several thicknesses of insulating material when set going.

Four types of sand were compared, Boston Island, a good sample of singing sand from Port Noarlunga, and two quite dead sands from Moana and Semaphore. The noise in each case appeared to be somewhat like that produced by a whistling kettle before the water is thoroughly boiling; something like the rustling of rain on an iron roof or the sound produced by sand falling on to a piece of crumpled paper. The note produced by the Noarlunga sand was perhaps slightly higher in pitch than the other sounds. Although the acoustic properties of these sands when tested by other means fall into two distinct classes, the sounds heard were almost identical.

There was a drop of 2 cm. from the hopper to the top of the incline, and also a longer drop at the base of the slope, and the sound produced by the grains falling in these two places may have altered the character of the sound heard. When once the slope was established, the sand moved uniformly as a rule, but at times it would accumulate on the slope, and then commence to move again on an increased scale. Listening to the sand this feature could be detected as the intensity of the sound alternately increased and decreased with the irregularity in the movement. It appears then that, although the falling sand contributed to the sound detected, the sliding grains were mainly responsible for the sounds produced.

TEMPERATURE

Musical sand which has been heated strongly or cooled with liquid air still gives forth a note in a mortar, both under these extreme conditions, and also when it has regained its normal state. Sand which is normally silent is similarly unaltered by heating or cooling.

ELASTIC PROPERTIES

After removing all large fragments which would clog the apparatus, the sand was placed in a funnel with the spout drawn out so that only a fine stream of sand emerged. A piece of 2·5 cm. plate-glass was rigidly fixed at an angle of 45° to the horizontal, so that the sand had a fall of 30 cm. before impact with a point about 1 cm. from the lower edge of the plate. In falling this distance the sand grains did not diverge to any extent, the area of cross section at impact being about 0·5 cm. in diameter. As there was a tendency for the sand grains to fly out

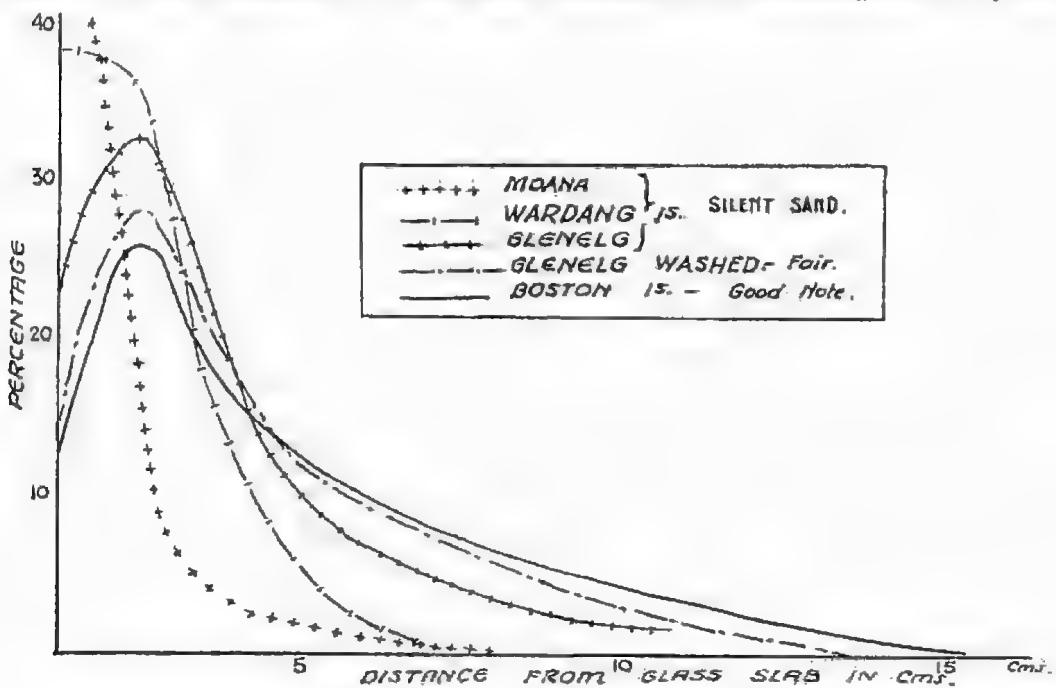


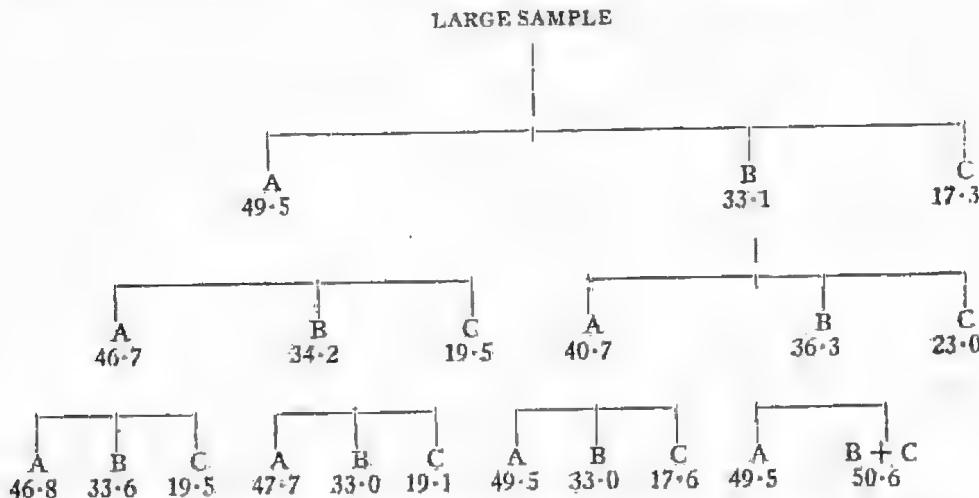
Fig. 4
Sand "Spectrum"

The percentage of sand collected by a series of narrow containers placed against each other so that the sand falling on to a piece of tilted glass is reflected along the series.

in all directions a screen caught all particles which moved beyond a fixed sector, the centre of which was the point of contact with the glass. The grains which bounced off at an angle less than 10° with a central line were caught in a set of narrow troughs placed perpendicularly with the motion of the particles. The sand caught in various containers was weighed separately. With all the samples tested practically all the grains fell short of 13 cm. The first experiments were conducted with five troughs, and, as the results appeared to be consistent, the number of divisions was increased to 14.

A number of different sands has been examined by this apparatus, and some of the results obtained are illustrated by the graphs above (fig. 4). In each case the percentage of sand retained by a particular box as ordinate has been plotted against the number of that particular box giving a kind of sand spectrum.

In order to check the method to compare the elastic properties a large sample of Glenelg sand was separated by this procedure. The five divisions in the receiving apparatus were employed, but the samples of sand collected in the last three divisions have been weighed together, giving only three fractions. The sand collected in each of the first two divisions was again passed through the apparatus, and in each case the first and second fractions were again separated. The results are set out in each case as a percentage into three classes—A, B and C.



The direction and speed of the grains after impact will depend upon their direction and velocity before collision, as well as on the shape and composition of the particles. It is obvious that this procedure does not separate the grains according to their elastic properties alone, but the separation is influenced by some other factor—most likely by the interference which is certain to take place among the falling grains. Although not a true "spectrum" of the elastic properties of the sand, the results obtained do demonstrate with regularity some very complicated property of the particles. As a rule there appears to be some difference between silent and singing sand. In most cases the singing sand grains are projected further after impact with the slab of glass. This difference has been noticed with sand that has been improved acoustically by washing. On the other hand, singing sand from Boston Island which has been silenced by abrasion gives almost the same "spectrum" as the untreated sand.

As the musical sand from Hawaii is composed of tiny fragments of coral, while in other deposits the principal constituent of the singing sand is quartz, it appears most likely that the elasticity of the particles is not the deciding factor in determining whether the sand will sing or not.

CONCLUSION

It appears that the presence of singing or musical sand depends upon the treatment that the beach receives. Many beaches do possess, at intervals, sand with definite sonorous properties. However, Boston Island beach, Port Lincoln, appears to be more favourably situated, and it always can be relied upon to squeak when dry.

It has been shown that rough treatment of musical sand, or the addition of impurities, will destroy its properties, and it is suggested that its condition can be altered by the action of the sea.

A study of the size of the particles, their uniformity and their purity, seems to indicate that there is little difference between singing sand and sand which is silent. Air is not necessary for the production of sound in the mortar, nor do any high frequency tones accompany the audible note. Further work is being undertaken in order to investigate the origin of the sound, and no explanation can be offered at present.

In conclusion, the author wishes to thank the many kind friends who have assisted in the collection of samples and information. Without their valuable aid this work could not have been possible.

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**THE SIMPSON DESERT EXPEDITION, 1939
SCIENTIFIC REPORTS: NO. 6, GEOLOGY – THE SAND
FORMATIONS**

BY C. T. MADIGAN

Summary

As it was already known that the chief features of the Simpson Desert were sand and spinifex, one of the principal objects of the Expedition was to study the sand formations with a view to discovering the mechanics of their building, the origin of the sand, the past history of the area and the present position in the desert cycle. These are all fundamental questions which are exercising the minds of geologists and geographers in connection with all deserts of the world, and to which no wholly satisfactory answers are yet agreed upon. The problems of the Simpson Desert has already been discussed by the author (Madigan 1936 an 1938), and it seemed no further progress could be made without the help of more field observations. It was partly for this reason that the desert crossing was made in a west-east direction instead of north-south, so that the journey that lay across the sandridges and not in the lanes between them, making it much more arduous but allowing the maximum sand ridge observation

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[Taken as read 11 April 1946]

PLATES V TO VIII

INTRODUCTION

As it was already known that the chief features of the Simpson Desert were sand and spinifex, one of the principal objects of the Expedition was to study the sand formations with a view to discovering the mechanics of their building, the origin of the sand, the past history of the area and the present position in the desert cycle. These are all fundamental questions which are exercising the minds of geologists and geographers in connection with all the deserts of the world, and to which no wholly satisfactory answers are yet agreed upon. The problems of the Simpson Desert had already been discussed by the author (Madigan 1936 and 1938), and it seemed that no further progress could be made without the help of more field observations. It was partly for this reason that the desert crossing was made in a west-east direction instead of north-south, so that the journey lay across the sandridges and not in the lanes between them, making it much more arduous but allowing the maximum of sandridge observation.

The first thing to do was to observe and record not only the morphology of individual sandridges but also their distribution and variation throughout the area, so as to provide a picture of the whole desert as well as to give details of particular sand piles. Such general descriptions of deserts are at present very rare. In the past, examination of sand-dune or sandridge areas has presented great difficulties, but these have largely vanished in this age of air travel, and no doubt complete accounts of the nature and arrangement of the sand formations in all deserts will soon be available from aerial surveys.

The general nature of the Simpson Desert sandridges was observed by the author in the aerial reconnaissances of 1929 (Madigan 1929). These observations have since been supplemented by ground visits to the desert margin, as well as by Mr. Colson's observations on his crossing along the 26th parallel, and finally by the ground work of the Simpson Desert Expedition, 1939. This discussion will therefore begin with an account of all the known facts about the Simpson Desert sand formations as they exist today. The reader is referred to the map of the area already published by the author in these Transactions (Madigan 1945), spare copies of which would be gladly supplied on application.

DESCRIPTION OF THE SAND FORMATIONS

The area occupied by sandridges is shown on the map referred to. The western margin is the Finke River, with the outliers of the James and MacDonnell Ranges to the north-west, a sand plain to the north and Lake Eyre to the south. Taking the Mulligan as an eastern boundary (or the rabbit-proof fence to the west of it), and the lower Diamantina and Warburton as a south-east boundary, the whole of the area thus enclosed is a flat plain rising from below sea level at Lake Eyre to 600 feet in the north-west, and covered with a grid of parallel sandridges of almost constant trend which is shown by the courses of the Hay and

Mulligan, the end of the Finke and the long axes of the dry lakes in South Australia. North of the 26th parallel the sandridges are regularly spaced and continuous, but south of it they tend to be in groups with more sand-free open spaces between and dry lake beds elongated in the direction of the ridges. The area thus defined is the Simpson Desert. To the south-east of it, that is in the country north of Birdsville, and on the flood plains of the Diamantina and Cooper, the sandridges still continue but fade away not far beyond the New South Wales border with a definite margin only in the northern Flinders Ranges to the south. In this south-eastern area the sandridges still have definite trends and are of the same nature but they are much further apart, often occurring as great isolated individuals on the gibber plains (see pl. viii), to which special names have been given in some cases. They are not in general a hindrance to motor transport as there is plenty of open country. The exception to this is the country in South Australia between the Cooper and the Northern Flinders, and particularly north of Lakes Gregory and Blanche and in the neighbourhood of the Strzelecki Creek, where the sandridges are close and jumbled and the country is sandridge desert, which also applies to the country along the east side of Lake Eyre as far as the Birdsville track. Otherwise the country to the south-east is very different from the Simpson Desert, and the borders of the Desert are quite obvious and familiar to the local inhabitants. They may be recognised as the limits beyond which no one would attempt to go with an ordinary motor vehicle, for there is never anything to be seen ahead but an unbroken series of sandridges. Most of the details following apply to the sandridges of the desert proper.

Numbers and spacing of sandridges—Although the ridges are so strictly parallel, the spacing is not as even as seems at first, but varies from a few hundred yards to half a mile in the desert proper. Invariably, the smaller the sandridges, the closer the spacing (see pl. vi, fig. 1). Between Camp 5 near the Hale, and Camp 14 near the Hay, 477 sandridges were crossed in a distance of 90 miles measured across the ridges. This is five sandridges to the mile, and gives an average spacing of 332 yards from crest to crest, which may be taken as the mean for the main part of the desert. The biggest desert sandridges were seen between Camps 8 and 10, in the middle of the desert, where 84 were crossed in 21·6 miles, which gives just under four to the mile or 450 yards intervals.

At Andado Station there were two big sandridges half a mile apart with the station in the lane between them, followed to the east by the first of five small ridges 760 yards away, the five being separated by an average distance of 135 yards, then another big ridge a further half mile or more to the east (see fig. 7). At Camp 8 (see fig. 2) the intervals between crests were 347 yards, 193 yards and 622 yards, giving a mean of 387 yards. Between Camp 22 and Birdsville, outside the desert, where the big sandridges are separated by gibber plains, the spacing was more irregular and much greater—37 ridges occupied 22 miles, giving an average interval of just over 1,000 yards.

In all, the Expedition crossed 754 sandridges between the Finke near Charlotte Waters and Birdsville, a distance across the ridges of about 230 miles, which gives an average of over three to the mile, but advantage was taken of some stony country on the west side of the desert which would bring the overall average to about four to the mile.

Trends—The trends were extraordinarily regular and the ridges practically straight in the main desert (see pl. v, fig. 2). The trend of the nearest ridge to the camp was taken each morning by prismatic compass from a point on the crest to the furthest peak visible, often only a few hundred yards away, and recorded without any reference to or memory of the previous day's reading, yet the figure was often the same on successive days, at places up to sixteen miles apart.

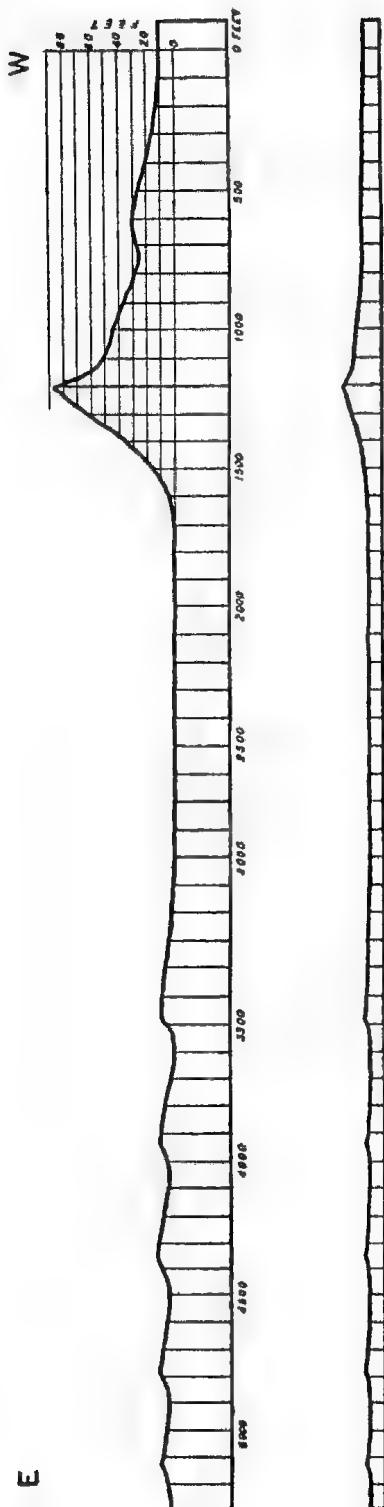


Fig. 1
Section across Sandridges at Andada. Above, vertical scale five times horizontal; below, true scale.

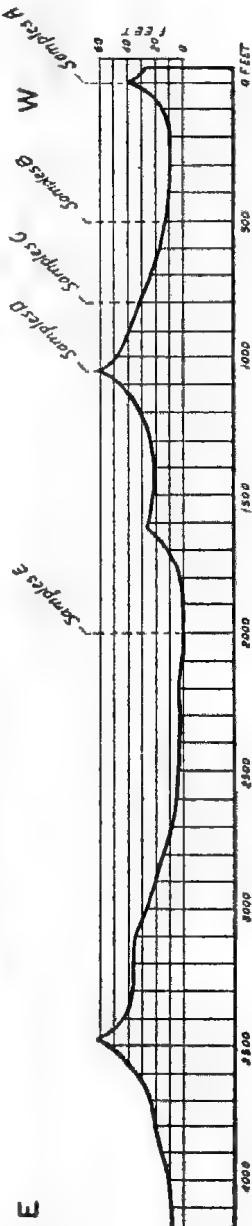


Fig. 2
Section across Sandridges at Camp 8. Above, vertical scale five times horizontal; below, true scale.

Between Camps 6 and 14 the readings were 325, 325, 326, 330, 332, 328, 330, 327, 327, giving a mean of 328, which, with a compass variation of 5° E., gives the true mean trend as 333° , or N. 27° W. Between Camp 16 on the Hay and Camp 23 near Birdsville the successive readings were 322, 325, 330, 329,

336, 330, 326, 332. On the east side of the desert, particularly east of the Mulligan, the ridges are more straggly, yet the mean of these trends is 329° , giving a true trend of 334° , or N. 26° W., which is practically the same as for the main desert crossing.

At Camps 26 and 27, south of Birdsville, the trend was N. 20° W., a distinctly more northerly trend; at Camps 40 and 41 near Lake Eyre at the north end it was N. 10° W., and at Camps 47 and 48 near the south end of the Lake it was N. 8° W.

On the west side of the desert, at Mayfield's Swamp, the trend was N. 11° W., and at Andado Station N. 9° W., but at Camp 1 it was N. 25° W., practically the mean trend for the main part of the desert.

Height and Length—The height varied from about 30 feet to 100 feet. Cross sections were measured with tape and clinometer at Andado Station and at Camp 8 (fig. 1 and 2). At other places heights were determined from a single angle of elevation from the base and pacing to the crest. The crest of the big sandridge at Andado Station was 86 feet above the ground immediately east of it. At Camp 8 the highest crest in the section was 63 feet above the bottom of the lane. At Camp 10 a height of 84 feet was measured. At Camp 17 on the Queensland Border the height was 38 feet, and at Camp 18 it was 35 feet. A big sandridge on the gibber plain at Camp 23 (pl. viii, fig. 1) measured 77 ft. 6 ins., and another near Andrewella Waterhole on the Diamantina (Camp 28) gave 80 feet. It was reckoned that some of the sandridges in the middle desert attained a height of at least 100 feet. The highest ridges seen on the march were not measured.

The sandridges in the main desert run right through it unbroken, and many of them must be 200 miles or more in length. From the air, at 4,000 feet, they were seen to run from horizon to horizon, a visible distance of some hundred miles. Only one sandridge end was seen and rounded among all the 626 encountered on the desert crossing between the Hale and the Mulligan. This one ended at a claypan between Camps 11 and 12. All the others presented an unbroken front and had to be climbed over. Occasionally two sandridges converge and join, with a single ridge continuing on, the stem of the Y thus formed invariably pointing northwards, but not more than half a dozen examples of this were seen on the desert crossing.

The aerial examination and this crossing of the centre showed that the main desert is a grid of very long, straight and parallel sandridges of moderate height and fairly evenly spaced at five to the mile. In all this area of 300 miles by 200 miles the structure is astonishingly uniform and simple. There are no complications of pattern, no spurs or cross ridges, nothing but a succession of sandy lanes separated by low ridges of sand, ribbing the level surface in straight and parallel lines. There can be no area of this size in the whole world of such complete and orderly uniformity. Of few places surely could it be said that there is nothing in any one particular locality to distinguish it from another a hundred miles away.

This uniformity is confined to the main desert. Round the borders it is much less marked. To the north, between the Hale and the Hay, the sandridges fade down through sandy undulations, still keeping their direction, into level sandy plains, but on other sides of the desert the marginal sandridges are wavy and straggly, and though maintaining a constant general direction they may change their trend in curves through as much as 45° , and convergences are the rule rather than the exception. This has been observed and photographed from the air in the neighbourhood of the railway line on the western side of the desert near the Finke, at Goyder's Lagoon on the Diamantina, and to the east of Lake Eyre (see pl. v, fig. 1, and illustrations in the Geographical Review (Madigan 1936, pp. 211, 214, 215)).

Mr. E. A. Colson, who traversed the 26th parallel in 1936 with one black bay and camels, reported that the sandridges along this parallel occurred in groups, about two miles wide, with some ten sandridges to the group, separated by narrow rubbly flats, which became dry lakes towards Poeppel's Corner. The trend was about N. 20° W. On the return journey he made a detour of some 40 miles to the south and found the sandridges smaller and straggly, with a larger proportion of flats of rubbly loam and the travelling much easier.

Cross Sections of Sandridges—It has long been known that the ridges throughout the desert are unsymmetrical, the slope on the west side being gentler than that on the east, giving the effect of a series of gentle dip-slopes and escarpments. Of the pronounced slopes on each side of the crests, the western one averaged about 15° and the eastern about 25°, but the western approach rose almost imperceptibly from near the foot of the next ridge to the west, while the eastern slopes changed direction comparatively abruptly at the base of each sandridge. The lowest part of the lane between ridges was always towards the west. This is well shown in fig. 1. The floors of the lanes seem flat, and this gentle rise might have escaped notice if levels had not been taken.

The great mass of the ridge, the plinth, to use Bagnold's term, is entirely fixed, chiefly by spinifex (*Triodia* sp.) and canegrass (*Spinifex* sp.), and there can be no question of any lateral movement at all in recent times. All the high ridges, however, have a crest of live sand of the order of 50 to 100 feet across, which is subject to continual modification by varying winds. There is no hard-and-fast line between the fixed sand of the flanks and the live sand of the crest, and vegetation often reaches to the top, but on most ridges the sand along the crests is obviously subject to movement, with frequent slip-slopes or sand-falls. These sand-falls would not exceed 10 feet in vertical height in a 50-ft. sandridge, the remainder of the flanks of the ridge being even and gentle spinifex-covered slopes.

On the western side of the desert the steep faces and sand-falls were mainly on the eastern side of the crests, but on the eastern side the position was reversed. Often there was a knife-edge along a crest which was equally inclined on both sides at the angle of repose of the sand. The reason for this will be discussed later. The object is first to set out the facts.

The sharp crest of live sand was not universal but it was the general rule, and applied to most ridges in the main desert of 50 feet or over. In some localities, particularly in the neighbourhood of the Hay, the 30-foot ridges had rounded summits with no sand-falls.

Fig. 1 and 2 both show the same phenomenon, a hump on the western side of the sandridge, which was in fact fairly general though not conspicuous. It gives the impression that the crest tends to migrate eastward, leaving a broad whale-back behind it.

Longitudinal Profiles—Although the pattern of the desert is simple, and the ridges straight, parallel and fixed, yet the formations of the live sand on top of the fixed and similar plinths show considerable variation. The simplest case is shown in pl. vi, fig. 2, where the crest is a straight ridge with gentle slope on the west side and sand-falls on the east. This picture was by Colson along the 26th parallel. Although it illustrates the general principle it is exceptional in its simplicity. Most often the crests were wavy in plan as seen well in pl. v, fig. 1, and in the case of the bigger ridges they showed a distinct serration when viewed from the side, due to the occurrence of a series of summits, as shown in pl. vii, fig. 1. These were referred to as saw-tooth ridges in the field, and were most conspicuous in the middle of the desert and on the highest sandridges. The live

sand of the crest rises gently northwards to the highest point, with sand-falls on the east side, then falls away more rapidly, the knife-edge curving back westward down into a saddle, to continue in an easterly curve and rise to the next summit. Sometimes the knife-edge was continuous across the saddle, sometimes the crest in the saddle was a rounded curve or whaleback. The sharp crested ridge is the *seif* (plural *siouf*) or sword-blade of the Arabs of North Africa. The appearance was of a series of sand-drifts with their long axes crossing the ridges at a small angle, which placed the drifts slightly in echelon.

The arrangement is shown diagrammatically in fig. 3. The summits were not more than a hundred yards apart, being much less on smaller sandridges. It is to be noted that the summits are convex towards the sand-falls or slip-slopes. The effect can be seen at the upper end of the desert sandridge in pl. v, fig. 2, and better in pl. v, fig. 1, which shows sandridges near Lake Eyre with the convexity and steep sand-falls on the west side instead of the east, which latter was

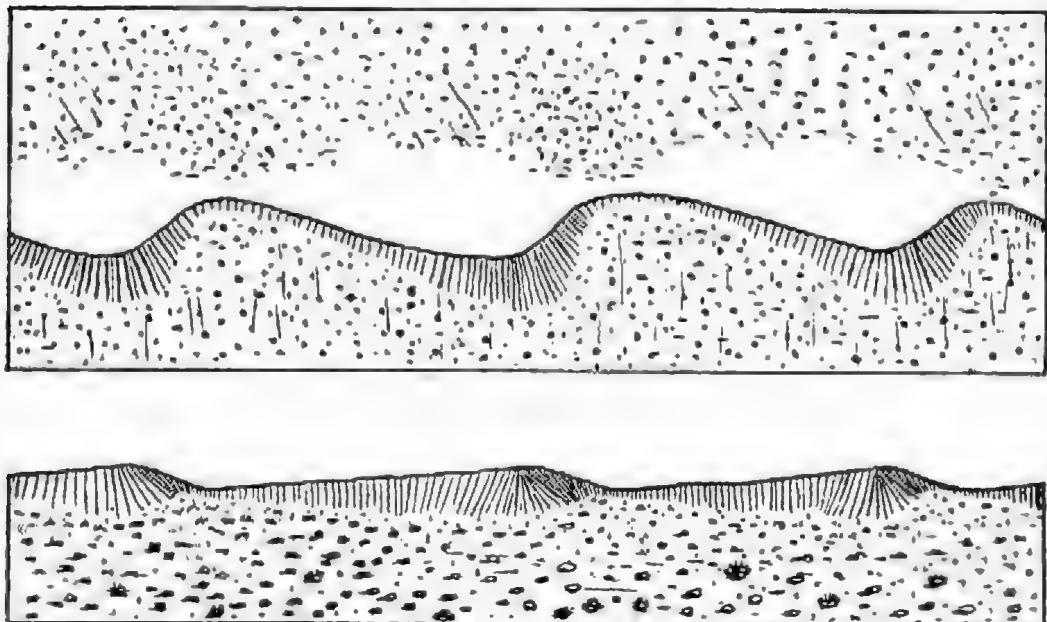


Fig. 3
Plan and eastern elevation, showing a common formation on Sandridge Crests.

the rule further north. This formation of the crests seemed very similar to Bagnold's "tear-drops" (Bagnold 1941, pl. xii b).

Route Notes on the Desert Crossing 1939—The nature and variations of the sand formations having been described, a general picture of the Simpson Desert can now be given from the route notes of the crossing of the centre. Sandridges begin immediately the Finke is crossed near Charlotte Waters. They are entirely absent on the south side of the river, which is a stony tableland. On the river flats there are some short ridges and the track to Andado winds between them without the necessity of crossing. They are similar in every way to a section of a long desert ridge. There are no signs of barchans. From Mayfield's swamp on to the stony area of Mount Day the track runs for 12 miles between low parallel sandridges.

Andado Station is on the north-east side of this stony area and on the western side of the desert proper. The station and well lie in the lane between two very

high sandridges which run up from the Finke 40 miles away and continue on to the stony area at Andado Bore No. 1. Between Camps 1 and 2, in the lee of this stony tableland the sandridges were small and close, with sand in the lanes between.

From Camp 8 near the Hale to Camp 15 on the Hay the course lay across the desert sandridges. Camp 5 was on the eastern side of the valley of a branch of the Hale. The country was at first stony with occasional small sandridges, five in the first four miles, but 70 were crossed in the next 15 miles, and 73 in a similar distance the next day. They became progressively straighter and higher, up to 50 feet, and sand was continuous between the ridges. Between Camps 7 and 8 the sandridges rose to an estimated height of 100 feet. At Camp 8 they were again smaller. Fig. 2 shows a cross section at this camp. The saw-tooth appearance of the crests was very conspicuous here. Post-hole boring showed that gravel underlay the sand in the lowest part of the lane at Camp 8, at a depth of 11 feet, beyond which the borer would not go. Sandstone fragments indicated that silicified sandstone underlay the sand at that depth.

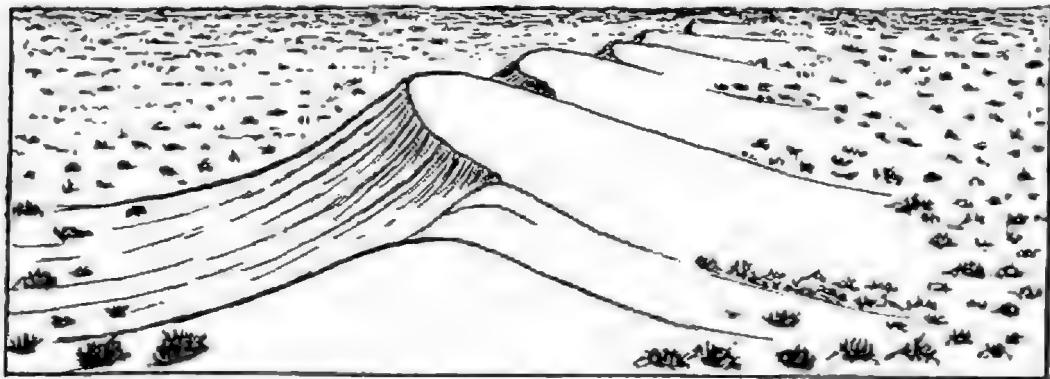


Fig. 4
Looking south along a Sandridge at Camp 8, showing Crest formation.

At Camp 9 the ridges were big and somewhat irregular on top, with the crests double in a few places, enclosing a long narrow basin or *fulje* which was open at the south (windward) end.

Between Camps 9 and 10 the biggest sandridges of the crossing were found. They were higher and rather further apart, 40 being crossed in 10 miles. They were also more symmetrical, the west side being considerably steeper and the bottom of the lane nearer the middle. The crests were again more irregular, with some transverse superimposed dunes and hollows. A sandridge measured at Camp 10 was 84 feet high, but higher ones had preceded it.

Camp 11 was less than a mile from Camp 10 and was on the edge of an area about 10 miles wide where claypans occurred between the sandridges. The ridges were still high in this area but the sand was thin between the ridges, with some exposures of porcelainised sandstone and here and there the clay floors of the claypans. At Camp 11 the crests were in snaky curves with the higher points to the east, the saddles to the west. The saw-tooth effect was most pronounced in this area. The spinifex-covered lower slopes were uniform. In some cases the saddles were quite low, forming what almost amounted to a breach running diagonally across the ridge in a north-east direction. It was only in this central area, between Camps 9 and 11 that the summits and saddles were sufficiently pronounced to make choosing a crossing-place worth while, except for the great ridges on the gibber plains east of the Mulligan.

In many places along the knife-edge crests in the centre the live sand was equally steep on both sides, as had been noted at Andado.

Between the claypans (Camp 11) and the Hay the sandridges dwindled to 30 feet in height or less, with no definite crests or live sand, but with broad rounded summits, made hummocky with small hollows and mounds. The country looked level from the top of a ridge and the view was wide, not obstructed east and west by the next jagged crest. The ridges, however, maintained their direction and spacing throughout.

East of the Hay the sandridges again became somewhat higher, 35 to 40 feet, and straighter, with a little live sand on top but no conspicuous serration. The herbage became more plentiful and some shrubs were permanent on the crests. The lanes east of the Queensland border became groves of gidgee (*Acacia Cambagei*) and clay soils replaced the everlasting sand between the ridges. At the Mulligan the ridges became broad undulations which could not be described as ridges.

Between the Mulligan and Birdsville there are some patches of sandridges with sand between the ridges as in the desert, but mainly they are big ridges standing isolated on the gibber plains, and sometimes a mile or more apart. The plinths are more symmetrical than in the desert and the crests tend to be rounded (see pl. viii). There is a marked absence of knife-edges in the Birdsville area, but where there were sand-falls they were mostly on the western side at that time, making crossing more difficult. The smaller ridges show a marked asymmetry, with gentle slopes on the western side.

Observations previously made in the vicinity of Birdsville (Madigan 1929) were checked. The small, short sandridges show ablation at the south-east ends and extension in an apron of sand at the north-west ends. Wind erosion is much more marked on the west sides than the east, though there are many sand-falls along the crests on the west sides. A search was made for anything resembling barchans, without success. The only small new formation on the gibbers noted was near the police station. It was a narrow strip of sand rising to a height of about four feet and running for a hundred yards in a N.N.W. direction, parallel to all the big ridges. It was made up of two distinct lines of coalescing mounds with a depression between them, making the surface hummocky. There were also transverse hollows. At the north end there were several separate low mounds continuing in the same alignment as the two parts of the continuous sand-strip. Mr. R. Gaffney informed the author in 1943 that this sand-strip had broken up into several independent dunes which trended N.N.W. and were long, narrow and very gentle rises terminating in a crescent-shaped sand-fall at the northern end, from which they tapered back to a point up-wind.

Mineralogy of the Sands—Dr. Dorothy Carroll has examined the samples collected by the author and Mr. Crocker and the results have appeared in these Transactions (Carroll, 1944). An account of Mr. Crocker's work on the samples will appear later. The Simpson Desert sands are somewhat finer than most other desert sands, but they agree with Bagnold's general findings, both as to fineness and distribution of gradings. Dr. Carroll found that the main bulk lay between 0.24 and 0.06 mm. Bagnold (1941, p. 6) gives the usual values for wind-blown sand as between 0.3 and 0.15 mm.

Dr. Carroll considered that the quartz grains had had a long past history, though not more worn than many beach sands or beach dune sands. There was considerably more rounding in the finer grains. The grains could possibly have passed through several cycles of sedimentation. The distribution of the heavy fraction was very significant. Sillimanite was rich in the middle of the desert,

poorer to the east and south; garnet was much more plentiful to the west, and epidote was also notably common to the centre and west. These minerals are characteristic of metamorphic rocks, which occur in abundance comparatively near in the MacDonnell Ranges to the north-west but would be rare in the Mesozoic and later sediments of the desert basin. The variety of the heavy minerals suggested to Dr. Carroll that they had not travelled far from their source though they showed considerable abrasion.

III METEOROLOGY

The weather conditions during the expedition have been described (Madigan 1945). They applied only to two winter months and have little bearing on the annual wind regime. Unfortunately, information on the desert winds is very meagre. There are no meteorological stations on the eastern side near enough to take into consideration at all. On the western side there are Oodnadatta and Alice Springs, but they have only been small stations where temperature, barometer, rainfall and wind directions have been recorded by the postmasters at 9 a.m. and 3 p.m. There were no records of wind velocities till the war years, when Air Force stations at those places noted wind direction and velocity at 1330 hours, that is, once a day. A summary of these observations is given in the following tables for the years 1941 and 1943.

ALICE SPRINGS

| Wind Veloc. M.P.H. | Year | N. | No. of observations at 1,330 S.A.S.T. | | | | | | | | Total |
|-----------------------|------|-------|---------------------------------------|----|------|-----|------|----|------|-----|-------|
| | | | N.W. | E. | S.E. | S. | S.W. | W. | N.W. | | |
| 4-15 | 1941 | 33 | 16 | 77 | 80 | 18 | 0 | 3 | 14 | 241 | |
| | 1943 | 13 | 14 | 74 | 97 | 32 | 12 | 10 | 23 | 275 | |
| 16-31 | 1941 | 5 | 0 | 0 | 3 | 1 | 1 | 0 | 4 | 14 | |
| | 1943 | 1 | 0 | 4 | 2 | 0 | 0 | 1 | 5 | 13 | |
| 32-47 | 1941 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1943 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | |
| | | Total | 52 | 30 | 155 | 182 | 51 | 13 | 15 | 46 | 544 |

OODNADATTA

| Wind Veloc. M.P.H. | Year | N. | No. of observations at 1,330 S.A.S.T. | | | | | | | | Total |
|-----------------------|------|-------|---------------------------------------|----|------|-----|------|----|------|-----|-------|
| | | | N.W. | E. | S.E. | S. | S.W. | W. | N.W. | | |
| 4-15 | 1941 | 33 | 26 | 49 | 30 | 28 | 10 | 5 | 10 | 191 | |
| | 1943 | 25 | 25 | 43 | 42 | 43 | 16 | 11 | 12 | 217 | |
| 16-31 | 1941 | 31 | 14 | 9 | 16 | 22 | 12 | 6 | 6 | 116 | |
| | 1943 | 12 | 0 | 7 | 12 | 44 | 12 | 9 | 9 | 105 | |
| 32-47 | 1941 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 5 | |
| | 1943 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 | |
| | | Total | 104 | 65 | 109 | 101 | 139 | 50 | 33 | 37 | 638 |

The tables show that for Alice Springs the east and south-east winds greatly predominate, these two directions accounting for over 60% of the winds. West and south-west winds are rare. 516 of the 544 recordings in the two years, or 95%, are for winds between 4 and 15 m.p.h., with 27 from 16 to 31 m.p.h. and 1 from 32 to 47 m.p.h. Of the 16-31 m.p.h. winds, north-west was the commonest direction, with north the next, followed by east and south-east. There were no recordings for this velocity from the north-east and only one each from south, south-west and west. The one recorded 32-47 m.p.h. wind came from the west.

The stronger winds did not show any marked seasonal tendency but were well distributed. The winds tend to be easterly in summer, south-easterly in winter. At Oodnadatta the régime is somewhat similar, the main differences being that the winds are stronger and more of them blow in a meridional direction. South winds are commonest but not much more frequent than those from the south-east, east and north. Westerly winds are rarest. Over 34% of the winds were in the 16-31 m.p.h. group, with south winds making up 30% of their number and north winds 19%. Nine winds in the 32-47 m.p.h. class were recorded in the two years, three of them from the north and two from the south. Northerly winds are most frequent in the winter. The strong winds show a marked increase in September, when they are well distributed, with a bias towards south and west.

Alice Springs is in the middle of the MacDonnell Ranges, at a height of over 1,900 feet, and is a hundred miles north-west of the straggly sandridges of the nearest edge of the desert, and over 200 miles from the middle of the desert. Oodnadatta is 100 miles west of the south end of the desert, on a stony tableland intersected by countless water-courses. There are no sand accumulations in either vicinity. The two places are 300 miles apart. Although they are 100 miles west of the desert, climate varies in this great interior mainly with latitude, and the differences in the two wind régimes are distinctly reflected in the sand formations to the east of them.

Mr. R. P. Gaffney of Birdsville, a reliable observer, states that of the gentle winds at that place, that is those up to 20 m.p.h., 50% blow from the south-east and 30% from south-east to north-east. Of winds from 20 m.p.h. to 60 m.p.h., 40% blow from south-south-west to south-south-east, and most of the remainder from west of the meridian, with fewest between south-east and north-north-east. Others have stated that the strongest winds come from the south-west. Observations, as well as the mean monthly isobars, show that the winds tend to be north-easterly in the summer and south-westerly in the winter.

Rainfall figures are much more carefully recorded in Australia than any other climatic factor, and are available from most of the pastoral holdings throughout the country, which makes the Commonwealth Weather Bureau rainfall maps fairly reliable even in the desert areas. The 5-inch isohyet, a closed ring, has its most southerly point at the north end of Lake Torrens, from which it practically follows the railway line northward to Bundoora on the north-west side of the Simpson Desert, from whence it runs north-easterly, following almost exactly the borders of the desert sandridges round and down to Birdsville, and thence southerly to Lake Callabonna and back round the edge of the northern Flinders Ranges in a curve down to Lake Torrens. It marks the border of the sandridge area to the north and west, and encloses all the main sandridges to the east and south, and might in fact have been taken as the margins of the Desert except for the different nature of the country east of the Diamantina, as explained above. The 8-inch isohyet passes between the desert and Alice Springs, skirts the central ranges and loops up north of the desert to about latitude 22° 30'. It is followed closely by the 10-inch line which borders the Southern MacDonnells.

Inside the 5-inch line the rainfall is very erratic. It can better be described as a 10-inch or nothing rainfall. For example, the rainfall at Mungerannie east of Lake Eyre was 1,511 points in 1890, but for the years 1898 to 1902 it was successively 232, 204, 191, 275 and 119 points, followed in 1903 by 507 points, the last disposing of the oft-quoted jest that "they never get the average." 1,198 points were recorded in 1908, 1,237 in 1917, the year of the greatest recorded floods when the Cooper is said to have run into Lake Eyre, and 1,209 points in 1920. (One inch is 100 points.) Between these years there were some with falls of two inches and below. The lowest record is 98 points in 1929.

At Mooloorna Station at the south end of Lake Eyre North, where records were kept between 1881 and 1902, the highest fall was 771 points in 1883 and the lowest 70 in 1888. For 1900, 1901 and 1902 the figures were 204, 267 and 125 points.

It may be mentioned here that an examination of the rainfall records of 15 stations in the Lake Eyre region showed that no conclusion could be drawn from them as to whether aridity was increasing, as is often claimed, or not. The outstanding feature of the records is that the rainfall is extremely variable, with no marked rhythm. Records began at the telegraph stations at Charlotte Waters and Strangways Springs in 1874. The best general season was in 1920 with an average rainfall of over 11 inches, and the best on the Birdsville track (the stock route from Marree to Birdsville) was in 1917 with rains of 13 inches. The worst general season was 1929 with an average of 1.8 inches, but in 1876 Charlotte Waters only received 1.7 inches, and Strangways Springs 2.1 inches. The worst year on the Birdsville track was 1888, with 0.6 inch at Cowarie and 0.7 inch at Mooloorna. Good seasons in general were 1878, 1885, 1890, 1917, 1920 and 1939, and very bad seasons were 1876, 1888, 1898 to 1902, 1927 to 1929, and 1940. There were eight good seasons in 62 years, giving an average of about nine years apart. The good season is the exception, drought conditions the rule, a hard fact about the arid interior that Australians are reluctant to face up to.

The Simpson Desert lies in the zone between summer and winter rains, so rainfall is fairly evenly distributed, with a bias towards December, January and February. The mean monthly rainfall is $\frac{3}{4}$ inch for those months, and less than $\frac{1}{2}$ inch for the other nine.

As to temperature, the Climatological Atlas of Australia, published by the Commonwealth Bureau of Meteorology, 1941, gives the daily normal maximum for the desert during the three summer months as 100° F., with an average maximum for the year of 86°, an average minimum of 59°, and an average mean temperature of 73°. The same publication gives the mean relative humidity for the year at 9 a.m. as about 38%, and at 3 p.m. about 22%. The figures for January are 31% at 9 a.m. and under 20% at 3 p.m.; for April, 35% and 25%; for July, 45% and 30%, and for October, under 30% and 20% respectively.

IV THE ORIGIN OF THE SANDRIDGES

From the morphology and nature of the sand-formations of the Simpson Desert and the meteorology and physiography of the region as set out above, it remains to deduce both the origin of the sand and the mode and time of formation of the ridges, which should throw some light on the problem of the advance or retreat of the present aridity.

The Origin of the Sand—Broadly the post-Mesozoic geological history of the Lake Eyre Basin is simple and accepted by all. The retreat of the Mesozoic seas was followed by lacustrine conditions with the deposition of the Upper Cretaceous Winton Series, mainly sandstones, on the lower Cretaceous marine shales. Scattered about round the marginal areas of the desert are low flat-topped remnants of freshwater beds known as the Eyrian Series, consisting of sands and clays with much gypsum. Some of these remnants contain Pleistocene freshwater shells (Madigan 1932, pp. 98-100), others silicified wood and even derived Jurassic cycads. They almost certainly do not belong to any one period but represent any chance lacustrine or terrestrial depositions occurring throughout the Tertiary and Quaternary, though they are generally regarded as of early Tertiary age. Those in the Lake Eyre region give the impression of being late Pleistocene. The "flat-tops" or "tent hills" are characteristic of the Lake Eyre Basin. They include not only Eyrian formations but also lower and upper Cretaceous beds, as

well as Permian glacial sandstones along the Finke River. All show the same superficial silicification, which is no indication of their age. As the silicification is so universal it can reasonably be ascribed to the Pleistocene. It was once generally regarded as due to deposition of silica by the evaporation of water at the surface, and was thus associated with the oncoming of aridity, but it is more probably the B horizon of a former soil profile, as put forward by Whitehouse (1940, p. 13-14), though formed in the genial periods of the Pleistocene glaciation rather than in the Pliocene.

It is also clear that there were highly pluvial times in the Pleistocene when rivers were running, lakes were full, vegetation was plentiful and there was an abundant fauna of giant forms whose remains are well known in the ossuaries of Lake Callahonna and the Diamantina, while today we have a desert with a rainfall of under five inches, an arid psammophytic vegetation, and a much reduced and relict fauna. There were world-wide fluctuations of climate in the Great Ice Age, with advances and retreats of the ice, but a change of a comparatively few degrees in mean annual temperature can bring about such alternations. It seems quite unnecessary, even unreasonable, to postulate any such violent changes as from pluvial to arid as we know it today, and back again, perhaps several times, but more probable that there has been a long-term set towards aridity, a gradual desiccation with some temporary halts and reverses, whether or not the peak of aridity has now been passed. The probabilities should be more in favour of uniformity than of what is more in the nature of catastrophism, with the swing to aridity beginning at the close of the Pleistocene glaciation.

The upwarping of the east-west ridge in South Australia and the initiation of inland drainage took place in the early Pleistocene. Even since then the rivers from half a million square miles of country have continued to discharge their loads into the Lake Eyre basin right down to the present day, though those from the north of the desert no longer reach the present Lake Eyre. The desert is thus a great alluvial basin which is still receiving sediment, coarser round the margins, finer towards the lake, due to lessening grade. This is surely the origin of the aeolian deposits. The subaerial erosion of the Cretaceous and Eyrian beds, *in situ*, under arid conditions, without the aid of accumulation by water transportation was formerly invoked (Madigan 1936, p. 226), but this now seems no more than a supplementary source. Those formations in the sandridge desert tend to be buried by the sands, not eroded. They are found only outside the area of deposition, particularly to the south where denudation has left scattered remnants. There are no "tent hills" in the main desert, but only very occasional silicified crusts are found in the low places as at Camp 11 and on the Hay. These can be correlated with the duri-crusts of the desert margins. In the main desert, then, the sand covers the older deposits. The rivers brought in the sand from the Lower Palaeozoic and Pre-Cambrian formations and crystalline rocks to the west and north-west and the Upper Cretaceous and Eyrian sands and later alluvium to the east, and they are still doing it, so that the sandridges must still be growing where the streams flood out, though at a reduced rate owing to the reduction in supply.

Gautier (1935, p. 44) says: "It is in these alluvial basins that, as a general rule, the ergs are formed; and these sedimentary regions seem to be places particularly favoured by the big dunes." This statement appears to be of world-wide application. The worst sandridge deserts are in alluvial basins, for example the Thar, the Karakum, and the Simpson, as well as the Saharan ergs, at least in the west. Insolation and deflation may cause lesser sand formations, but for the enormous quantities of sand found in the places mentioned, transport and accumulation by water seem essential. This view is also held by Aufzère. In

the case of very old deserts, as the Libyan Desert appears to be, alluvial deposition may not have played the major role, but in a young desert like the Simpson the conclusion seems inescapable that the dunes and ridges have been formed from alluvial deposits that have never been consolidated.

Doubianski (1928, p. 232-233) shows that the sand formations of the south-eastern Karakum were derived from the sandy-clayey alluvium of the River Oxus or Amu Daria. He further states that single barchans, regularly crescent- or sickle-shaped, regarded by Mushketov as the most frequent and characteristic form for all deserts, are entirely missing in Karakum. He regards his ridges, however, as "barchan rows," formed by the fusion of the low flanks of slightly curved barchans. The wind regime is not fully stated, and it seems more likely that these are secondary formations on longitudinal ridges. He makes no attempt to explain how the barchans come to be arranged in rows. A fluvial origin is not supported by Bagnold (1941, p. 168), who says of the Libyan Desert: "The place of origin of the sand is usually fairly obvious, an escarpment or a series of depressions where wind erosion is actively taking place," and also "The most typical kind of country in which desert dunes are found is a flat erosional surface." In the case of the Simpson Desert it seems equally obvious that the rivers are actively supplying the sand into an area of 300 miles by 200 miles, completely covered with sandridges, and with no other adequate source of supply, as it is hardly possible that pre-existing sandstones can have disintegrated *in situ* to such an extent.

That the sands of the Simpson Desert have a fluvial origin is strongly supported by the distribution of the heavy minerals in the sands, as found by Dr. Carroll and referred to above.

The conclusion is that the Simpson Desert is the most uniform, active and well-developed sandridge desert in Australia because it is a single basin of deposition in the driest part of Australia.

The Formation of the Sandridges—How the sand came to be piled up in longitudinal ridges parallel to the prevailing wind direction has been the subject of considerable discussion. That the dominant direction is parallel to prevailing winds was first pointed out by Aufrère (1928) and noted independently by the author somewhat later (Madigan 1929). Vaughan Cornish (1908) first derived the longitudinal ridge from dunes transverse to the wind by the joining up of crests in successive dunes and the blowing clear of the line of saddles. Then there is the theory of blow-outs in a sea of sand, in the manner of the *fulje* or Aufrère's *craouleyres* of Gascony, where the wind scours out longitudinal furrows like *sastrugi* in snow.

The author (Madigan 1936, p. 225-227) suggested that longitudinal ridges begin as many wavy longitudinal lines and evolve into fewer and larger straight and parallel sandridges, a view that is supported by the further evidence of this expedition and is, in his opinion, now removed beyond all doubt. Lastly, we come to Bagnold's dune-chain theory (Bagnold 1941, p. 222-223), wherein the longitudinal ridges grow by the extension of barchan dunes under the influence of a dominant together with secondary winds.

The origin from transverse dunes can be dismissed on the grounds that such a transition has nowhere been observed in operation, and such a complete and wholesale conversion as must have taken place in the Simpson Desert for example, where no transverse dunes occur at all, seems impossible. Blowouts could initiate a longitudinal parallelism, but whether the long hollows bordered by sandhills each side, in the form of a hairpin open up-wind, would be capable of almost indefinite extension seems very doubtful. This theory requires a thick existing sand sheet as a starting point.

Walther (1900) considered the barchan to be the fundamental structure and formed his chains by lateral unions of barchans, so that their direction would be at right angles to the dominant winds.

Austrère (1928) and Madigan (1929) pointed out that long chains were parallel to dominant wind, but drew attention to the importance of secondary winds in modifying the crests and producing asymmetry of the whole ridge.

Prince Kemal ed Din (1928) showed that the direction of the chains in the Libyan Desert was not that of barchan-forming winds, as the crests on the chains were transverse to the chain direction. Caporiacco (1934) confirmed this, and stated four facts that applied to his zone, from Kufra to Aweinat, namely, that the dunes are not crescentic but elongated in the direction of the wind, that the chains are parallel to the dominant winds, that there is a distinct asymmetry of slope and that the gentle slope is on the side of the principal cross wind. He stated further that he found small drifts on bare patches that were a few metres long, half a metre high and a few metres apart, that were never crescentic but all elongated in the same direction as the great chains and identical in profile with them. The only crescentic dunes seen owed their origin to an obstacle such as a stone and were only a few centimetres high but could form in chains discordant with the direction of the main chains. In some places he found the ridges continuous, but in others, notably north of Zighen and Gebel el Hanaisc, all chains, which were running north-west to south-east, were interrupted by vast sheets of smooth sand with a meridional trend, the sand sheets being as wide as the areas covered by chains. This also obtained south of Aweinat.

Caporiacco (1936) later agreed with the author's suggestion (Madigan 1936, p. 225) that the chains originated from longitudinal sand-drifts.

Bagnold (1941) has given us the fundamental principles of sand movement. Their application under ever-varying winds, winds whose movement is further complicated at the surface as soon as a considerable sand pile is accumulated, is still a very complex problem. To apply physical principles exactly to the building of grand-scale sand formations it is necessary to know the complete wind regime as well as the morphology of the accumulation in its various stages. Otherwise we are restricted to probability and conjecture.

Bagnold refers to the Libyan sandridges as dune chains and derives them from a single barchan dune whose horns are extended by strong secondary winds at a small angle to the dominant wind, the gentler dominant wind being responsible for the recurrent crests. The principal agent in the extension is here the secondary wind. This requires that a chain grows away from a source of sand out on to bare country. Chains of separate barchans are known in Peru, where alone they seem to be the chief type. Gautier (1935, p. 47) says the barchan is very rare in the Sahara, there being no word among the indigenous people corresponding to barchan. "One must search carefully through the biographies of Saharan literature to find any reference to this formation, and the barchan theory would never have been formulated from observations made in the Sahara alone. We should not, therefore, be too hasty in adopting the barchan or wind-formed dune as the elementary unit of the ergs." This applies also to the Simpson Desert. It is doubtful whether a typical barchan occurs in the whole of Australia. In the Simpson Desert we are dealing with a great widespread alluvial basin, as is the case with most of the world's big sandridge deserts, and we must look for a mechanism that will form ridges throughout the area rather than one that drives long ridges or a trailing line of barchans away from a relatively restricted source. This mechanism is found in the long, narrow sandstrips noted in the Libyan Desert by Caporiacco and Bagnold and the single example described above near Birdsville. Bagnold himself shows (1941, p. 176-179) how such

longitudinal sandstrips could originate, and it seems that he neglects this fundamental and common formation in favour of the rarer and more doubtful barchan origin. It is true that the larger Simpson Desert sandridges, with their crests and saddles, suggest an extended line of dunes, but there are no signs of the initial stages of this even on the most favourable country, the gibber plains to the east, where the sand supply is meagre. The serrations in the Simpson Desert sandridges are regarded as a secondary effect, not a primary. At present they concern the live sand crests only and are forming and changing today. They are not reflected in the main bulk of the plinths themselves. No vestigial barchan wings are seen, such are shown in Bagnold's illustration (1941, pl. 12 A, p. 224). This should be compared with pl. vii, fig. 1 and 2, in this account. The chain of barchans is, of course, possible, and Bagnold's picture looks like one, but even there the effects could be secondary and formed upon an already piled sandridge. The conditions postulated for the origin of the Libyan Desert barchan chains and the Simpson Desert sandridges are, however, quite different. In the one case the chain is visualized as growing away from a source out over a bare plain, in the other the ridges may originate anywhere within the widespaced source itself.

The origin and history of the Simpson Desert sandridges is considered to have been as follows. They originated when aridity set in during the late Pleistocene by wind action on the alluvial deposits, mainly unconsolidated, on the great plains of the Lake Eyre basin.

The siliceous crust so common in the region is probably an old soil horizon which remains covered and possibly unbroken under the sandridges of the main desert, but is exposed and mostly broken up and gone in the areas to the east and south. If it is a B horizon, then it has been laid bare by the washing down of the A horizon into the basin, together with great quantities of the underlying beds, a process that has continued at a decreasing rate down to the present day.

Longitudinal sandstrips were first formed by strong southerly winds. The great majority of the sand-moving winds are southerly. The strips are formed through transverse instability of the wind as shown by Bagnold, and so frequently seen on a small scale in drifting sand on a pavement or in surface snow-drift. Suitable southerly winds will extend the strip down-wind, others may build up the up-wind end. Strong side winds will build up the whole length of the strip, increasing its height and bulk. gentler winds will tend to spread it laterally. When it reaches a certain height it will become an obstacle that will arrest all sand driven by side winds at whatever angle, so that the lanes between strips may be swept free of sand. The gentler southerly winds, between south-east and south-west, will drive the sand along the strips, now becoming ridges, and deposit it at the northerly ends, so that all ridges will extend northward. This is seen wherever the end of a sandridge can be found. The northern ends end in a fan of sand on the gibbers, never a drift running off at an angle, and the southern ends show erosion. All sand becomes trapped on the ridge and travels along it. Owing to alimentation from the side, the leeward end grows much faster than the windward end is abraded; in fact, recession of the southern end is very slow if not no more than seasonal, as it may be built up from time to time by stronger southerly winds. The result is that the ridges are always growing in length, and the net movement of sand is along their length. These formations of ridges may begin anywhere in the sand sheet; they have not necessarily all begun at the windward side. That the sand has not all been driven northward from a southerly source is shown by Dr. Carroll's distribution of the heavy minerals in the sands. They are concentrated at the northern and western sides, near their source, and fade away as one goes southward. This would be reversed if the origin of all the sand were to the south-east.

Side winds will tend to move the ridges laterally and will be much more effective while the ridges are small. Smaller ridges will overtake larger ones, so that the larger absorb the smaller and grow at their expense, and eventually the sandstrips that began as parallel bands whose length was measured in hundreds of yards and heights in feet, become ridges up to a hundred feet high and a hundred miles or more long. The regularity of size and spacing of the Simpson Desert sandridges was not as perfect as at first supposed from aerial observations. Everywhere large and small ridges were mixed, the larger ones invariably much further apart than the smaller and the intervals varying as described above. The spacing is sufficiently irregular to be no more than a statistical effect, and not regular enough to warrant any further search for a principle determining it. Small ones often occurred in batches. There was, however, an almost perfect parallelism. This is in accordance with the processes here suggested. The trend varies with the direction of the resultant of all sand-driving winds. It is east of north in the Lake Callabonna area, a little west of north near Lake Eyre, and west-north-west in the northern part of the desert, which agrees with the regional variation in wind regime. The only feature that still remains at all surprising is the rarity of junctions of ridges. They are plentiful round the margins, particularly on the south and north-west sides, but on the journey of this expedition, between the Hale and Mulligan, hardly a junction was seen in crossing 700 ridges; in fact, only one junction was actually noted down. The interior is regarded as the oldest and most mature part of the desert, and it appears that there all ridges that had made contact had completely joined up before all became fixed by vegetation assisted by their size. In the immature margins where junctions are common the ridges are very wavy, whereas in the interior they are straight.

The strongest side winds blow from between north-west and south-west, with a preponderance of north-west winds in the north and south-west winds in the south. Towards the east, north-easterly winds are more frequent than towards the west, though not often strong. It is impossible at present to be more exact than this. The results of these generalities are seen in the cross sections of the sandridges. The gentle slope is invariably on the west side, but is more pronounced on the west side of the desert than on the east, the ridges being more symmetrical to the east. This indicates that during the process of building and before the ridges became fixed, there must have been a slow migration to the east in the manner of barchan movement. The sandstrips or small ridges would have been more bulky at the up-wind or southern ends, trailing away to the north, as strong winds tend to build up the up-wind end, and it seems certain that a majority not only of all winds, but of strong winds as well, blow from between south-south-west and south-east. Also, as the sandstrips grow northward, the south end is the oldest and thus will have received more additions from the side winds. This means that the westerly lateral winds would move the northern ends of the small ridges faster than the southern ends, as the rate of movement is proportional to the bulk of the dune, and this conclusion leads to a very pretty and satisfactory explanation of the only remaining puzzle, why when there is a junction of ridges the stem of the Y thus formed is invariably to the north, a fact several times drawn attention to by the author. The reason is now obvious. The north end of a ridge moves faster and will make contact first with the ridge being overtaken, leaving the lane between them open to the south. This would also be the case even if the net movement were westward and not eastward, but the symmetry of the ridges as well as what is known of the wind regime clearly indicate an easterly drift in the northern parts of the desert, though to the south, and particularly east of Lake Eyre, the movement may be westerly, as strong south-east winds are common and the trend of the ridges is more nearly north (as seen in pl. v, fig. 1). This picture clearly shows a swing to the west at the

north end of ridges. Differential lateral movement also explains the waviness of the ridges in the immature marginal zones. As the bulk has grown, movement has slowed down, and the development and spread of the psammophytic vegetation has by now permanently fixed the ridges in the main part of the desert, though along the southern margins some of them seem to be still alive and moving. This may be a revival of movement due to the destruction of cover by stock and rabbits, though the author has always held that such destruction has never been on a sufficiently large scale to have any regional effect in this area.

Now as to what is actually going on today in the main desert. The sand-ridges are fixed as far as any movement has been detected since the white man entered the region. Owing to the bulk of the big ridges, as well as to the vegetation, any net displacement must be very small, particularly as there are sand-moving winds from both sides. The plinths are fixed, but there is live sand on nearly all crests, with sandfalls mostly to the east on the west side and to the west on the east side, but reversible according to the strength and duration of the last side wind. These crests were studied in detail at Andado and at Camps 8 and 11, and the general form is shown in fig. 3. The slope of the crest or seif is determined by the side winds, and where a welldeveloped saw-tooth arrangement of crests and saddles was seen on the desert crossing it was under the action of south-west winds at the time. These were driving the sand diagonally up the side of the ridges and moving it northward. At Andado, when the wind was about 30 m.p.h. from the south-west and the crests were "smoking," it was noted that on the lee side of the crest the wind at the surface was blowing along the ridge and even upwards towards the summit and carrying sand northwards and upwards along the steep slip-slope. These eddies were preventing sand from rolling down the lee slope, and in fact bringing back the grains that tried to escape. The configuration shown in fig. 3 is referred to as common, but it was not universal. The smaller ridges with more vegetation and less live sand had gently rounded crests with no peaks and saddles. Where the crests were sharp an attempt was made to find some general pattern, with the result shown in fig. 3. In this the sharp edges at the peaks are concave towards the wind, not convex as in the barchan, and the northern end of the edge as it falls curves back slightly against the wind and does not trail down-wind. The saddles are thus re-entrants against the south-west wind. There was definitely nothing to be found on the ridges resembling barchan formation. Conditions at the top of a 50- or 60-foot ridge are, of course, quite unsuitable for barchan formation. It was not quite obvious what caused the saddles, but the process seems to be this. The bases of the ridges are fixed and there is practically no general sand movement up the sides of the slopes, which are protected by close clumps of spinifex. The live sand we are concerned with is already at the top of the ridge. Where the vegetation does not approach so near the summit there is a wider source of sand and a greater sand supply, hence a summit will tend to form between tongues of vegetation that are creeping towards the crest. Pl. vii, fig. 2, definitely indicates this. The principle is akin to the formation of parabolic blow-outs or fuljes, and indeed these forms were seen lying across some of the broader crests, but not where sharp crests were in evidence. The fulje effect will be modified by the sloping side of the ridge. It may also be the cause of the not infrequent sandfalls found on the windward side of the sharp crests, at their northern and recurring ends, where both sides of the crest were often at the angle of rest of the sand.

The sand, then, from an eroding patch on the side of the ridge is driven upwards and northwards, rising to a summit to the north. The interval between summits was not very regular and can be ascribed to statistical effects. Actually the present live-sand crests form only a minor part of the whole sand pile. The

saddles were never low enough to be regarded as breaches in the ridge, and there were no dunes or sand piles to the leeward of the saddles. In the case of the small primitive ridges a strong cross-wind could cause complete breaches in them. The sand-drift at Birdsville, referred to above, was thus broken up, probably by south-west winds, but the dominant winds can fill the gaps and maintain the alignment. This continual change and reforming of the live sand of the crests under winds of wide variation in strength would lead to considerable variation with depth in grading of the sand. The importance of grading was not sufficiently appreciated on this expedition, with the result that samples were taken more for mineralogical purposes. It was only at Camp 8 that any systematic sampling was done, and this was at rather wide intervals along the section. The higher percentage of finer grades and clay particles in the two inter-ridge samples as compared with crests is probably due to the winnowing effect on the crests, where under present conditions of no net lateral movement and secondary winds from both sides, the coarser fractions will tend to remain as residuals on the crests and the crest sand to become more regular than that in the lanes. The "smoking" effect in strong lateral winds will carry the dust and finer particles well down into the lee of the ridge, where it will remain.

The dying out of the ridges to the north into sandy plains can be ascribed to two causes, first the rapid increase in rainfall from five to ten inches, and second the nature of the sands which, being much nearer their source in the ranges, will be more mixed, with a larger proportion of grit and pebbles which inhibit the drifting of sand.

V THE PRESENT TREND OF ARIDITY

No valid reason presents itself to justify the widely held view that aridity was greater in the past when the sandridges had their birth. That the sandridges are now fixed is no proof, for the psammophyte and drought-resisting vegetation which is mainly *Triodia* and *Spinifex* (cane grass) throughout Australia, would take a long time to replace the flora of the pluvial Pleistocene and become established over these vast areas. The ridges could form in the possibly barren times between the decline of the old vegetations and the establishment of the new. Aridity in the Lake Eyre basin may actually have increased in recent times, as a desert tends to become increasingly more arid by the mutual effect of desert influences, without change of climate, as indicated by Gautier (1935, p. 106), particularly by the blocking of waterways and the consequent withholding of water from the interior areas.

The sandridges are now fixed throughout most of the desert, but sand is still being delivered in reduced quantities to the area by the streams which do not in most cases travel so far, and deflation of the gibber plains to the south-east still continues, so that there is still some growth of sandridges in the marginal areas where they show signs of immaturity. Sandridge building has been very greatly slowed up but is not yet quite dead. There is no evidence to show that the advance of aridity has been halted, but it is not improbable that it has reached its maximum. Owing to the higher rainfall round the Simpson Desert borders and the strong hold of the protective "spinifex" cover which is practically immune to the attacks of stock and rabbits, no appreciable extension of the sandridges area is possible at present and conditions appear to have become stabilized for all practical purposes.

SUMMARY

The source of the sands of the Simpson Desert is almost entirely the alluvial deposits of the streams flowing into the Lake Eyre basin. Sandridge formation began at the close of the Pleistocene fluvial times when aridity became estab-



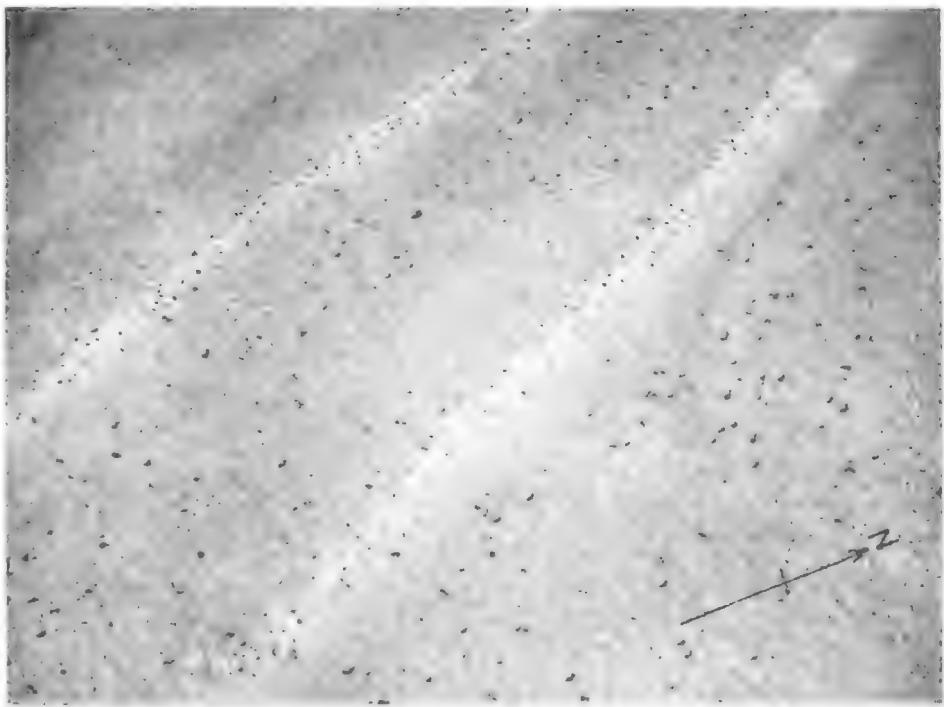
(C. T. Madigan, photo)

Fig. 1
Sandridges east of Lake Eyre, near the Birdsville track.



(C. T. Madigan, photo)

Fig. 2
A typical Simpson Desert Sandridge. Length shown, about $\frac{1}{4}$ mile.



(C. T. Madigan, photo)

Fig. 1

Small parallel Sandridges and dense Spinifex, Simpson Desert.



(E. A. Colson, photo)

Fig. 2

A Sandridge Crest, looking south.



(D. Marshall, photo)

Fig. 1

A "Saw-tooth" Sandridge at Camp 11. A Claypan in the foreground.



(D. Marshall, photo)

Fig. 2

Looking south along the Crest of the Sandridge shown in fig. 1.



(C. T. Madigan, photo)

Fig. 1

A giant Sandridge on the Gibber Plains west of Birdsville, Camp 23.



(C. T. Madigan, photo)

Fig. 2

Crossing a great "Whaleback" Sandridge west of Birdsville,

lished, and has continued down to the present day at an ever decreasing rate. The primary form is the sandstrip. The dominant prevailing winds originate and maintain the longitudinal arrangement. The lateral secondary winds build up the height, clear the lanes between, cause lateral shifting of the whole ridge and thus bring about the coalescence of ridges, so that the larger ridges absorb the smaller. Barchan formation is absent and the ridges cannot be regarded as barchan chains.

There is no evidence of greater aridity in the past. The present fixation of the ridges by vegetation does not prove amelioration of climate, as it would have taken this flora a long time to originate and colonize the vast areas involved. Aridity may have reached its peak; at any rate, owing to the "spinifex" cover and the greater rainfall round the desert margins no material extension of the sandridge area is possible under the present conditions, which appear to have reached a state of balance.

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**SOME RAISED BEACHES OF THE LOWER SOUTH-EAST
OF SOUTH AUSTRALIA AND THEIR SIGNIFICANCE**

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[Read 11 April 1946]

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INTRODUCTION

Attention has been drawn to raised beaches in the South-East by Tenison Woods (12), Howchin (8) and Tindale (10). The first writes of them in a general way, and Howchin mentions a specific raised beach on the slopes of Mount Graham and another in the Mosquito Creek near Struan. Tindale has described a beach on the Woakwine Range about six miles south of Robe on the Beachport Road, and in an interesting paper has stressed the desirability of studying the shell fauna of the ranges further inland. In view of the increasing interest being taken in Recent geology by anthropologists, geographers and pedologists, investigations of these deposits are particularly worth while.

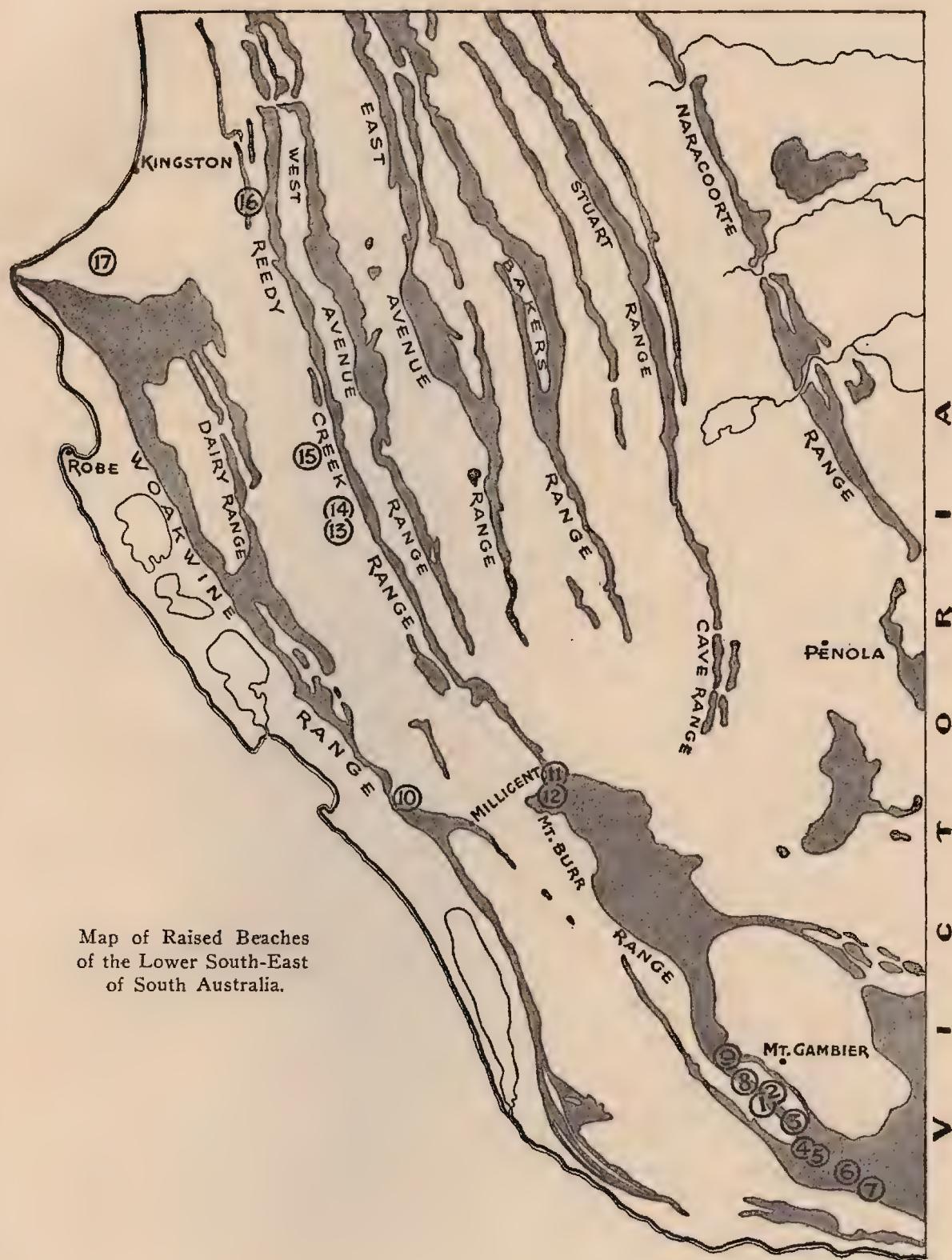
The present paper gives the locations, conchology and physiographic and geologic information relative to 16 previously unrecorded raised beach sites, in addition to a full description of the occurrence mentioned by Howchin at Mount Graham. The significance of the deposits in the Pleistocene-Recent chronological sequence is also discussed. The study is essentially one in paleoecology.

**GENERAL FEATURES OF THE GEOLOGY AND PHYSIOGRAPHY
OF THE SOUTH-EAST**

Unique physiographic features in the South-East of South Australia result from the arrangement of a series of ranges, with intervening plains, more or less parallel to the existing coastline. They were first recognised by Tenison

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Map of Raised Beaches
of the Lower South-East
of South Australia.

Woods (11) as representing a repetition of older coastal dunes or dune remnants, which were stranded during successive stages in a retreat of the sea. This view has subsequently been endorsed by a number of workers, (8), (5), (2), and is now generally accepted.

The most inland range—the Naracoorte Range—is considered to represent the original shore-line prior to the recession of the sea. Fenner (5) believes this range to be an old fault scarp and not a sand-dune ridge, but it has been subsequently pointed out (2) that there are both older calcareous dunes and siliceous sands superimposed upon this scarp, and even though there also be a fault, it can be considered a dune range.

The country east and north-east of the Naracoorte Range is all very much higher and is an older and more mature land surface, but proceeding south-west or west towards the coast there is a fall in height above sea level with successive flats. The dune range remnants have impeded the natural drainage to the sea, and as a result the inter-range plains are normally very wet in winter and late spring. This is due largely to a general rise in the water table, both as a result of local rains and rain in more remote regions. In wetter winters the water-table may rise above the lowerlying portions of the plains. This has been modified a good deal by the construction of artificial drains. Originally the excess water slowly found its way north-west and much of it finally filtered through to the Coorong.

The chief physiographic features, together with the location of the raised beaches described in this paper, are shown on the accompanying physiographic map.

While the regular pattern of dune ranges and intervening flats is uninterrupted in the region from Padthaway-Comaum to the coast, in the more southerly parts of the South-East it is considerably modified by volcanic features. The most important physiographically is the Mount Burr Range, the general framework of which is composed of basalt, tuff and ash. Over most of this area, however, are superimposed aeolian siliceous sands, though older calcareous dunes also occur. Much of the Mount Burr Range region it has been suggested, was an island or islands prior to the retreat of the sea, and the volcanic activity here is thought to be considerably earlier than that at Mount Gambier and Mount Schank (2), which is very recent.

The older consolidated dunes are composed of fine shell material, foraminiferal tests, etc., for the most part, but may have associated shell beaches (see later). The calcareous aeolianite of which the dunes are composed is normally capped with six inches to two feet of travertine limestone, and occasionally the whole dune may be more or less cemented along the accretion layers. The travertine is considered due to lime enrichment through leaching from surface horizons of the aeolianite. The older dunes form the backbone to all the strand ranges, but superimposed upon them is a considerable quantity of highly siliceous sands. These sands are wind-piled and are the re-sorted upper horizons of soils which lost their stability during the last great period of aridity. It is thought that the leached surface horizons of the soils formed on the calcareous dunes made the greatest contribution to these sands and that the stripping of them exposed the lime-enriched (travertine) B-C soil horizons (2), (3).

The most sea-ward series of old dunes is the Woakwine Range, which is almost entirely travertinised calcareous aeolianite, and practically free of any superimposed siliceous sands (pl. xi, fig. 2). There are remnants, however, of another range at numerous places along the coast from Cape Jaffa to the Victorian border, which forms some interesting weathering features at such places as Cape Northumberland, Beachport, Cape Dombey and Cape Jaffa.

The inter-dune plains are underlain by Miocene limestones (12), (5). This, however, only outcrops at the surface or is very near the surface in a small area in the most southerly parts—roughly in the region enclosed by Mount Gambier, Nelson, Port MacDonnell, Kongorong, Tantanoola and immediately north of Mount Gambier. Elsewhere it is overlain by considerable quantities of calcareous material left when the sea retreated, and superimposed over this in many regions are aeolian siliceous sands, peats, soil, etc. Miocene limestone is also a prominent feature in the elevated regions east of the Naracoorte Range.

THE RAISED BEACHES

The raised beaches described in this paper all lie within 16 miles of the coast, but at varying elevations. Their positions are shown on the physiographic map and are referred to as numbers throughout the text. They fall naturally into four major groupings, according to their location:—

- (1) Mount Gambier district - - sites 1-9
- (2) Woakwine Range - - - site 10
- (3) Mount Burr Range - - - sites 11-12
- (4) Konetta - Kingston district - - sites 13-17

The heights above sea level are all from aneroid determinations and can be considered closely approximate. The readings were carefully made in reference to known datum points and usually checked back. They should be correct to within ± 10 feet.

GENERAL CONCHOLOGY

The following list covers the more obvious and dominant shells found in the 17 sites herein described. They can be conveniently grouped into Fine Sand Beach, Estuarine, Reef and Weed habitat facies. Under the various sites the assemblage peculiar to each is indicated. All are recent species, well preserved, and often retain their characteristic colours. Some of the dominant shells are reproduced on pl. ix.

FINE SAND BEACH SHELLS

PELECYPODA

| | |
|---|---|
| <i>Katelysia scalarina</i> Lamarck 1818 | <i>Glycymeris radians</i> Lamarck 1819 |
| <i>Cardium racketti</i> Donovan 1826 | <i>Mimachlamys asperrimus</i> Lamarck |
| <i>Tawera gallinula</i> Lamarck 1818 | 1819 |
| <i>Venerupis gallactites</i> Lamarck 1818 | <i>Equichlamys bifrons</i> Lamarck 1819 |

GASTROPODA

| | |
|---|--|
| <i>Uber conicum</i> Lamarck 1822 | <i>Parcanassa pauperata</i> Lamarck 1822 |
| <i>Bullaria tenuissima</i> Sowerby 1868 | <i>Niotha pyrrhus</i> Menke 1843 |

ESTUARINE BEACH SHELLS

PELECYPODA

| | |
|--|--|
| <i>Anapella pinguis</i> Crosse and Fischer 1864 | <i>Macoma deltoidalis</i> Lamarck 1818 |
| <i>Anapella adelaidae</i> Angas 1865 | <i>Laternula recta</i> Reeve 1860 |

GASTROPODA

| | |
|---|--|
| <i>Zeacumantus diemenensis</i> Quoy and Gaimard 1835 | <i>Cacozeliana granarium</i> Kiener 1842 |
| <i>Eubitium lawleyanum</i> Crosse 1863 | <i>Assiminea granum</i> Menke 1843 |

REEF SHELLS
PELECYPODA

Brachyodontes erosus Lamarck 1818 *Ostrea sinuata* Lamarck 1819
Mytilus planulatus Lamarck 1819

GASTROPODA

| | |
|---|---|
| <i>Turbo undulatus</i> Solander 1786 | <i>Cellana tramoserica</i> Sowerby 1825 |
| <i>Austrocochlea torri</i> Cotton & Godfrey 1934 | <i>Patelloidea alticostata</i> Angas 1865 |
| <i>Austrocochlea odontis</i> Wood 1828 | <i>Murexsul fimbriatus</i> Lamarck 1822 |
| <i>Micrastrea aurea</i> Jonas 1844 | <i>Floraconus anemone</i> Lamarck 1810 |
| <i>Isoclanculus dunkeri</i> Koch 1843 | <i>Fasciolaria australasia</i> Perry 1811 |
| <i>Sabia conica</i> Schumacher 1817 (attaches to other shells) | <i>Colus australis</i> Quoy 1833 |
| <i>Cominella lineolata</i> Lamarck 1809 | <i>Nerita melanotragus</i> Smith 1884 |
| <i>Cominella eburnea</i> Reeve 1846 | <i>Melarhaphe unifasciata</i> Gray 1826 |
| | <i>Neothais textiliosa</i> Lamarck 1822 |

WEED SHELLS

| | |
|--|--|
| <i>Zemitrella austrina</i> Gaskoin 1852 | <i>Austrocochlea zebra</i> Menke 1829 |
| <i>Phasianella australis</i> Gmelin 1788 | <i>Naccula punctata</i> Quoy and Gaimard |
| <i>Cantharidus lehmanni</i> Menke 1843 | 1835 |
| <i>Thalotia conica</i> Gray 1826 | |

DETAILED DESCRIPTION OF SITES

(1) MOUNT GAMBIER DISTRICT

In earlier physiographic studies of the South-East the strand dunes and old shorelines in the Mount Gambier district have never been clearly defined. These extend to within a very short distance of the Mount—less than three miles. In discussing Howchin's raised beach at Mount Graham, in the Mount Burr Range, Fenner (4) has stated that "there is no evidence whatever of such an encroachment affecting the Mount Gambier area." The major physiographic features associated with the recent inundations in the Mount Gambier district are shown in fig. 1 a, on which the beach sites have also been placed and the approximate extent of the volcanic soils shown. The main strand ranges have been named for convenience. Fig. 1 b is a cross-section along the line A-B on this map.

SITE 1:

Location—In pasture field, adjacent road, Section 38, Hundred Macdonnell.
Height above sea level—150 feet.

General features of occurrence—Series of old dunes capped with travertine limestone. Section exposed in quarry shows terra rossa - rendzina soil developed from travertine in which there is evidence of very small traces of volcanic ash. Below approximately six inches of travertine occurs calcareous sand, probably partly aeolian in origin. In both the travertine and underlying sand are abundant shells.

Conchology—The shells found in both travertine and the aeolian sand are principally of the fine sand beach suite, *Katelysia scalarina* being the dominant species. There are also a few estuarine species such as *Anapella pinguis*, *adelaidea* and *Macoma deltoidalis*, which suggests that a creek of brackish water may have existed in the vicinity of this beach. Reef forms, or those which may attach to debris are represented by the mussels *Mytilus planulatus* and *Brachyodontes erosus*. Both of these are found as odd examples washed up on sand beaches. The shells of this suite retain their living

colours, the nacre of the mussel being preserved as in living specimens. At the Outer Harbour, near Adelaide, the same suite of shells in the same relative dominance, size and colours may be found living today. Pl. xii, fig. 1-3.

SITE 2:

Location—Roadside cutting adjacent Section 179, Hundred Macdonnell. About 100 yards from Blanche-Macdonnell hundred line, near the cheese factory corner.

Height above sea level—145 feet.

General features—In small consolidated sand rise which is an outlier to the main strand range in which Site 1 occurs.

Conchology—An exactly similar suite of shells as in Site 1.

SITE 3:

Location—Roadside cutting adjacent Sections 428-487, Hundred Macdonnell. Mount Gambier - Nelson Road.

Height above sea level—110 feet. The site is actually in a saddle, with consolidated dunes on either side rising to approximately 140 feet.

General Features—Occurs with wind-blown calcareous sand in travertinised dune.

Conchology—Similar suite and same dominant species as in Site 1.

SITE 4:

Location—Roadside, adjacent Sections 267-401, Hundred Caroline.

Height above sea level—105 feet.

General features—Consolidated dune series. In valley between two dunes polyzoal (Miocene) limestone is exposed at surface and in a quarry, demonstrating the superficial nature of these strand dune and beach deposits.

Conchology—A similar suite of shells to that of Site 1.

SITE 5:

Location—Roadside adjacent Sections 267-402, Hundred Caroline.

Height above sea level—90 feet. Another site a few hundred yards further south-east and not mentioned individually here is 100 feet above sea level.

General features—This is a pebble beach exposed as a bench in a road cutting at the edge of one of two dunes, which have an interesting long narrow corridor running between them. This corridor is locally and incorrectly considered to be an old river. The pebbles are water-worn flints, obviously weathered from Miocene limestone, and they are cemented in lime matrix which contains shell material.

Conchology—Fine sand beach shell fauna as in Site 1. See pl. x, fig. 2.

SITE 6:

Location—Roadside adjacent Sections 146-616, Hundred Caroline.

Height above sea level—88 feet.

General features—Shell material in travertine at edge of old dune.

Conchology—Fine sand beach shells as in Site 1.

SITE 7:

Location—Roadside adjacent Sections 140-107, Hundred Caroline.

Height above sea level—95 feet.

General features—Travertinised shell bed.

Conchology—Here is a suite of exclusively reef shells similar in size, relative dominance of species and colouration to that living at Cape Northumberland today. The dominant shells such as *Turbo undulata* and numerous opercula of that species, *Patelloidea alticostata*, *Nerita melanotragus* and *Cellana*

tramoserica form the bulk of the deposit (see pl. xiii, fig. 1). On the flats towards the sea south of the site the Miocene reef, on which this recent reef suite lived, is exposed. It appears to be an extensive flat reef as seen on parts of the South-East coast today, and the usual Miocene species of Polyzoa, *Chlamys* and other marine fossils of the Miocene limestone are plentiful in the rock.

SITE 8:

Location—Roadside, adjacent Sections 121-580, Hundred Blanche.

Height above sea level—145 feet.

General features—Travertinised aeolian sand and shell deposits; associated with a series of old strand dunes.

Conchology—Similar suite of shells as in Site 1.

SITE 9:

Location—Section 170, Hundred Blanche, about one chain from road between Sections 170 and 192, and in young pine plantation.

Height above sea level—210 feet.

General features—This is a deposit of small, water-worn flint pebbles, in which no shell material was observed (pl. xi, fig. 1). It rests directly on Miocene polyzoal limestone.

(2) WOAKWINE RANGE

Tindale mentions raised beaches on the Woakwine Range about 25 feet above sea level. These were apparently on the seaward side of the range. The site described here is near Rendelsham on the northern side of an arm of the Woakwine Range, which extends east to eventually become the series of consolidated dunes on which Millicent is built.

SITE 10:

Location—About 200 yards west Rendlesham Railway Station.

Height above sea level—54 feet.

General features—A small outlier to the main dune range. Abundant shell material exposed beneath a travertine capping of about 6-8 inches.

Conchology—This deposit is interesting in that fresh water shells occur above the marine suite. The marine suite is like that of Site 1, but immediately above it are numerous freshwater shells of the species *Lenameria pectorosa* Conrad 1850, an Eastern Australian species. There is also a lot of fragmentary shells in a similar state to those found at Mount Graham.

(3) MOUNT BURR RANGE

Although the framework of the Mount Burr Range is volcanic, Miocene limestones occur and probably underlie the basalt tuff and ash at depth. There is a large system of fossil dunes which flank the range in a practically unbroken line from Mount Graham past Mount Muirhead to Mount Burr and the Bluff. While this interesting series of dunes, which appears to be of at least two definite elevations, occurs on the north-west, west and south-west side of the range, there is no counterpart on the north-eastern (landward) side of the range.

The first line of dunes along the Millicent - Mount Burr road going over the Mount Muirhead saddle is approximately 140 feet above sea level, and the second apparent line 210-225 feet above sea level.

In addition to these two series of strand dunes, there are several old dunes in the valley which extends from the Mount Burr Mill to the Forest headquarters, and others occur scattered throughout the whole area.

SITE 11 (pl. xiv, fig. 1):

Location—Slopes of Mount Graham, Forest Reserve, Section 181, Hundred Riddoch.

Height above sea level—Actual site 205-210 feet, associated travertinised dunes to 240 feet.

General features—The shell beach is towards the base of an old dune perched on the fairly steep sides of Mount Graham and is about 70-80 feet above the lower lying country at the foot. The deposit is overlain by fairly dense travertine 6-12 inches thick, which contains little or no shell material except in the bottom inch or two.

Conchology—The mollusca are of the reef type and retain in part their living colours. The remarkable feature is that the shells are of a steep beach type and those found in deeper water. The community is like that of say, Middleton near Port Elliot, and has the same shells, notably *Scaeoleda illepida* Iredale 1929 and *Negyrina delecta* Cotton 1946; both species are found on exposed deep water beaches (see pl. xiv, fig. 2).

SITE 12:

Location—Observation Pit, Mount Burr Research Station, Section 449, Hundred Mount Muirhead.

Height above sea level—190-195 feet (actual bed).

General features—The deposit occurs at a depth of about 12 feet, and is overlain by soil and underlain by volcanic material.

Conchology—The mollusca are similar to those of Site 11.

(4) KONETTA - KINGSTON REGION

This is predominantly plain country—very flat and with very poor drainage. It is indeed portion of the great plain that extends from the Coorong in the north to practically Nelson (Victoria) in the south-east, and which is interrupted only by isolated occurrences of older dunes like the Hatherleigh Range and the Millent Ridge. From enquiries made by the authors, it is apparent that much of this Konetta-Kingston area is underlain by very recent marine shells at fairly shallow depth.

SITE 13:

Location—Main road adjacent Section 54, Hundred Smith. Near Konetta Station homestead.

Height above sea level—36 feet.

General features—The exposure is made in a small rubble pit in a low bank adjacent to the road.

Conchology—Estuarine shells are here imbedded in travertine limestone, beneath which the same suite continues in a calcareous clay material. The species are of the estuarine flat types—*Salinator fragilis* and *Eubittium lawleyanum* as dominants and odd species of the same facies.

SITE 14:

Location—Sections 64 and 65, Hundred Smith, Koniak Station.

Height above sea level—35 feet.

General features—The soil in this area is a shallow rendzina developed on a travertine limestone, which is frequently turned up in cultivation. This limestone is crowded with very recent shells.

Conchology—The shells are principally of the fine sand beach suite with a mixture of reef and weed types (pl. xv, fig. 2). The dominant species is *Katelysia scalarina*, and there are a few *Glycymeris radians*, the common

globular ark. The weed dwelling *Phasianella australis* is represented and retains much of its beautiful living colours. The mussel *Brachiodontes erosus*, found in colonies on reefs, is represented by odd separate valves which have evidently been washed up on the sandy beach. They still retain the characteristic blue-brown colour of the nacre. The small *Murexsul fimbriatus* is represented by odd specimens, which suggest that it also has been washed up from an outlying reef.

SITE 15:

Location—Approximately 5 miles north of Site 14, on main Kingston road.

Height above sea level—As for Site 14.

General features—As for Site 14.

Conchology—As for Site 14.

SITE 16:

Location—Section 1, Hundred Murrabinna.

Height above sea level—30-35 feet.

General features—The site extends over 2-3 miles in a low travertinised ridge, the Ashmore-Murrabinna ridge, which flanks the main road and skirts the Kingston-Konetta plain. The ridge carries an open savannah woodland of blue gum and pink gum.

Conchology—Similar shells to those found in Site 1 (see pl. xv, fig. 1).

SITE 17:

Location—Well, Section 99, Hundred Mount Benson, Wongolina Station, Flint's Paddock.

Height above sea level—Shell bed (about 4 feet below the surface) is 8-12 feet above sea level.

General features—The country is flat and featureless, and carries depauperate red gums. The shell horizon occurs at about 4 feet, below a fairly hard travertine limestone.

Conchology—Here the dominant shell is the Port Lincoln oyster, *Ostrea sinuata*, and the second dominant the Queen Scallop, *Equichlamys bifrons* (see pl. xvi, fig. 1 and 2). Both are in living condition, the latter exhibiting its deep red colour. Then follow in order of dominance and retaining much of their living colour, *Katelysia scalarina*, *Thalotia conica*, *Micrastrea aurea* and *Tawera gallinula*. The oysters are in clusters and have probably formed on beds of old oyster shell.

ADDITIONAL SHELL BEDS OF INTEREST

OYSTER BEDS—On the Mount Gambier Range (see fig. 1 a, 1 b) exposures of underlying strata are rare due to the superimposition of siliceous sands, and, in the neighbourhood of Mount Gambier, volcanic ash. The only exposure examined in this range was a road cutting in Section 764, Hundred Blanche. Here a soft horizontally bedded calcareous sandstone is exposed which contains the living Port Lincoln oyster, *Ostrea sinuata*, in good condition, dispersed throughout a thickness of some eight feet of the exposure (pl. x, fig. 1).

A very similar sandstone was noticed on a hill-top road cutting on the outskirts of northern Mount Gambier. This material is much older than the calcareous sandstone of the raised beach deposits already described, and is probably Pleistocene in age.

FRESHWATER SHELLS—On the rendzina plains of the Millicent-Rendelsham district, and in other parts of the plains, freshwater swamps were very extensive

before artificial drainage, and as a result of this freshwater shell deposits of varying thickness have been built up.

The most prevalent species is the freshwater snail *Lenameria pectorosa*, which is still living in swamps in these parts, and is common in the Murray River and its billabongs. Shells of this species occur both in the soil, the underlying travertine and/or marly material, and may be present in considerable numbers.

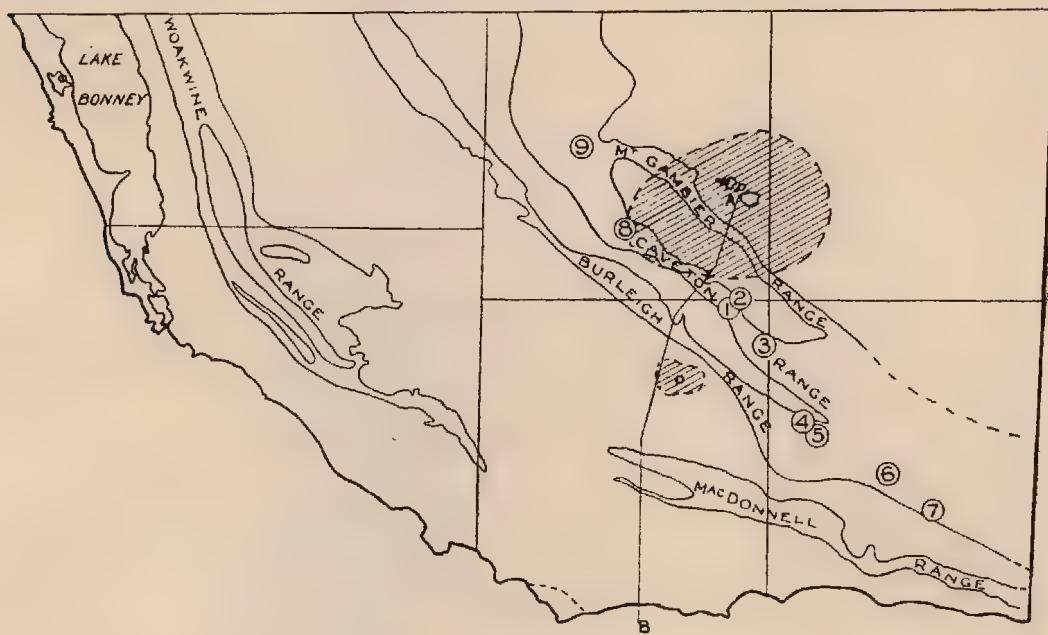


Fig. 1 a

Raised beach sites (1-9) and the consolidated dune ranges in the neighbourhood of Mount Gambier. Approximate extent of volcanic soil shown by shading.



Fig. 1 b

Sketch section from the coast near Port MacDonnell to Mount Gambier (A-B in Fig. 1 a). Thickness of volcanic material exaggerated.

At times the travertinised layer may be some feet thick and almost entirely composed of shells of *Lenameria* (see pl. xiii, fig. 2). At other times the soil is so full of remains of these shells and is so completely formed from them that it is loose and "snuffy."

The shells are usually bleached white on the outside, though the inside retains the natural delicate brown colour. Beneath the purely freshwater deposits and incorporated with them to some degree, there is occasionally seen an estuarine suite of rather small and scattered *Katelysia scalarina* and other associated species, which indicate an abrupt change from estuarine to freshwater conditions.

The absence of *Coxiella* shells supports the indications of a quick change in conditions.

LAND MOLLUSCA—South of Meningie the only native land snail recorded is *Magilaoma penolensis* Cox 1868, and the type locality is Penola. It is synonymous with *M. pictilis* Tate 1878, from Cape Northumberland. This species, about 3 mm. in diameter, is also found in Victoria and closely allied to *M. parpictilis* from north-west Tasmania; the two species being the only ones in the genus. Although the region has not been thoroughly searched and some further small species might yet be found, the apparent absence of larger characteristic native snails is of interest.

There are a few European species introduced during the last 30 years, and they are now abundant. These include *Helix aspersa* Muller, *Helicella caperata* Montagu, *Helicella ericetorum* Muller, *Euparypha pisana* Muller, and *Cochlicella acuta* Muller.

AGE AND SIGNIFICANCE OF DEPOSITS

CHARACTERISTIC SOUTH AUSTRALIAN BEACHES

The characteristic features of some of the more important beaches in South Australia and their shell fauna can be briefly described before discussing the significance of the present raised beaches.

(1) THE OCEAN SAND BEACH

The surf swept ocean sand beach carries few species of Mollusca or Crustacea, and practically no visible flora. Such beaches are found along the ocean shores of the Coorong from Goolwa to Kingston. Here the dominant mollusc is *Plebidonax deltoides* Lamarck 1818 (*Donax* of earlier writers), which occurs in great numbers in coarse sand of about 0·5 mm. in diameter. The same species occurs on various ocean beaches where the sand is coarse all around Australia. It occurs on similar beaches near Port Lincoln and Kangaroo Island. In South-Eastern Australia the species is probably a recent introduction carried by ocean currents from the west in larval form.

(2) THE ESTUARINE AND FINE SAND BEACHES

The estuarine type of beach runs almost imperceptibly into the fine sand beach and many of the species of mollusca are common to each. *Katelysia scalarina* is found in the almost pure fine sand beyond the muddy sand of the estuary, while *Katelysia peroni* is dominant in the muddy habitats which occur adjacent to the *K. scalarina* bed. *Uber conica* prefers clean fine sand, but may still be found in the muddy estuarine sand. These two types of beaches are so closely associated that it is not surprising to find their shell fauna grade one into the other.

(3) THE WARM MUD FLAT

Common on raised beaches at Murat Bay, Port Augusta, Yorke Peninsula, Fowler's Bay, Dry Creek and Port Wakefield is the sub-fossil *Anadara trapezia* Deshayes (*Arca* of some earlier writers). This belongs to a suite of warm-water surface-dwelling mud-flat species found in the *Zostera* meadows. The associated species include *Torvamurex denudatus* Perry 1811, *Pyrazus ebinus* Bruguière 1792, *Pyrazus australis* Quoy and Gaimard 1834, *Campanile laeve* Quoy and Gaimard 1834.

Although still living in New South Wales and Queensland, these species all became recently extinct in almost all of South Australia. A living specimen of *Anadara trapezia* is said to have been taken in Spencer Gulf.

ECOLOGICAL CONDITIONS OF DEPOSITION OF THE RAISED BEACHES

The shell fauna preserved in the old beaches reflect the ecological conditions under which they were deposited. Thus there are typical sand-flat, reef, estuarine, deep water and weed suites. These can be signified by a name derived from their most dominant species. They show a remarkable species convergence with present-day fauna.

| | | | |
|----------------------|---|---|--|
| (a) Sand flats suite | - | - | <i>Katelysia scalarina - Bullaria tenuissima</i> association |
| Sites 1-6, 10, 15 | | | |
| (b) Estuarine suite | - | - | <i>Anapella adelaidae - Salinator fragilis -</i> <i>Zeacumantus diemenensis</i> association |
| Sites 1-6, 10, 15 | | | |
| (c) Reef suite | - | - | <i>Turbo undulatus - Brachyodontes erosus</i> association |
| Site 7 | | | |
| (d) Deep water suite | - | - | <i>Negyrina delecta - Scaeoleda illipeda</i> association |
| Site 11-12 | | | |
| (e) Weed suite | - | - | <i>Phasianella australis - Thalotia conica</i> association |
| Site 14 | | | |

It is of some interest that the deposits conform with what might be expected from an examination of the position of the sites in relation to the surrounding country.

The reef deposit site occurs adjacent to the Mount Salt-Nelson flat for example, which is characterised by large surface exposures of Miocene limestones. These are frequently very reef-like in appearance and were undoubtedly sub-marine reefs at some stage during the inundation. Many similar reefs are exposed at low tide today off Port Macdonnell and Cape Northumberland.

The deep water suite is perched on the steep sides of Mount Graham with an immediate fall below the site of 50-60 feet over a distance of 10 chains, and at least 100 feet within 40 chains. Such conditions are relatively unique in the South-East, with its general lack of relief, and it is interesting that in the only site where one could reasonably expect a deep water association, it is found. It probably means that the relationship between the original beach and sub-marine contours was of the same order as that between the position of the site on Mount Graham and the adjacent flat.

It has already been suggested that the higher peaks and a large portion of the Mount Burr Range were insular during some stages in the retreat of the sea (2). The absence of any wave-cut terraces, however, would suggest that the still stand periods were of short duration. What terracing there is appears to be more apparent than real, and to be chiefly due to the superimposition of older dunes (now consolidated) upon the slopes.

RELATIONSHIP OF SITES TO THE MAJOR STRAND-DUNE RANGES

The relative heights of the probable foreshores associated with the strand ranges have been given by Tindale (10). In general they are agreeable with the authors'. There is, however, a fall in level in all the ranges and intervening flats, going northwards. As the beach terraces with which we are attempting to relate them are all in the south, it has become necessary to use the southerly-most limits of the ranges for correlation. These would give the following terrace levels:—

| | | | | | |
|-------------------|---|---|---|---|--------------|
| Woakwine Range | - | - | - | - | 20- 25 feet |
| Reedy Creek Range | - | - | - | - | 70- 75 feet |
| West Avenue Range | - | - | - | - | 85- 90 feet |
| East Avenue Range | - | - | - | - | 105-110 feet |
| Baker's Range | - | - | - | - | 140-145 feet |
| Cave Range | - | - | - | - | 180-190 feet |
| Naracoorte Range | - | - | - | - | 220-250 feet |

Sites 4-7 inclusive, 88-110 feet above sea level, occur in Burleigh Range and are probably the extension southward of the West Avenue and East Avenue Ranges. The steeper gradient of the country here has telescoped those two ranges into one. The intervening flats are obviously only developed where the fall is very slight. Thus skirting the Mount Burr Range it is probable that at least the West Avenue Range, East Avenue Range and Baker's Range are all telescoped into one. Tindale (*loc. cit.*) has suggested that the first strand terrace east of Tantanoola is analogous to the West Avenue Range. This is most likely, although it may even be correlated with the Reedy Creek Range. The occurrence of a series of residual flints, chiefly overlying polyzoal limestone in a narrow zone on the south-western side of the Mount Burr Range in Hundred Hindmarsh is interesting (9). There is a large series of consolidated dunes 125-200 feet above sea level on the higher side, and another series 85-100 feet on the lower side. This narrow flat with flints is probably closely correlated with the Joyce flat between East Avenue and Baker's Ranges.

Sites 1, 2, 3 and 8 in Caveton Range have a general height above sea level of 145-150 feet and are considered to be analogous to the old foreshore associated with Baker's Range, and one of the lower series of terraces skirting the Mount Burr Range.

Site 10, 54 feet above sea level on the base of the Millicent ridge near Rendelsham, is quite obviously connected with the western side of the Woakwine Range, and does indeed suggest that the sea was in the area subsequent to the formation of that range. This could have been either a late incursion, or that the range formed on an exposed sub-coastal spit during a minor fluctuation in sea level or elevation of the land. The strand line of the Hatherleigh ridge would be about the same height above sea level.

Sites 11 and 12 in the Mount Graham region, 190-210 feet above sea level, are either related to the original Naracoorte Range still-stand, or as would seem more likely to the Stuart⁽³⁾ Range - Cave Range period, and are the oldest deposits in the beaches described.

The position of Sites 13-17, inclusive, in the Kingston - Konetta district is so well defined in relation to the dune ranges that no further discussion is required. They are the most recent of the shell fauna described, and this is very well reflected in their retention of the more delicate natural colours.

A reconstruction has been made of the old coastlines relative to the stages represented by Sites 1, 2, 3, 8, Sites 4-7, and Sites 11-12, and are shown in fig. 2. The coastline analogous to the Stuart Range - Cave Range still-stand is indefinite in the Mount Gambier region. Portions of the area north of Mount Gambier, which is fairly steeply rolling are at a lower level, and in fig. 2B the coastline has been shown as possibly being north of Mount Gambier. However, it would seem equally likely that the Mount Gambier Range just south of Mount Gambier itself was the coastline at this stage. This range is 210-270 feet above sea level.

THE ANADARA BEACHES AND SUGGESTIONS OF CLIMATIC CHANGES

Attention was first drawn to the sudden extinction of *Anadara trapezia* (*Arca*) by Howchin (7). It was later suggested by Hedley (6) that "its extinction and that of its neighbour *Pyrazus* in South Australia are due to refrigeration, and may mark a period in geological climate and time subsequent to that of the Maitland raised beach (Hunter delta near Maitland, N.S.W.). The last cold phase was reckoned by Professor David from the Kosciusko moraines to be three to ten thousand years past." It can readily be accepted that the extinction of

⁽³⁾ Also frequently spelt Stewart, which is probably more correct.

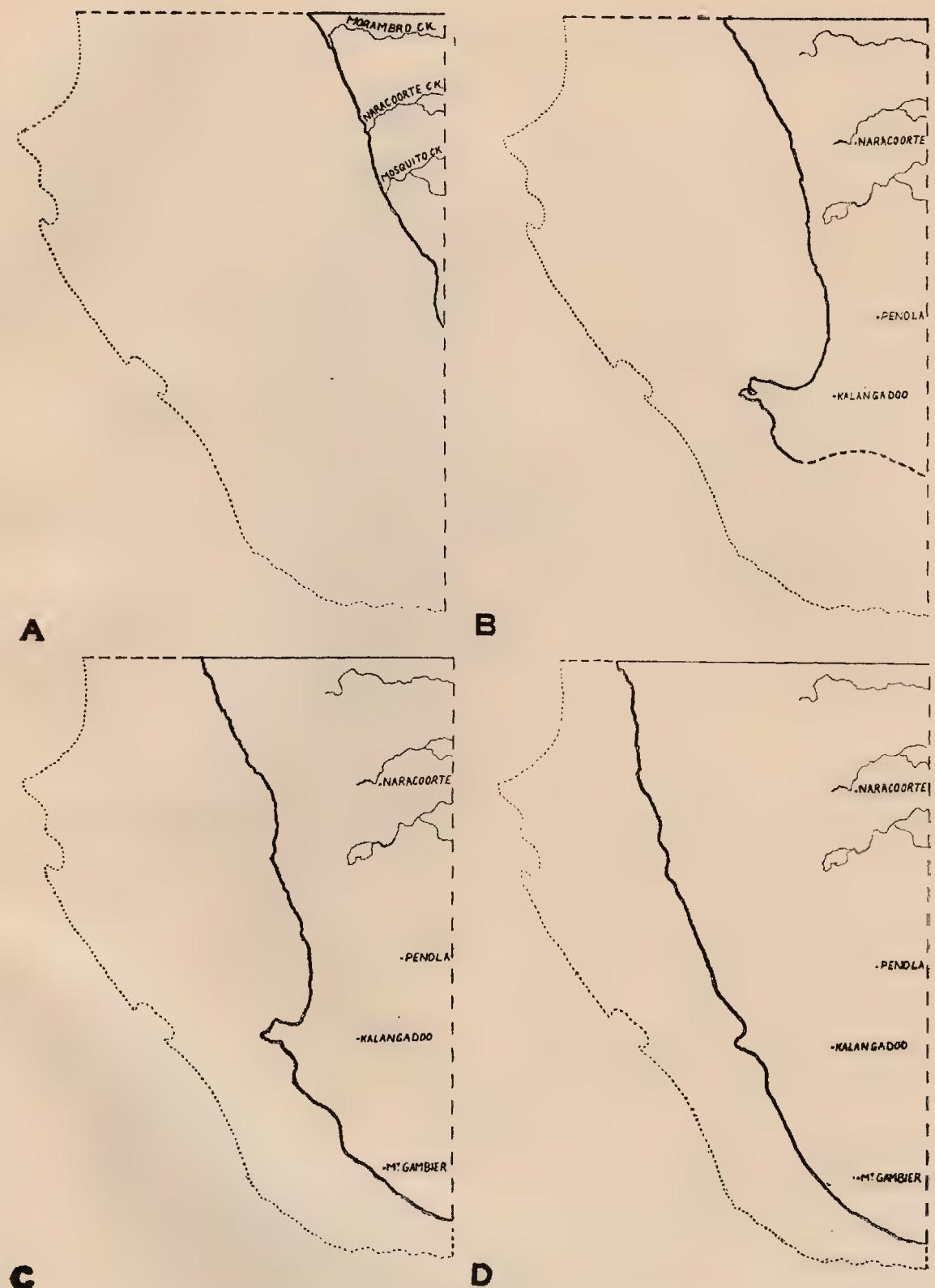


Fig. 2

Stages in the retreat of the sea: A, Naracoorte Range foreshore; B, Stuart Range - Cave Range still-stand; C, Bakers - Caveton Range still-stand; D, Avenue - Burleigh Range.

this warm mud site could be caused by low temperatures as they are all surface dwellers. One would not expect such extensive casualties, for example, amongst the oyster, *Ostrea sinuata*, because it lives at greater depth, although it might suffer some damage.

The large deposits of *Anadara* at Port Augusta and elsewhere are in some places washed by the tides and still show comparatively little wear. They can readily be mistaken for living shells cast up on the foreshore. There is no doubt that the *Anadara* horizon is very recent, and is a most important time factor in our Recent geology.

No raised beaches have been located and recorded in the South-East where this species or its normal associates have been dominant or even present. Occasional specimens have probably been picked up, as they were known to have been used by some South Australian natives in their implements, and may well have been bartered. There is apparently no evidence of the species in Kitchen middens, however. The only definite *Anadara* from the South-East seen by the authors was one isolated specimen found in a quarry in Miocene limestone at Naracoorte, where its occurrence was undoubtedly accidental, and from which no conclusion can be drawn. The discovery of a definite *Anadara* horizon in the South-East would be most valuable and worthy of close search.

From the evidence of a single Woakwine Range terrace in which *Katelysia* (*Chione*) was prevalent and the sub-fossil *Anadara* (*Arca*) absent, a migration has been postulated by Tindale (10) for *Anadara*, *Katelysia* and *Plebidonax* (*Donax*) with successively falling sea temperatures from the more southerly to the most northerly latitudes in South Australia. He has also suggested that there was "a relatively uniform 20-25-foot terrace extending along the whole of the stable portions of the sea-front of South Australia, disturbed only by minor movements in the unstable down-faulted region of St. Vincent Gulf." The shell fauna at the Woakwine site was taken to be analogous in time with the raised *Anadara* beaches about the St. Vincent Gulf, Spencer Gulf and Eyre Peninsula coasts, though there seems little justification for this in view of the evidence for local instability in the South-East.

It is known that *Anadara* was, for a brief time, present far south of the South-East of South Australia, in Bass Strait for example. Tindale has suggested that it had migrated north to about the Murray mouth by the time the Woakwine Range terrace was built up. A good deal depends on whether *Anadara*, with rising temperatures, made an entirely westerly migration or an easterly one. It may well have been that *Anadara* came from the west, and far from retreating to the south, was advancing thereto at the time the Woakwine Range terrace was forming.

Interpreting negative information such as the absence of a particular species as indicative of a certain environmental condition, requires to be done with great caution and is very dangerous. For example, the fact that *Anadara* does not occur in the beach site at Woakwine and elsewhere does not necessarily mean that temperatures were too low. Other ecological conditions might well have been unfavourable and limiting. It is known that this species is confined to shallow water and mud flats and does not occur on sandy or rocky beaches. It is significant perhaps that practically all the known occurrences of *Anadara* raised beaches in South Australia are where the requisite muddy conditions could have been anticipated, and many are adjacent to where a stream or small river enters the sea. In the South-East there are no such mud flats occurring along the coast today, and in the absence of any defined hydrology it is unlikely that any occurred west of the Naracoorte Range. A very similar reasoning can be used in the case of *Plebidonax*. It does not occur, nor would it occur, either in the raised beaches

here under discussion or Tindale's Woakwine Range site, just as it does not live nor has not established itself on the Gulf St. Vincent beaches. Knowledge as to whether it was present in the South-East at this time must await the discovery of raised beaches of a suitable type.

Although the absence of *Anadara*, unless the other relevant environmental factors can be suitably evaluated, cannot be assumed to mean low marine temperatures, its occurrence can be taken as indicative of warmer seas than at present. It has been suggested that these warmer seas may have been co-incident with the last great period of aridity (3), which for want of a name will be called the Great Australian Arid Period. If this is correct, the Woakwine Range, because it was stripped of its leached upper soil horizons during the aridity, would be pre-arid and pre-*Anadara*. On the other hand, were Tindale's proposal correct, the Woakwine Range would be post-*Anadara*. In any case the Woakwine Range is pre-Arid.

The co-incidence of *Anadara* and the arid period seems logical, though no evidence of a reliable nature has yet been produced. It is to be expected that accompanying the meteorological conditions which led to the aridity, and finally to the piling up of such large dune systems, were higher temperatures. It is not known at what stage in the development of these conditions *Anadara* and its associates became established along the South Australian coast, but they certainly persisted beyond the period of maximum aridity. It is probable that the onset of aridity was rapid, but that the return to more ameliorable conditions has been gradual. The last traces of desiccation have not yet disappeared, for the crests of the larger dunes in the more arid parts of Australia (e.g., Lake Eyre Basin, Simpson Desert, etc.) are still unstable.

CHRONOLOGICAL SEQUENCE IN LOWER SOUTH-EAST SOUTH AUSTRALIA FOR POST-MIOCENE GEOLOGICAL FEATURES

It has generally been considered that the recession of the sea, which led to the stranding of the sequence of ranges from the coast to the Naracoorte Range, was initiated some time in the Pleistocene, (11), (12), (5). However, reconsideration of the evidence, together with the new information presented here, leads one to suspect that it might have been more recent than originally believed.

The beach site at Mount Graham is, for reasons given earlier, considered contemporaneous with the Stuart Range - Cave Range shore line, perhaps even with the Naracoorte Range. The Cave Range is the first range in the series west of the Naracoorte Range. The fact that there is no higher series of consolidated dunes on Mount Graham, which rises to over 600 feet, is additional evidence to support this view.

The absence of any well-defined wave-cut terraces on the slopes of Mount Graham would suggest that the early still-stand periods at least were not of lengthy duration, and that the first elevations of the land were due to a series of relatively close and sharp upward movements.

The oldest rocks in the region are the Miocene marine limestones, and superimposed upon these in the Mount Gambier district are more recent limestones which are tentatively placed as Pleistocene. They are certainly much older than the consolidated dunes, and later than the Miocene. The oyster in these beds is apparently the living *Ostrea sinuata*, and not the Pliocene "*O. hyotidoidea*" Tate, which apparently does not belong to the genus *Ostrea* but is one of the tropical "coxcomb oysters" of the genus *Lopha* common in the Pliocene beneath the Adelaide plains.

The old strand dunes overlie the Miocene limestones about Mount Gambier, and in the Mount Burr region are often superimposed on basalt, ash and tuff deposits (2). The fossil dunes have been preserved by leaching of lime from the uppermost horizons and its deposition lower down in the dune, so "consolidating" it. The lime-free leached upper horizons, it has been suggested (2, 3), were stripped in the Great Australian Arid Period, to expose in many places the underlying travertinised horizon. This re-sorted leached material, both from the dunes and other sources, has been left piled over all manner of material—calcareous aeolianite, Pleistocene sandstone, Miocene limestone, volcanic material (Mount Burr Range), and recent calcareous material left in the inter-range flats, etc.

In the Mount Gambier region the siliceous sands are overlain by the volcanic material which has been brought forward as evidence (2) in support of Fenner's theory that the volcanism in this area was so recent as to be "pre-historic." It clearly demonstrates that the activity of the Mount Burr region preceded that at Mount Gambier and Mount Schank.

The present beaches of the South-East differ from the raised beaches, for nowhere are they estuarine. It is indeed difficult to understand how estuarine conditions could have prevailed in this region at that time, for there is no evidence of ancient streams associated with the old foreshores. If the Murray River discharged at a more southerly outlet or into a southerly extended Coorong, or if the Glenelg River or an off-shoot of it had discharged more northerly, the estuarine conditions could be readily explained. That there has been a northward draining of the Coorong very recently could be expected in view of the warping that has apparently taken place in the south. This is possibly related to the Mount Gambier volcanic activity. It is reflected in the fall in height above sea level of the old foreshores proceeding northward. It seems also that there is a south-easterly fall in the old foreshore heights from the vicinity of Mount Gambier towards the Glenelg River.

A point of considerable interest in connection with the old foreshore shell deposits described in this paper is their remarkable state of preservation. In almost all deposits a large proportion of the shells retain much of their original colour and markings and their especial nacre. This even holds, though to a lesser degree, for the most elevated, and therefore oldest, deposit—that at Mount Graham. As stated earlier, this deposit is considered to be at least comparable in time with the Stuart Range-Cave Range foreshore.

The condition of the shells in raised beaches was commented upon by Tenison-Woods, who when discussing in a general manner recently raised sea and estuary beds (12) in the region, says, "The shells in these beds have all a most recent appearance, always retaining their colour and only slightly bleached This circumstance I look upon as very remarkable; if the process of upheaval had been gradual and slow, the shells found at 24 miles distant inland should have a much more ancient appearance; moreover, it is impossible to understand, since these shells are within a few inches of the surface . . ." The only inference that can be drawn from this state of preservation would appear to be that they are very new indeed.

As pointed out earlier, no defined *Anadara* horizons which would be of value as a chronological time index has yet been discovered in the South-East. The most important recent chronological feature there would appear to be the widespread evidence of aridity. Could the age and extent of the Great Australian Arid Period be fixed, it would probably prove the most significant chronological horizon in our Recent, because of its bearing on pedogenetics and the dynamics

of the native flora and fauna. Unfortunately, very little direct evidence has yet been obtained. Browne (1) has recently suggested it was about 5,000 years ago, while Crocker (3) believes it considerably less than 9,000 years ago.

There is no doubt that the raised beach deposits described in this paper, on the evidence to be found in the general relationship between the exposed travertine surfaces and siliceous sands presented elsewhere (Crocker, *loc. cit.*), are pre-Arid. In view of the well-preserved nature of the shells, even where they have been exposed in the surface travertine since the arid period, together with the more important fact that the order of relative dominance, size and trueness to type of the species are identical with living suites, it is thought likely that they are of Recent age and that the Great Australian Arid period may have reached its maximum in these parts as late as 3,000 years ago or even more recently.

The post-Miocene chronological sequence in the South-East probably was:—

| Period | Features | Epoch |
|---|--|---|
| Late Pliocene to Late Pleistocene | Volcanic activity, Mt. Burr Range. Certain Limestones with <i>Ostrea sinuata</i> near Mt. Gambier. | |
| — | Old Dunes from Naracoorte Range, to Woakwine Range and beyond. | <i>circ.</i> 20,000 years to 6,000 years |
| Recent | Great Australian Arid Period | <i>circ.</i> 3,000 years |
| | Mt. Gambier — Mt. Schank volcanic activity | <i>circ.</i> 1,500 years |

SUMMARY

A description of 17 raised beach sites, 16 previously unrecorded, in the Lower South-East of South has been given. The characteristics of the beaches, their shell fauna, the ecological conditions they suggest, and their probable relationship to the old foreshores have been presented. The significance of the deposits in the chronological sequence in this region has also been discussed.

The remarkably recent facies and state of preservation of the shell material, even where it has been exposed in surface travertine since the Great Australian Arid period, leads to the conclusion that the aridity may have reached its maximum in these parts as late as 3,000 years ago.

Volcanic activity at Mount Gambier and Mount Schank has been the most recent geological event in the South-East. It is believed to have occurred about 1,500 years ago. Fenner (4) had previously considered it so recent as to be "pre-historic."

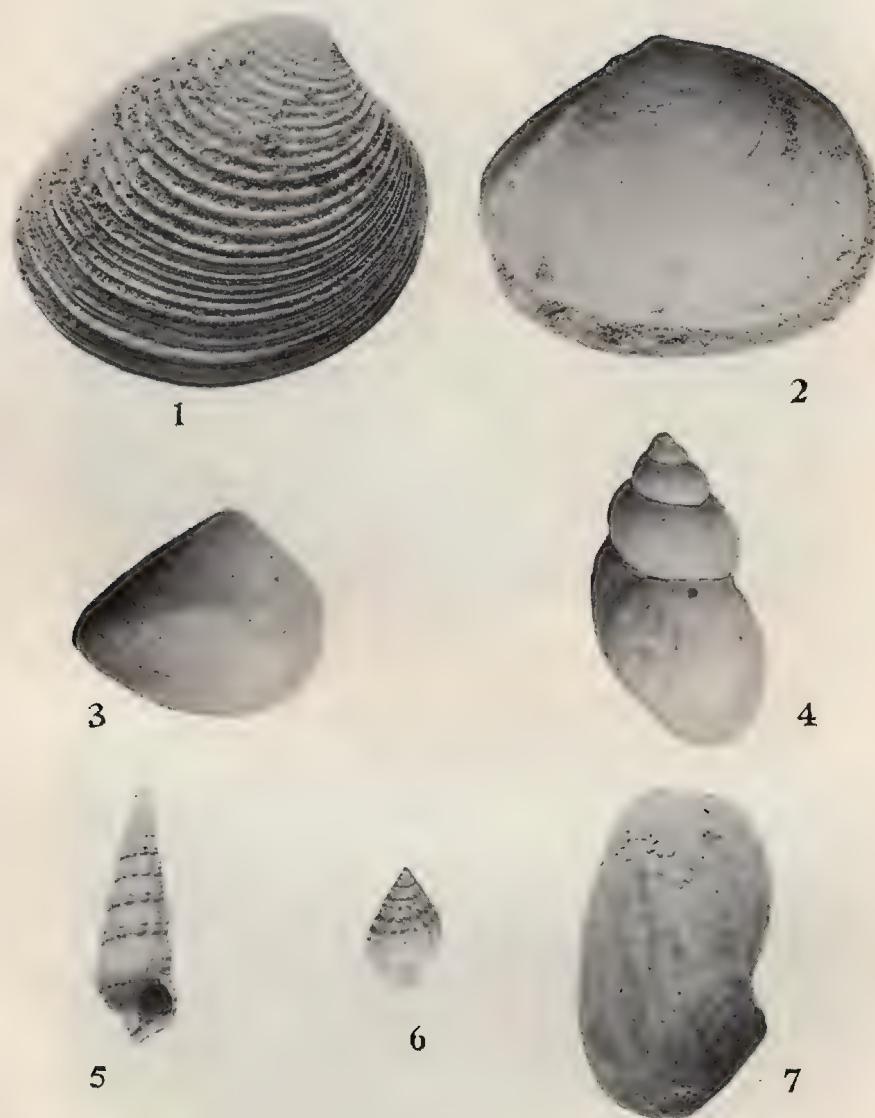
A short description is also given of some freshwater shell deposits, and the land snails of the South-East.

ACNOWLEDGMENTS

The authors are grateful for the assistance of Mr. R. Williams, of Mount Graham, in helping to locate the raised beach described by the late Professor Walter Howchin. Thanks are also due to E. J. Leaney and D. W. Drew, who assisted with some of the figures.

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Shells from various Sites.

- | | |
|-------------------------------|----------------------------------|
| 1. <i>Katelysia scalarina</i> | 4. <i>Lenameria pectorosa</i> |
| 2. <i>Macoma deltoidalis</i> | 5. <i>Zeacumatus diemenensis</i> |
| 3. <i>Anapella adelaidae</i> | 6. <i>Parcanassa pauperata</i> |
| 7. <i>Bullaria tenuissima</i> | |



Fig. 1 Pleistocene Beds with *Ostrea sinuata*, Mount Gambier Range.



Fig. 2 Site 5, Pebble and shell beds, Hundred Caroline



Fig. 1 Site 9, Flint pebble beach



Fig. 2 Aeolianite limestone, showing the old accretion layers, Cape Northumberland.

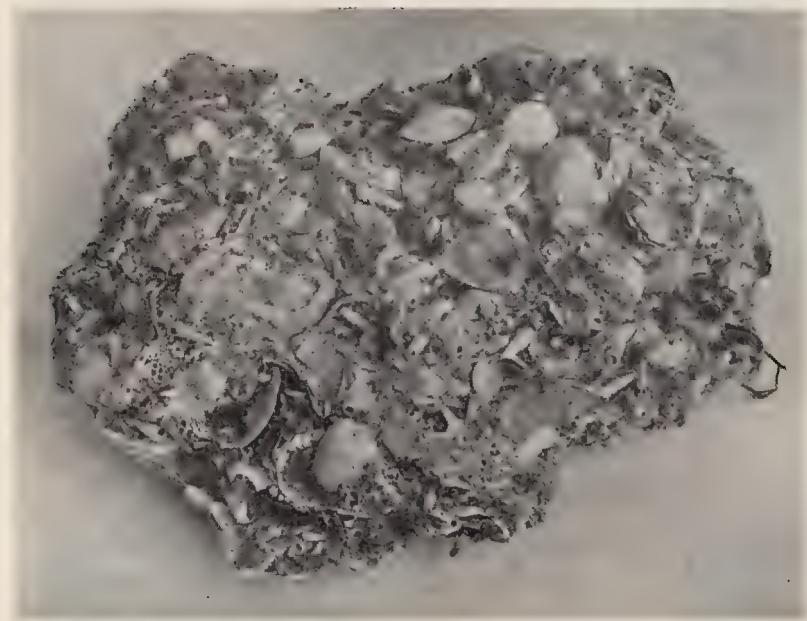


Fig. 1
A typical example of the dominant shells, Site 1.



Fig. 2
Travertine layers alternating with loose sand, containing the same suite of shells, Site 1.



Fig. 3
A close view of the travertine layer (above) and free sand layers (below), Site 1.

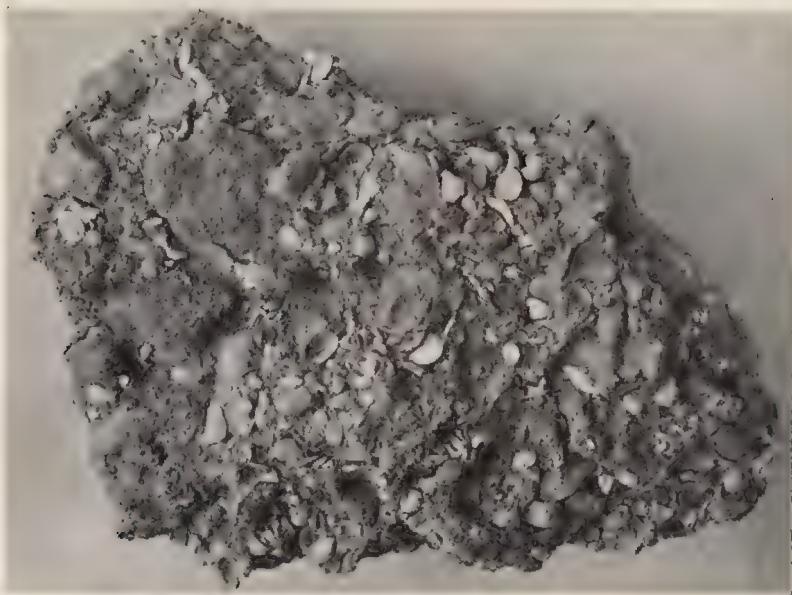


Fig. 1
Reef community shells in travertine, Site 7.



Fig. 2
Travertine limestone packed with *Lenameria pectorosa*, low-lying flats near Millicent.



Fig. 1
Site 11, Mount Graham.

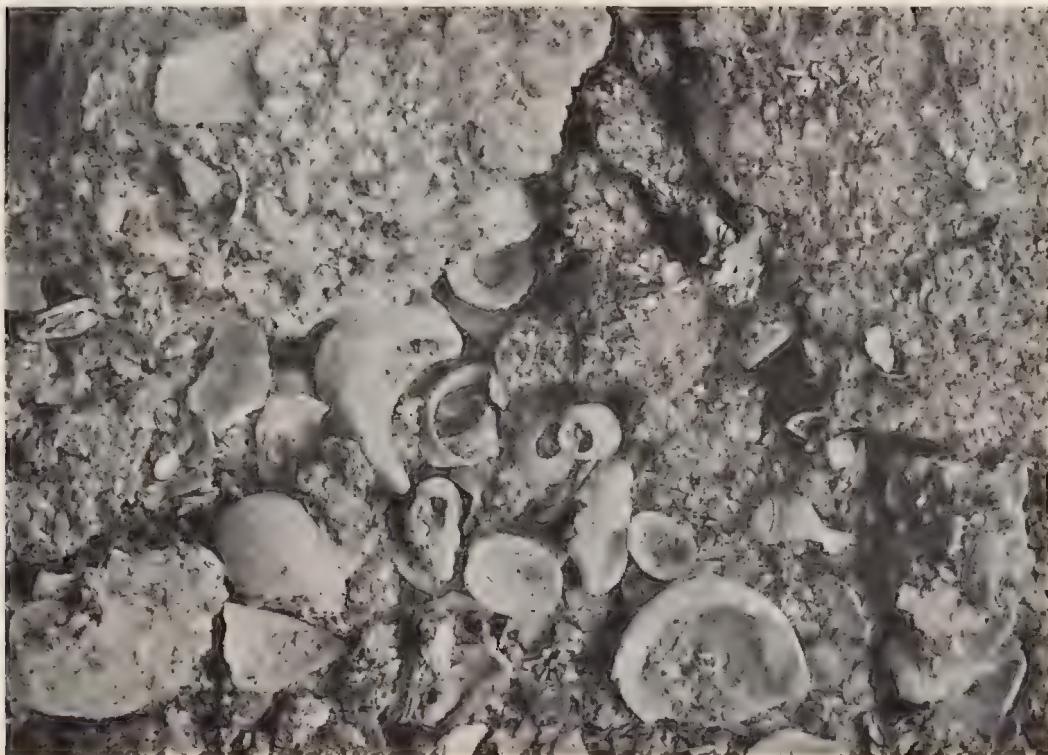


Fig. 2
Shell material from Site 11.



Fig. 1
Shells from Site 16, from Ashmore-Murrabinna Bank.

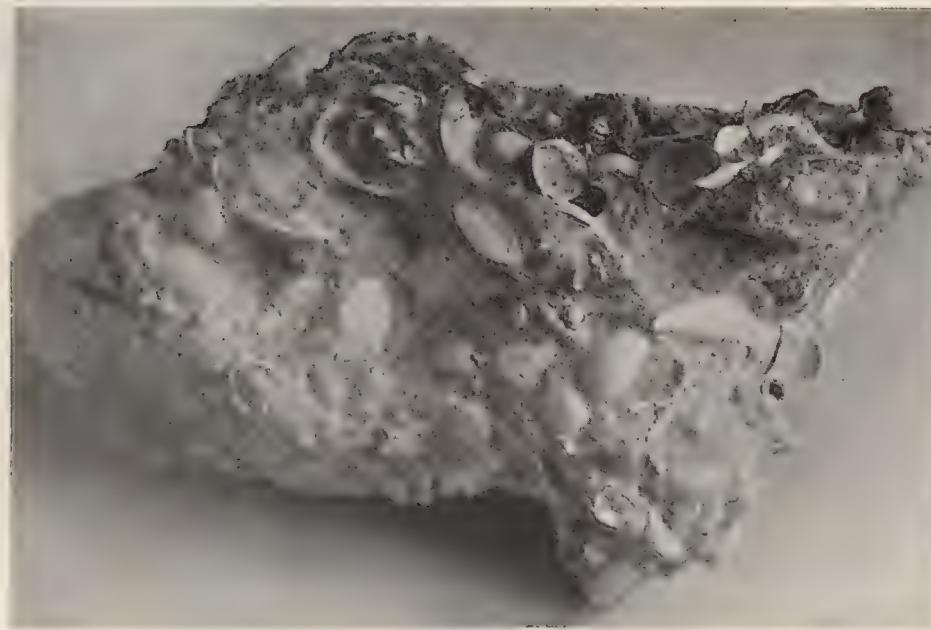


Fig. 2
Travertine, rich in shells, ploughed up at Koniak Station.



Fig. 1

Equichlamys bifrons, Queen Scallop, together with other shells with living colour,
from Site 17.



Fig. 2

Oyster cluster, *Ostrea sinuata*, from Site 17.

AN INTRODUCTION TO THE SOILS AND VEGETATION OF EYRE PENINSULA, SOUTH AUSTRALIA

BY R. L. CROCKER

Summary

The study of the ecology of the natural vegetation of South Australia has been directed towards a classification of the formations and major associations, together with an analysis of the climatic and edaphic conditions which govern their maintenance and stability. The modification of our natural flora over the last decade by rapid and revolutionary changes in the land usage and local agricultural economy has meant that the final picture is so far from complete and stresses the necessity of finishing the work at the earliest.

**AN INTRODUCTION TO THE SOILS AND VEGETATION OF
EYRE PENINSULA, SOUTH AUSTRALIA**

By R. L. CROCKER

PLATES XVII TO XXIII

[Read 11 April 1946]

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INTRODUCTION

The study of the ecology of the natural vegetation of South Australia has been directed towards a classification of the formations and major associations, together with an analysis of the climatic and edaphic conditions which govern their maintenance and stability. The modification of our natural flora over the last decade by rapid and revolutionary changes in land usage and local agricultural economy has meant that the final picture is far from complete and stresses the necessity of finishing the work at the earliest.

Eyre Peninsula is one of the regions that has been least studied and one in which the original flora is still represented by large relict areas, which for varying reasons (but chiefly infertility or shallowness of the soil), have been spared the many land utilisation projects.

Presented in this paper are the chief features of geology, physiography, soils and climate, which have an important bearing on the distribution of the plant communities of Eyre Peninsula. Many of the communities are described and their principal constituents indicated. Some of the associations are only dealt with in a very general manner, and still others, before their relationships can be fully appreciated, require much fuller investigation of the floristics and a more intensive analysis of edaphic conditions.

The area concerned is included in Counties Flinders, Jervois, Musgrave, Buxton, Le Hunte, Robinson, and York and occupies approximately 15,100 square miles. Agriculturally this region is to be considered chiefly of importance for

grazing and cereal growing (mostly wheat). Unfortunately, cereal growing was originally extended beyond the economic climatic limits and, in recent years, has had to be withdrawn to the more reliable districts. In the very restricted areas with an annual rainfall of 17 inches or more, temporary or longer leys have been established to a limited extent. Elsewhere grazing has been entirely based upon the foundation native perennial grasses (chiefly *Stipa* spp. and *Danthonia* spp.) or, where cultivation has been abandoned, on volunteer annual herbs and grasses.

GEOLOGY AND PHYSIOGRAPHY

The geology of portions of Eyre Peninsula has been described in a general way by a large number of authors (11), (12), (13), (15), (22). Their work, however, has been chiefly of a reconnaissance nature and little or no detailed geologic mapping has been carried out. Further, there have been no very recent studies apart from those of Segnit (21) in the Robinson Freshwater Basin, Dickinson (9) in parts of the Gawler Ranges, and the author on certain aspects of the Pliocene-Recent (5). The geology of the region is, therefore, only imperfectly known.

The framework of Eyre Peninsula is essentially a gneissic and granitic complex of the Pre-Cambrian age and is considered the stable Foreland of the great Continental Shield that characterises Western Australia (10). It is bounded on the east by the downfaulting of Spencer Gulf.

A metamorphic complex chiefly consisting of gneiss, schist, quartzite and quartzite schist is widespread in the more easterly parts and forms the dominant physiographic feature, with the exception of the Blue Range, from Central County York to Port Lincoln. In the centre of County Jervois in the Hundreds of Yadnarie, Mann, Jamieson, Campoona, Mangalo and Miltalie, there are particularly rugged hills up to 1,200 feet above sea level, but in the more southerly regions, as between Koppio and Port Lincoln, the older Pre-Cambrian crystalline rocks have been eroded to a peneplain over which primary laterites developed—probably in the Pliocene. This lateritic-capped peneplain has subsequently undergone considerable dissection, which is still proceeding. In many places the lateritic material has been completely stripped to expose the underlying schist and gneiss. Most of the region is between 300 and 800 feet above sea level.

The silicified sandstones of the Blue Range which rests horizontally and unconformably on the Pre-Cambrian metamorphic complex have been considered by Jack (13) as of doubtful Ordovician Age. Marble Range which is a prominent feature on southern Eyre Peninsula, is composed largely of slates and quartzites and crystalline metamorphic rocks of doubtful age.

The most prominent physiographic feature on Eyre Peninsula is the Gawler Ranges, which rise to over 1,400 feet above sea level and flank the region in the north. The rocks are essentially felspar porphyries of Proterozoic Age (11) considered to have been formed either as a tremendous sill or surface flow (Jack *loc. cit.*).

While in the Gawler Ranges, the Middleback Range, the high country in central County Jervois, and the Marble Range, heights between 1,000 and 1,500 feet above sea level are frequent, by far the greater part of Eyre Peninsula, including almost all the area west and south-west of the Edilloo-Minnipa-Cungena railway line, is less than 300 feet above sea level. In this region the older rocks are chiefly granites, but they are only occasionally exposed at the surface, as at Minnipa Hill, Calca Hill, Mount Hall, Mount Dunper, Wudinna Hill, etc. For the greater part the old buried granitic terrain is overlain by a considerable thickness of terrestrial deposits (Jack 1912, 1914), including

Pleistocene calcareous sandstones and sands. Very recent siliceous sands are frequently super-imposed upon the older terrestrial deposits. The Pleistocene and Recent geology is particularly significant from the point of view of the genesis of the soils.

The calcareous sandstones and sands on Eyre Peninsula are very widespread, extending from Cape Catastrophe to Streaky Bay and discontinuously beyond to the Western Australian border. Their features have been described in the neighbourhood of Port Lincoln by Mawson (15), in portions of County Dufferin and Robinson by Jack (12), in the Streaky Bay district by Segnit (21), and more recently their distribution and significance has been discussed by the author (1945).

They consist essentially of a very recent series of unconsolidated dunes, which discontinuously flank the coast and overlie a much older system of wind-piled calcareous sands. This latter calcareous aeolianite is very extensive and in

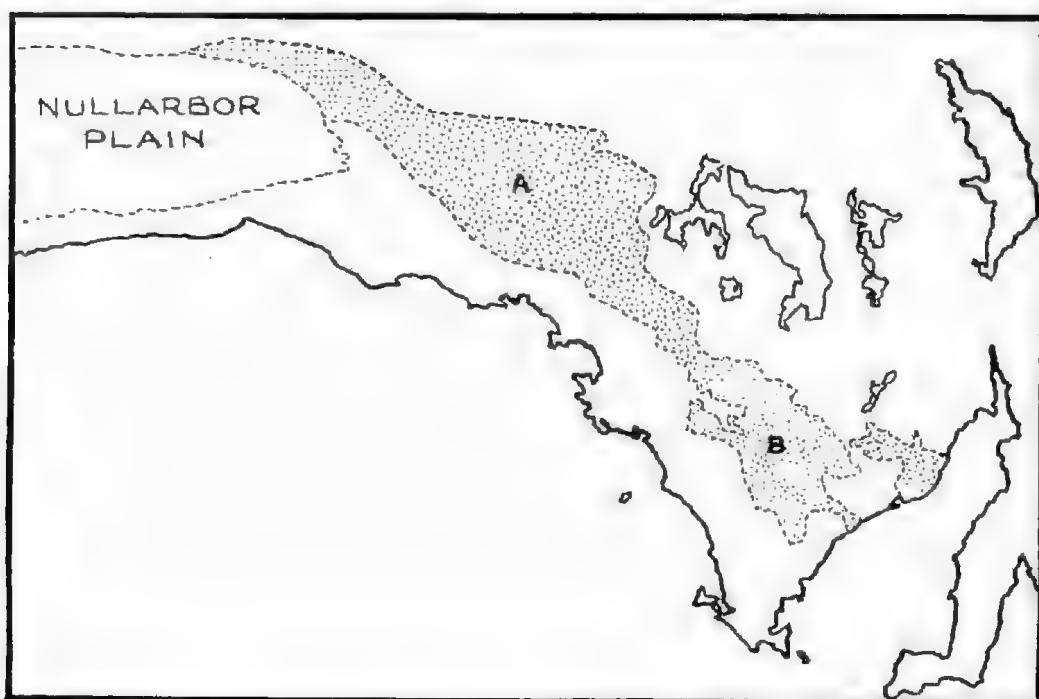


Fig. 1

The Nullarbor-Spencer Dune System. The portion marked A has largely drifted off the Nullarbor Plain, and that marked B from the calcareous aeolianite shown in fig. 2.

the area under discussion occupies no less than three thousand square miles. In general the aeolianite is in the nature of dunes or dune sheets, capped with a layer of travertine of varying thickness. At times the aeolianite travertine is only a few inches thick, while at others it is many feet, or a whole dune may be weakly consolidated along the accretion layers. In the underlying unconsolidated or partially consolidated material, foraminiferal tests and shell fragments are frequently recognised. In the neighbourhood of Port Lincoln in the Wanilla Basin, this aeolianite may be over 100 feet thick where it overlies transported lateritic gravels. It is considered to have been built up during the exposure of large areas of the continental shelf, which accompanied the fall in sea level associated with the Pleistocene glaciations (5). The travertine capping is thought

to have been formed by lime enrichment through downward leaching and deposition.

Extending from the Nullarbor Plain across the top of Eyre Peninsula to Spencer Gulf, in the neighbourhood of Cowell, is a huge dune system of very recent origin. It is apparently purely deflationary in origin and has been piled up during a severe arid period some 3,000-6,000 years ago (2), (6). The dunes are of the *seif* type and run in an approximate north-west-south-east direction. Their repetition distance is very variable.

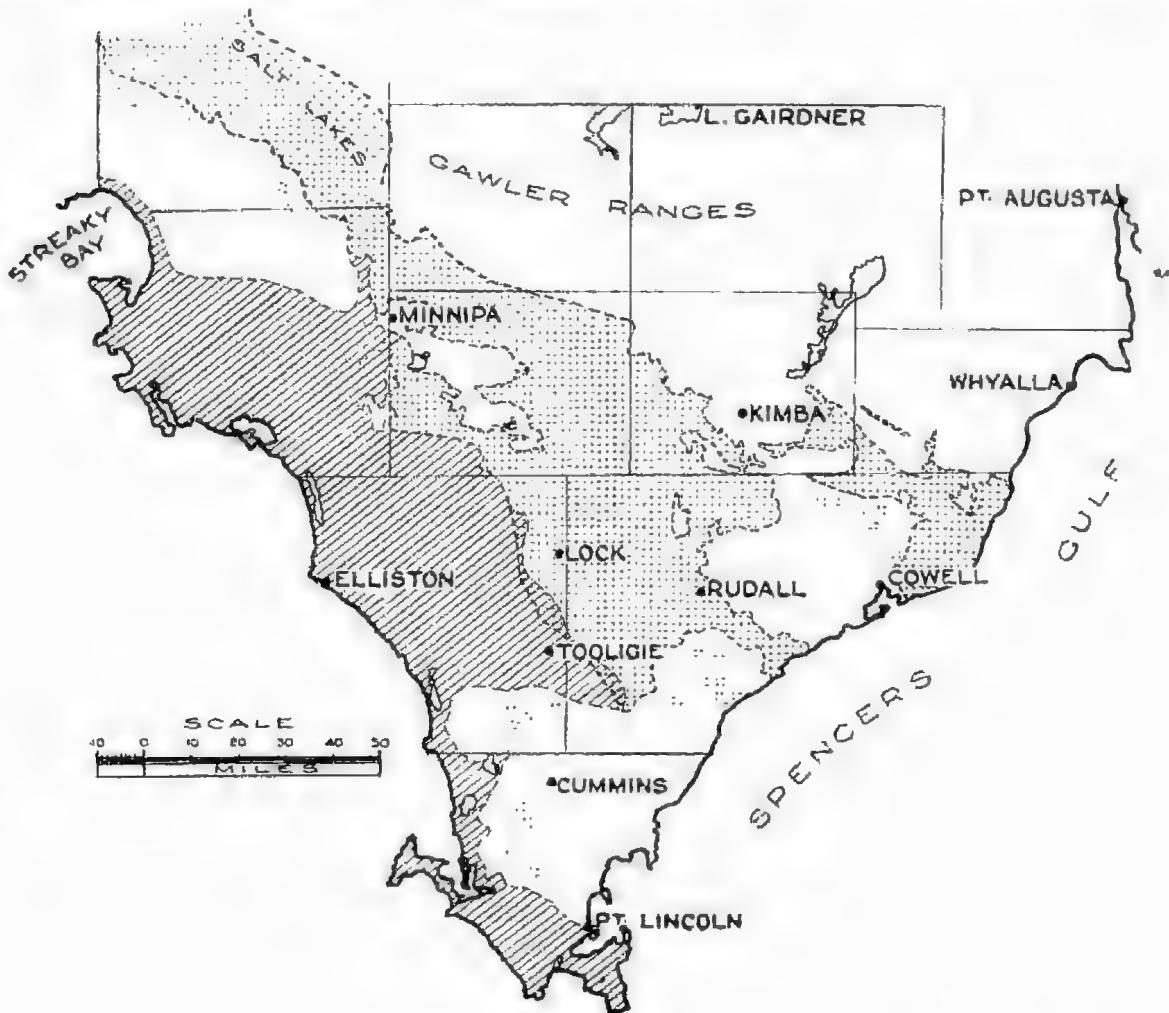


Fig. 2

Dune system (dotted) in relation to exposed aeolianite travertine (shaded) on Eyre Peninsula.

These sands are highly siliceous, and for the most part lie adjacent to large exposures of aeolianite travertine. It is believed that the original soils developed on the calcareous aeolianite were of a nature which rendered their upper (A) horizons particularly unstable with the loss of vegetative cover in the arid period, and that the now adjacent siliceous sands are chiefly from the stripping of the old A horizons. No doubt this material was considerably contaminated by soils from other sources during the re-sorting, but the leached upper horizons of the soils developed on the calcareous aeolianite would appear to form the chief contribution to the siliceous sands of the eastern portion of what might be called the

Nullarbor-Spencer dune system. In the Hundred Jamieson these dunes extend on to high country about 1,100 feet above sea level (pl. xvii, fig. 2), but for the most part they have skirted this high country and have only filtered through to Spencer Gulf through relatively restricted depressions north and south of the main ranges. The effect of more local ranges on the distribution and orientation of the dunes is sometimes very marked. A notable example is the influence of the Darke's Peak Range. This is a very spectacular range rising about 1,200 feet above the surrounding country. It is some eight miles long, running north and south and a quarter to half a mile in width. Fairly high white and yellow sand-ridges abut the range on the western side and southern end. These ridges are parallel, and are orientated in a north-west-south-east direction (that is the normal direction for the system as a whole), both at the southern end of the range and at some distance west of it. Immediately west of the range, however, the ridges

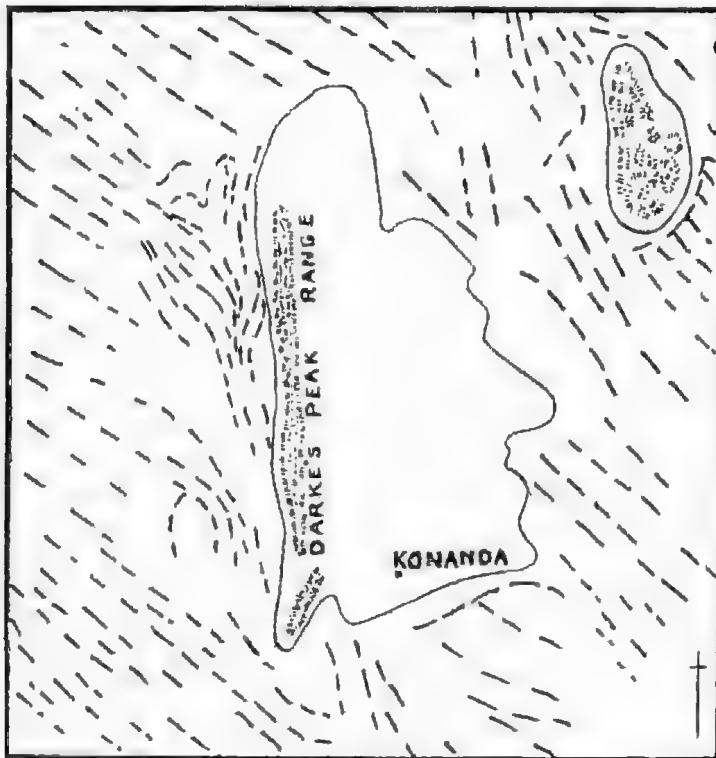


Fig. 3
Distribution of solonised sand dunes about
Darke's Peak Range, Eyre Peninsula.

become very jumbled and many of them trend almost north and south. For some four miles east of the range there is more or less sand-free country with good arable soil (fig. 3). This has been sheltered by the range from superimposition of the infertile leached sands, and it is obvious from the relationships of this sand-free area to the range and sandridges, that the sand movement must have been from directions lying between south-west and north-west.

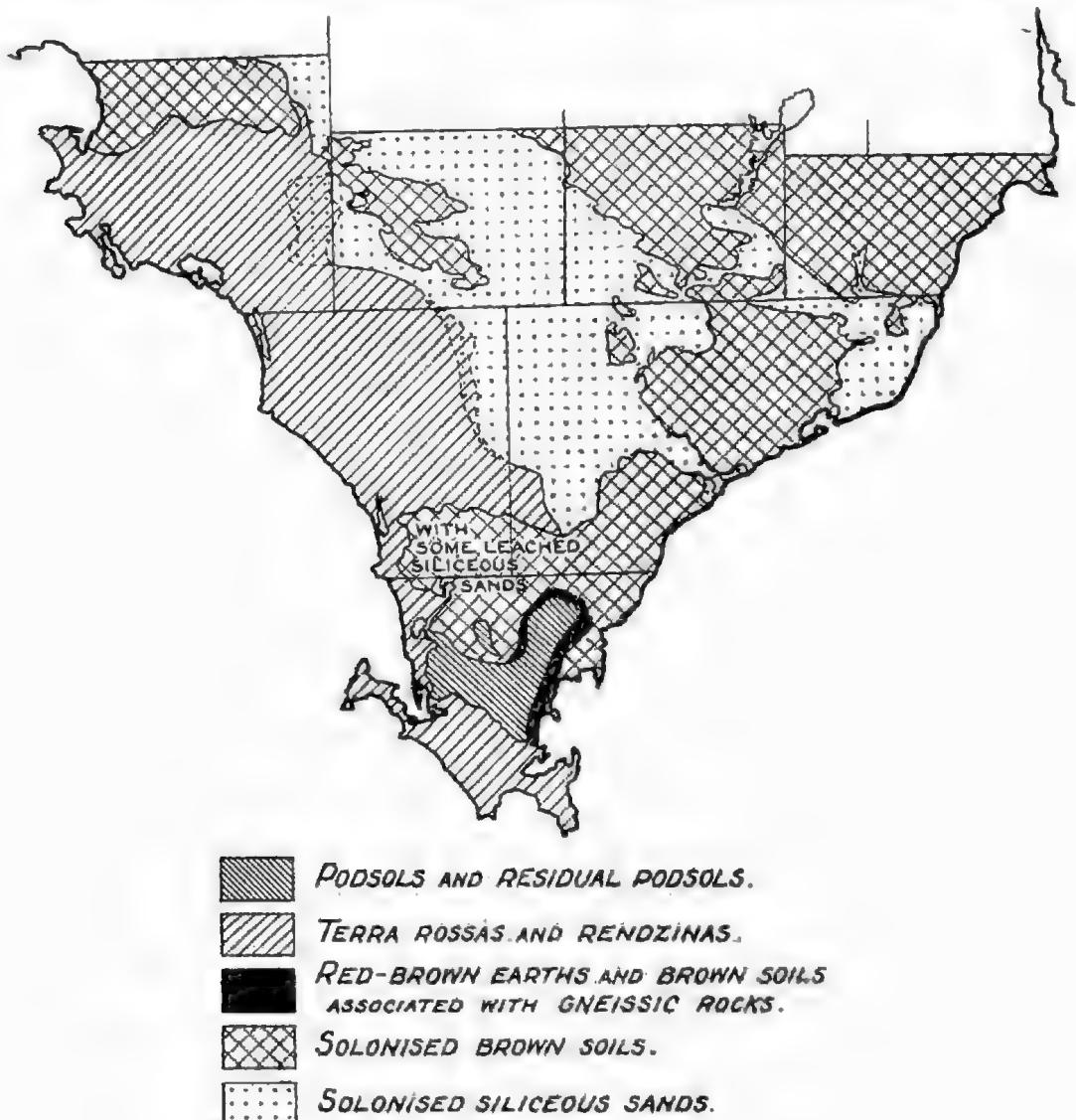
The more important features of physiography are shown in pl. xxiii.

THE SOILS

In the foregoing section a brief analysis has been made of the geology and physiography of Eyre Peninsula. In view of the fact that the greater part of the region is overlain by Pleistocene and Recent terrestrial deposits, it is to be

expected that the relatively recent geological history should be very important in affecting soil genesis. Owing to this rather unique post-Pliocene geological history, it might also be anticipated that most of the soils will be intrazonal.

Seven major soil groups occur, and their distribution is shown on the accompanying soil map (fig. 4). The soils are podsols and residual podsols, red-brown earths, terra rossas, rendzinas, solonised siliceous sands, solonised brown



soils and desert loams. In addition, skeletal soils are common in some of the more hilly areas associated with the ranges. These have not been mapped separately, though they are an especial feature in the Cleve-Miltalie districts.

1. *Podsols. Residual Podsol.*

Podsolised soils occur over a very restricted portion of lower Eyre Peninsula, and are very much intermixed with primary and secondary lateritic soils

and terra rossas. On the drier side they grade into what might be considered grey-brown podsols, and finally, particularly along the eastern coastal scarp north of Port Lincoln, to red-brown earths.

The dissection of the old laterised peneplain has led to a redistribution of the horizons of the laterite profiles and the formation of an interesting pattern of secondary soils, all podsolised to some degree and frequently containing a layer of heavy ironstone gravel immediately above the clay. The surface horizons are normally grey-brown or grey sandy loams of varying depths. The gravel horizon may vary from almost nothing to 15 inches or so thick, and is underlain usually by yellow and red mottled clay. From the limited number of analyses made⁽¹⁾ it appears that the pH of the surface horizons of these soils varies from 5.9 to 6.6 and their fertility status is low. One sample analysed⁽²⁾ contained 0.12% K₂O and 0.21% P₂O₅.

Podsolised sands, some of which may be very deep, and which may or may not contain ironstone gravel in the subsoil also occur. A small quantity of pisolithic gravel is usual in the upper horizons, especially in the shallower types. Most of these sands which are probably of aeolian origin and of diverse parent material were, no doubt, piled in their present position during the last period of aridity. In part they were derived from material transported during the break-up of the peneplain and may contain, therefore, some of the upper horizons of laterised profiles. It is hardly likely, however, that such a contribution could have been large, because dissection of the laterite must have been initiated fairly early in the Pleistocene. It had apparently proceeded a considerable distance by the time the calcareous aeolianite was blown up, for this abuts, overlies and incorporates transported lateritic gravel in the neighbourhood of Pearlah and Port Lincoln, and in the Wanilla Freshwater Basin there is as much as 100 feet of calcareous aeolianite in places overlying ironstone gravels and lateritic clays.

The podsols contain more pisolithic ironstone in the occurrences near the ranges. The podsols and residual podsols are, generally speaking, associated with sclerophyllous heath, mallee heath, or sugar gum heath vegetation.

2. Red-brown Earths, Grey-brown Podsols and certain Skeletal Soils.

Typical red-brown earths are rare on Eyre Peninsula, but there is a notable occurrence in a narrow band on the slope from the ranges, extending from north of Port Lincoln to Yallana. On the drier eastern (coastal) side this gives way to typical mallee soils, while on the wetter (western) side are soils derived directly in most cases from the old gneisses.

The red-brown earths are associated with peppermint gum (*E. odorata*) savannah with an admixture of mallee in places.

The soils developed directly on the old gneissic exposures in the wetter districts are very variable and frequently very shallow (skeletal). They are mostly grey-brown, brown and red-brown sandy loams, loams and clay loams, with considerable admixture of gneissic gravel or partially decomposed rock. These soils can be considered, at least in part, as grey-brown podsols, though the high base status of the parent material and erosion have retarded the development of a normal podsolic profile. These soils have carried a *Casuarina stricta* savannah woodland, but where more podsolised, admixture with heath or sugar gum is usual.

Deeper soils (alluvial) occur in the valleys between the gneissic hills, some of which are very wet and others of which exhibit evidence of salinity.

(1) Division of Soils, C.S.I.R. Divisional Reports, 22, 1943; 3, 1944.

(2) C. S. Piper—personal communication.

Two samples of the foregoing soils analysed by Dr. C. S. Piper⁽³⁾ had surface pH values of 6.1 and 6.5 respectively. Their potash status was 0.30% K₂O, and phosphate status 0.30% and 0.17% P₂O₅.

Some of the red-brown soils in Central Lower Eyre Peninsula appear to be closely akin to the red-brown earths. Their colour, however, appears in part to be derived from a sandy ironstone (possibly a fossil orstein) which is quite frequent in the Yallana-Cummins-Ungarra region.

3. *Terra Rossas and Rendzinas*

The large areas of calcareous aeolianite which occur on Eyre Peninsula are, for the most part, covered with a veneer of red, red-brown, chocolate, dark brown and blackish loams and sandy loams. This is a typical complex pattern of terra rossa and rendzina soils.

Although the aeolianite travertine is frequently exposed as sheet stone at the surface and the soil is in any case normally very thin, pockets of deeper soil occur, which in limited areas can be cultivated.

For the most part the soils are alkaline in reaction (pH 7.0-8.5) and are known to be deficient in copper and cobalt (Marston *et al.* 1938) in addition to superphosphate. Owing to their shallowness and the frequent limestone outcrops, they can only rarely be cultivated and are used chiefly for grazing of sheep. It is unfortunate that soils of such low fertility and limited agricultural value occupy such a large area of the reasonably reliable rainfall regions of Eyre Peninsula.

In portions of the Nullabor-Spencer dune system which fall within the scope of this paper, the soils of the inter-ridge regions are frequently shallow red-brown loams and sandy loams, which have developed from underlying travertine. These soils, although generally included with the solonised brown soils, have very close affinities morphologically and genetically with the terra rossas.

4. *Solonised Siliceous Sands*.

The distribution of the Nullabor-Spencer dune system has been shown in fig. 1, and portion is also shown on the soil map. Of that portion of the system with which we are concerned in this paper, only a small area about Lock is included in previous soil maps (19). The dunes in this system are piled into long parallel ridges which trend roughly north-west and south-east and are rarely more than 20-25 feet high. They vary considerably in their repetition distance, but are usually 10-30 chains apart, though 40-60 chains are not infrequent.

The sands are white, grey, yellow-grey or pale brown and, except at the north-easterly extremes, highly siliceous. They almost invariably overlie an illuvial horizon of brown and yellow-brown sandy clay loam or sandy clay at 1-4 feet, and this more or less forms a "core" to the dune. Yellow sands (A2) may underlie the more heavily leached grey and white sands of the surface horizons (A1).

The illuvial sandy clay loam and sandy clay core have probably been leached in the profile under the weak solonising influence of cyclic salt accessions, and for this reason Prescott has called the soils in the neighbourhood of Lock and similar soils on the Upper South-East, solonetz.

One interesting feature of these soils is that they are in a sense residual podzols, for they had undergone considerable leaching prior to being built up into the present dunes. It is believed, too, that the soils are largely of a more southerly origin and are the aeolian re-sorted residua of older leached soils which readily lost stability during the arid period. The principal source of supply of

(3) C. S. Piper—personal communication.

this leached material was probably the upper horizons of the soils developed on the calcareous aeolianite at this time, and these under a south-westerly wind component have migrated further north and east, and been finally built up into the present system.

On the whole the soils are of very low fertility, and on this account, and because of their marked tendency to drift when cleared and cultivated, have been little used agriculturally. The interdune corridors, however, when the travertine limestone is not too shallow, are frequently used for cereal growing.

The sands on the northern edge of the dune system are normally light brown and allied to the Winkie sands of the Murray Mallee. This is probably due to a larger component of less-leached, more-northerly-origin parent material, and the upper horizons of what were probably the older solonised brown soils have most likely made a much greater relative contribution. The frequent exposure of travertine limestone in the interdune corridors is evidence of complete loss of the old A horizon of some of the solonised brown soils. Indeed, the dunes along the northern-eastern side of the system are probably almost entirely from this source.

5. Solonised Brown Soils

The chief characteristics of the solonised brown soils (mallee soils) in South Australia have been described by Prescott (17), and later, and in greater detail, by Prescott and Piper (20). Although the Eyre Peninsula occurrences have been little studied, they conform in general with the principal morphological features described elsewhere. They typically have heavier subsoils, considered due to solonisation, are markedly alkaline with a pH varying from 7.5-9.5 and are characterised by large quantities of calcium carbonate. This latter is normally in the form of rubble or sheet travertine limestone, which, due to stripping of variable amounts of the surface horizons, and/or super-imposition of wind-piled material during the arid period, may either be exposed at the surface or at variable depth.

It was established on Section 12, Hundred Wilton, by boring through a dune, that the travertine exposed on either side was continuous beneath the sandridge.

The travertine and lime rubble horizons are illuvial zones, and it is believed that the calcium had a triple origin in: (a) the original soil parent matter; (b) accessions of cyclic calcium normally present in very small quantities in rain-water; and (c) accessions of loessial calcium winnowed from the Pleistocene calcareous aeolianite (5).

In the hilly and more actively eroding areas, as the elevated country in the central County Jervois (i.e., the Hundreds of Yaldowie, Mann, Jamieson, Campoona, etc.), where skeletal soils are very frequent, it is likely that accessions of calcium from outside sources have been more readily removed, either before being leached down in the profile, or subsequent to it, than in regions with no defined hydrology. This may well explain the more restricted occurrence of lime-rubble and travertine in this region. Higher rainfall would also lead to a greater groundwater removal.

The same reasons are probably also applicable to the Gawler Ranges. Although the soils on the hills themselves do not appear to contain very much calcium carbonate, considerable quantities are in evidence in the subsoils of many of the soils of the valleys and the desert loams further north.

6. Desert Loams

It has already been pointed out in an earlier publication that the solonised brown soils grade gradually into the desert loams (5), and that although the

limits of the mallee vegetation can be defined reasonably well, there is no clear-cut division between the soils with comparable physiographic relationships at this stage.

This is particularly evident on northern Eyre Peninsula, where much of the tree-steppe vegetation occurs on what could be considered an ideal "mallee" soil. As one proceeds further north, however, the solonising effect no doubt diminishes as a response to both lower rainfall and smaller contributions of cyclic sodium salts, until finally, with the very light precipitation, these soluble salts tend to be retained in the profile.

In the region dealt with in this paper, desert loams are of exceedingly limited occurrence, and as those that do occur have very close affinities with the solonised brown soils and the division separating the two is an arbitrary one, they can be best considered as solonised brown soils.

THE CLIMATE

Eyre Peninsula has a typical Mediterranean climate, with long summers when precipitation is low and erratic, and temperatures and evaporation high, alternating with the rainy winter seasons when temperatures and evaporation are lower.

The rainfall varies from 24-25 inches per annum in a small region in the vicinity of Green Patch behind Port Lincoln, to less than 10 inches in the region about Iron Knob and Yardea. The mean annual rainfall is shown on fig. 5.

There are two physiographic features which have a marked influence on the incidence and distribution of the mean annual rainfall. These are: firstly, the elevated, dissected peneplain country associated with the ranges which extend from Port Lincoln to Moody; and secondly, the hilly regions west of Cowell, in central County Jervois.

From the viewpoint of the climatic factors influencing the distribution of the natural vegetation, there is little doubt that the incidence of rainfall to evaporation, as a measure of available moisture, the sub-soil reserves of moisture built up during the period when soil evaporation and plant utilisation does not exceed precipitation, and the temperature over the whole of the period during which soil moisture reserves are adequate for plant growth, are the most significant.

In his climatic studies in connection with insect ecology in Australia, Davidson (8) has taken a P/E ratio of 0.5 as a threshold value, and considers that in a period over which P/E exceeds this value adequate moisture is available "for general plant growth." He has accepted mean monthly P/E values as his time units, and on that basis and a consideration of the mean annual temperatures, has defined bioclimatic zones in Australia. The region dealt with here falls within Davidson's Warm Temperate Semi-Arid Zone. The number of months in which P/E exceeds 0.5 varies from six in the most southerly portions to four in the north and three in the extreme north-east, and mean annual temperatures, except for the extreme north-east are between 60-65° F.

Taking the arbitrary value P/E = 0.5 as the threshold value for defining bioclimatic zones is probably satisfactory for general plant growth. In considering herbage plants specifically, however, Trumble (23), from direct observation of the growth of such plants at the Waite Institute and their correlation with mean monthly rainfall, together with information gained with the evaporation from soil blocks, defined the "influential rainfall." This is the amount of rain falling during the period in which P/E exceeds 0.3, when it is considered that the surface four inches of soil is maintained above the wilting point for annual herbage plants. The length of this period is known as the "influential rainfall"

period." Trumble has shown (*loc. cit.*) that the factor of $P/E = 0.5$ as used by Davidson in conjunction with the Adelaide evaporimeter gives essentially similar values under South Australian conditions as his value of 0.3 when allowance is made for differences in the two evaporimeters used as standards. The length of the influential rainfall period on Eyre Peninsula varies from 7.5 to < 5.0 months and the influential rainfall from about 16 inches in the lower Eyre Peninsula to less than 5 inches in the arid upper north-eastern portion (23).

In addition to mean values for the annual temperature, Prescott (18) has pointed out that two further constants are necessary to completely represent the

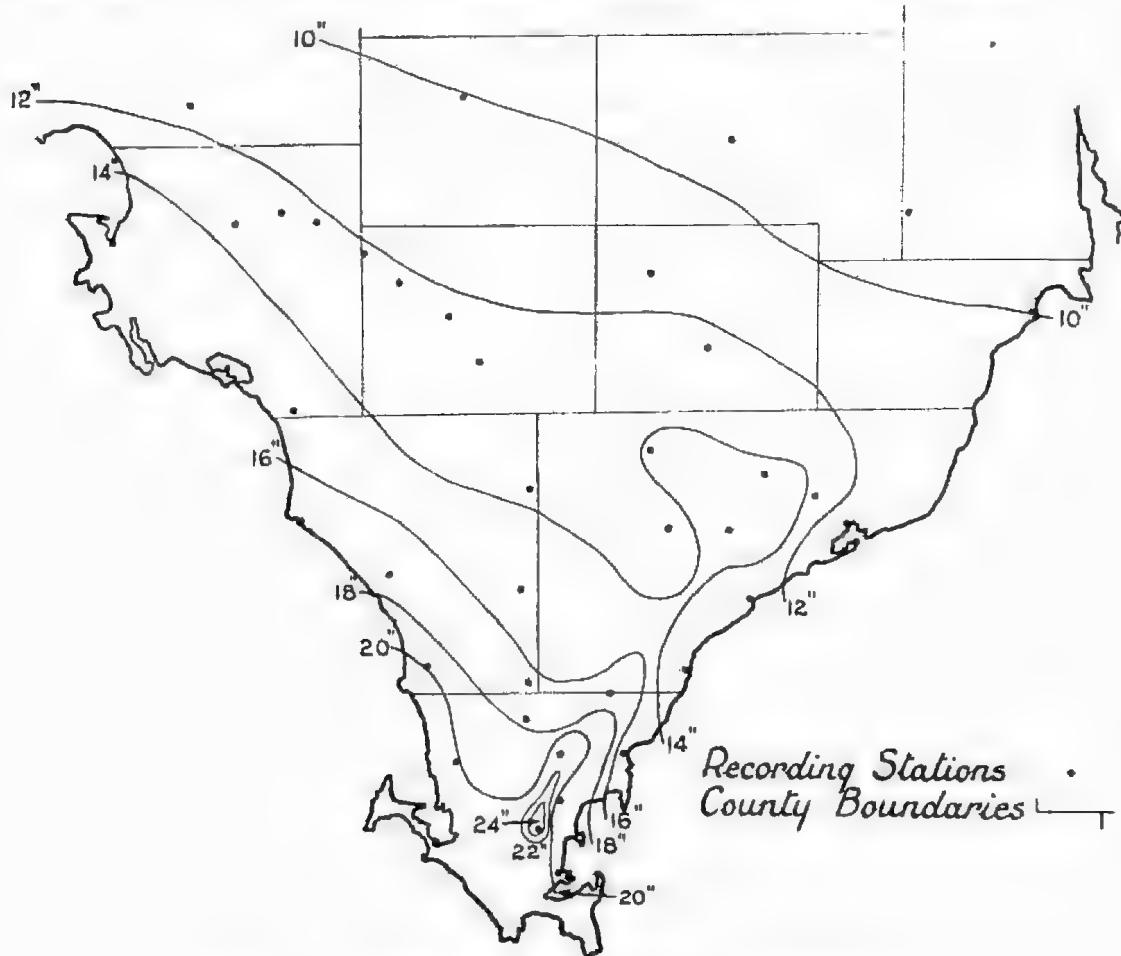


Fig. 5
Mean annual rainfall distribution on Eyre Peninsula.

march of monthly temperatures. These are the *amplitude* of the curve about the mean, and the *phase* or position along the time axis. Phase is expressed in terms of the lag between temperature and solar radiation. Prescott has constructed maps showing both the lag (in days) of temperature behind solar radiation, and amplitude (in °F.) of the mean monthly temperatures. The amplitude of the mean monthly temperature on Eyre Peninsula varies from 7-11° F., and the phase from 29-36 days lag of temperature behind solar radiation.

The climatic constants for Eyre Peninsula, after Prescott and Trumble, are shown below in fig. 6.

An important feature of climatic constants are their variability, and for a fuller analysis of climatic factors figures for expectancy of both rainfall and temperature conditions and P/E ratios should be made. Unfortunately, the small number of meteorological stations and the limited period over which recordings are available, together with the even greater scarcity of evaporimeters, necessitating the use of calculated figures for evaporation, make this impracticable at present. Some idea of the type of variability that occurs, however, can be

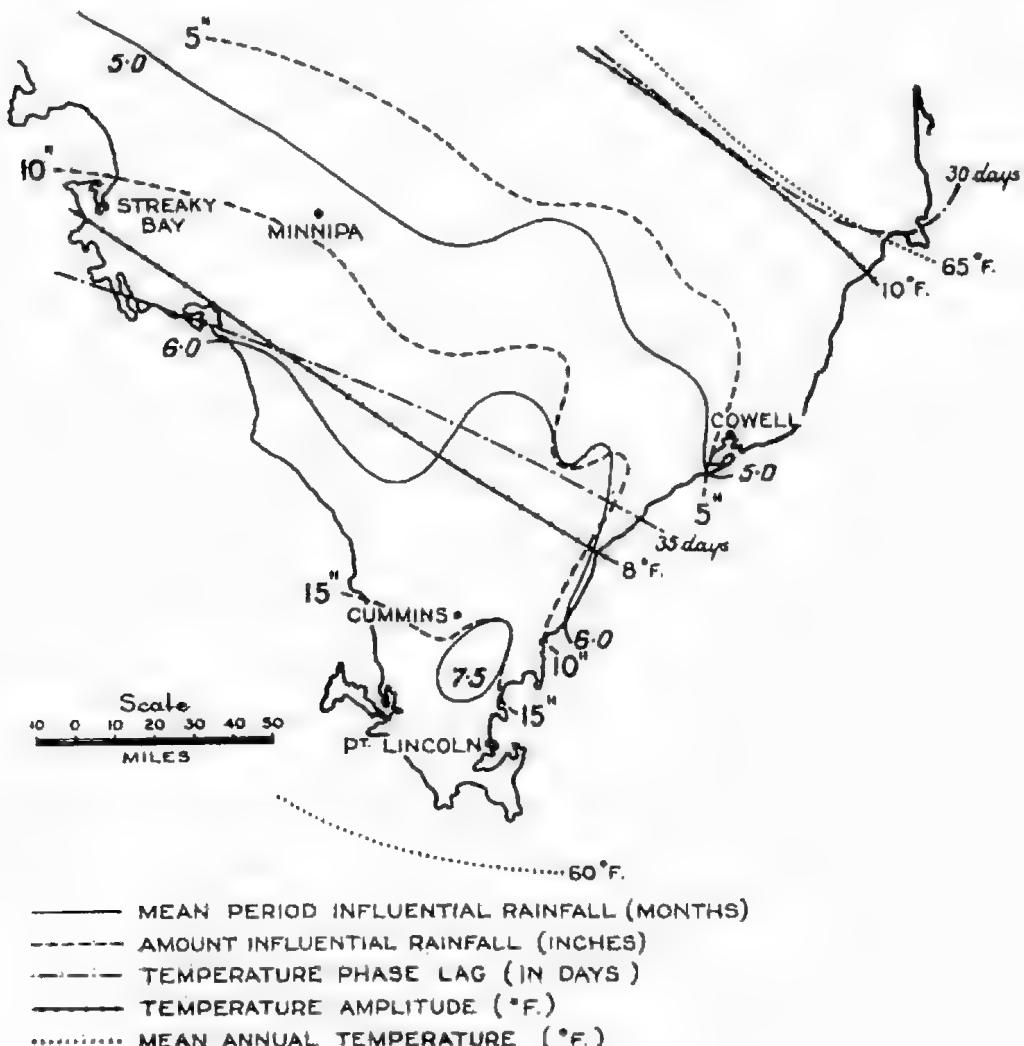


Fig. 6

Climatic constants for Eyre Peninsula (after Trumble, Prescott and Davidson)

gauged from the expectancies calculated by Wark (25) for the only two Eyre Peninsula stations with reasonably long records.

| Station | Record (years) | Influential rainfall (modal value) | Expectancies for Influential Rainfall (I.R.) | | | | | |
|--------------|-------------------|--|--|--------------------------|--------------------------|-------|-------|-------|
| | | | Once in 5 years I.R. | Once in 10 years I.R. | Once in 20 years I.R. | < | > | < |
| Port Lincoln | 48 | 17.37 | 13.77 | 21.55 | 12.09 | 24.01 | 10.79 | 26.2 |
| Streaky Bay | 49 | 11.26 | 8.44 | 14.07 | 6.95 | 15.56 | 5.70 | 16.81 |

| Influential rainfall period (months) (modal value). | Expectancies for Influential Rainfall Period | | | | | | |
|--|--|-----|-----------------------------------|-----|-----------------------------------|-----|-----|
| | Once in 5 years will equal or | | Once in 10 years will equal or | | Once in 20 years will equal or | | |
| | < | > | < | > | < | > | |
| Port Lincoln - | 7.3 | 6.4 | 8.3 | 6.0 | 8.8 | 5.6 | 9.9 |
| Streaky Bay - | 5.7 | 4.9 | 6.5 | 4.5 | 6.9 | 4.1 | 7.3 |

A further index of variability of the influential rainfall is given below in fig. 7, after Trumble (24), which shows the percentage of seasons with a minimum wet period of four months (p. 97).

THE VEGETATION

The vegetation of Eyre Peninsula, in terms of plant communities and vegetation types, has been so little studied as to be almost unknown. The region is relatively remote, and generally speaking, the soils are poor and unattractive. It is not surprising, therefore, that so little interest has been taken in the plant associations.

Two previous vegetation maps which include this region are Prescott's "Vegetation Map of South Australia" (16) and Wood's "Vegetation of South Australia" (27). In both of these pioneering works this region has been given perhaps the least attention of any. In this present paper the vegetation types are presented, together with the main soil factors, in much greater detail. The distribution of the major plant communities is embodied in one main map, which covers the whole Peninsula. The present work does not claim to be complete, but considering the area evolved (approximately 15,100 square miles), general inaccessibility, and the limited nature of the foundation work, it is thought to be a very great advance. It is hoped that it might prove a useful thesis to students in stating the major aspects of the ecology in perspective and might encourage someone to continue to sort out the finer details.

TERMINOLOGY

In the present paper the *edaphic complex* as defined by Wood (26) is used, as also is, in a restricted way, the analogous *climatic complex* which has been used previously in several of the author's earlier papers, (1), (4). These are considered as secondary groupings of convenience. They do, however, serve to illustrate some of the environmental relationships.

The primary units, the associations, are used in the sense of being characterised by several species which are prominent and always present in the community. In some cases the edaphic complexes, etc., are not subdivided into all or any of their more fundamental units, as more work is required to define these. One valuable feature of the climatic and edaphic complexes is that they can be used as mapping units fairly readily on account of the ease with which the relevant edaphic and/or climatic conditions can be defined. They can be used in conjunction with the text to give a logical picture when it is not practicable to map the associations. This latter condition occurs very frequently.

THE PLANT COMMUNITIES

About 20 of the more important associations have been individually recognised on Eyre Peninsula. Together with some of their more important inter-relationships they are summarised below in Table I. A large number of the associations have been mapped individually, but for the most part groups of associations or edaphic and climatic complexes are mapped.

As the associations change gradually where climatic complexes are involved, the boundaries are necessarily somewhat arbitrary in these cases.

TABLE I
THE VEGETATION ASSOCIATIONS AND THEIR INTER-RELATIONSHIPS

| EDAPHIC AND/OR CLIMATIC COMPLEX | ASSOCIATION | SOILS | CLIMATIC CONDITIONS |
|---|---|--|---|
| <i>Eucalyptus cladocalyx</i> – <i>Xanthorrhoea Tateana</i> – <i>Casuarina Muelleriana</i> – <i>Melaleuca uncinata</i> (heath) – <i>E. cladocalyx</i> – <i>Casuarina stricta</i> – heath ecotone | <i>Eucalyptus cladocalyx</i> – <i>Casuarina Muelleriana</i> – <i>Xanthorrhoea Tateana</i> – <i>Melaleuca uncinata</i> (heath) – <i>E. cladocalyx</i> – <i>Casuarina stricta</i> – heath ecotone | Podsols including primary and secondary lateric residuals. | Mean 61 - 62° F; Amp. 7° F; Lag 37 days. Rainfall Mean Period P/E > 0.3 (months) |
| <i>E. cladocalyx</i> – <i>C. stricta</i> – <i>E. cladocalyx</i> – <i>E. oleosa</i> – <i>Melaleuca uncinata</i> climatic com – <i>E. oleosa</i> – <i>M. uncinata</i> – <i>Triodia irritans</i> edaphic complex | <i>E. oleosa</i> – <i>M. uncinata</i> – <i>E. oleosa</i> – <i>M. uncinata</i> – <i>Triodia irritans</i> edaphic complex | Grey-brown & brown skeletal soils associated with metamorphic rocks. | Mean 61 - 62° F; Amp. 7° F; Lag 33-37 days. Rainfall Mean Annual (inches) |
| <i>E. odorata</i> – <i>C. stricta</i> – <i>E. odorata</i> association edaphic complex | <i>E. odorata</i> – <i>C. stricta</i> – <i>E. odorata</i> association edaphic complex | Red-brown earths. | Mean 61 - 62° F; Amp. 7° F; Lag 37 days. Rainfall Mean Period P/E > 0.3 (months) |
| <i>E. diversifolia</i> – <i>C. stricta</i> – <i>E. diversifolia</i> – <i>E. cicutaria</i> association – <i>Casuarina stricta</i> – <i>M. phillipsii</i> complex | <i>E. diversifolia</i> – <i>C. stricta</i> – <i>E. diversifolia</i> – <i>E. cicutaria</i> association – <i>Casuarina stricta</i> – <i>M. phillipsii</i> complex | Terra Rossa – Rendzina complex. | Mean 61 - 63° F; Amp. 7 - 8° F; Lag 34-37 days. Rainfall Mean Annual (inches) |
| <i>E. angulosa</i> var. – <i>E. leptophylla</i> – <i>E. leptophylla</i> – <i>E. leptophylla</i> – <i>M. uncinata</i> iiae edaphic complex | <i>E. angulosa</i> var. – <i>E. leptophylla</i> – <i>E. leptophylla</i> – <i>M. uncinata</i> iiae edaphic complex. | Solonised siliceous sands, (wind piled). | Mean 62 - 63° F; Amp. 8-10° F; Lag 31-35 days. Rainfall Mean Annual (inches) |
| <i>E. oleosa</i> – <i>E. gracilis</i> – <i>E. dumosa</i> – <i>E. dumosa</i> – <i>E. brachycalyx</i> var. – <i>E. oleosa</i> – <i>E. gracilis</i> – <i>Casuarina leptophylla</i> – <i>Callitris propinqua</i> | <i>E. oleosa</i> – <i>E. gracilis</i> – <i>E. dumosa</i> – <i>E. oleosa</i> – <i>E. gracilis</i> – <i>Casuarina leptophylla</i> – <i>Callitris propinqua</i> | Solonised Brown soils (Mallee), soils with lime-rubble and travertine. | Mean 62 - 64° F; Amp. 8-10° F; Lag 30-36 days. Rainfall Mean Annual (inches) |
| <i>Acacia Soudanii</i> – <i>C. leptocephala</i> edaphic com | <i>Acacia Soudanii</i> – <i>C. leptocephala</i> – <i>Casuarina leptophylla</i> – <i>Kochia setifolia</i> – <i>Atriplex vesicarium</i> – <i>Kochia paniculata</i> | Solonised Brown soils, usually with lime-rubble or travertine. | Mean 64 - 65° F; Amp. 9-10° F; Lag 29-31 days. Rainfall Mean Annual (inches) |

**1 E. CLADOCALYX—XANTHORHOEA TATEANA—CASUARINA MUELLERIANA
EDAPHIC COMPLEX**

This complex occurs in a region with an annual rainfall of 19-24 inches and an effective rainfall period of 6·5-7·5 months, with >15 inches effective rainfall per annum. The soils are essentially podsolts and include a complex pattern of primary and secondary lateritic soils. Some of the highly leached siliceous sands in this area are probably aeolian in origin.

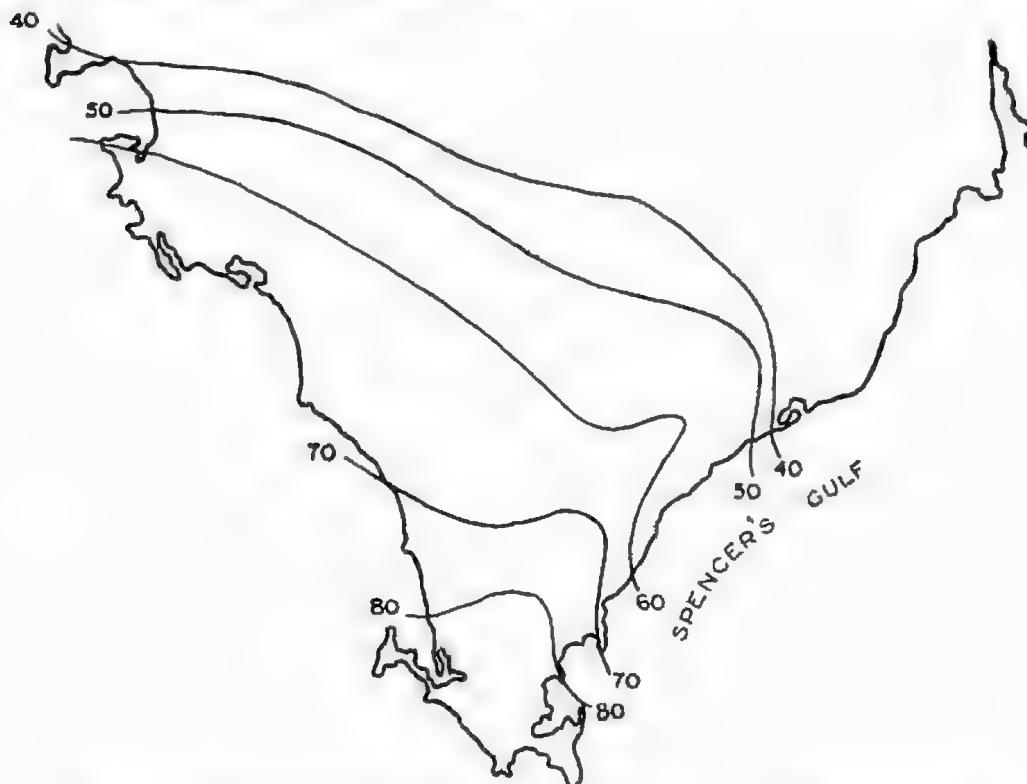


Fig. 7 Percentage of seasons with a minimum of four months wet period.

E. cladocalyx association (pl. xviii, fig. 2)

E. cladocalyx (sugar gum) is usually associated with sclerophyllous shrubs to form a lowly integrated dry sclerophyll forest, though occasionally on some of the podsolised skeletal gneissic soils it has a tendency to occur as a savannah woodland.

The *E. cladocalyx* dry sclerophyll chiefly occurs on residual lateritic podsolts and secondary podsolts, both of which normally have the characteristic pisolithic gravel layer immediately above the clay horizon as described earlier. The sugar gum is almost invariably depauperate and twisted as though it were growing towards the limits of its edaphic range. Amongst the sclerophyllous under-shrubs *Xanthorrhoea Tateana*, *Melaleuca uncinata*, *Hakea cycloptera* and *H. rugosa* are very prominent. Other important species include *Adenanthes terminalis*, *Lissanthe strigosa*, *Pultenaea trinervis*, *Leptomeria aphylla*, *Acacia rhetinodes* var. *angustifolia*, *A. rupicola*, *Exocarpus sparteo*, *Phyllota*, sp., *Grevillea ilicifolia*, *Spyridium leucopogon*, *Acrotriche cordata*, *Prostanthera spinosa* and *Baeckia Behrii*. *Goodenia robusta* is often quite abundant in more restricted localities.

In many of the local low-lying wetter hollows in this association communities dominated by *Callistemon rugulosus* and *Melaleuca decussata* are common.

Casuarina Muelleriana - *Xanthorrhoea Tateana* - *Melaleuca uncinata* heath association.

On the podsolic soils lying between the western slopes of the ranges west-north-west of Port Lincoln, and the Marble Range region, that is westward from Wanilla, and as far north as Edillilie, sclerophyllous heath, more or less admixed with mallee, is very widespread. It also occurs intermixed with *E. cladocalyx* sclerophyll forest in the eastern portion of Hundred Wanilla, the western portion of Hundred Louth, and the central northern section of Hundred Lincoln.

Where intermixed with the *E. cladocalyx* association the principal heath land shrubs are essentially the same species as occur as undershrubs in the adjacent sugar gum community, although *Daviesia brevifolia* and *Grevillea ilicifolia* may be much more abundant. It is not possible to define any soil characteristics which might be correlated with the occurrence of the *E. cladocalyx*. As pointed out earlier, however, this species appears to be towards the limits of its edaphic range, and it is very doubtful indeed whether it has ecceised in these cases.

The principal heath species are *Casuarina Muelleriana*, *Xanthorrhoea Tateana* (yaeka), *Hakea cycloptera*, *Melaleuca uncinata* (broombush), *Banksia marginata* (honeysuckle), and *Astroloma* sp. Other sclerophyllous undershrubs occurring include *Acacia rhetinodes* var. *angustifolia*, *Lasiopetalum Baueri*, *Calythrix tetragona*, *Hibbertia* spp., *Daviesia incrassata* (?) and *Baeckea Beltrii*.

In places there is a good deal of admixture of the heath with mallee, and scattered sheoaks (*Casuarina stricta*). Occasional mallee trees or mallee clumps occur throughout the whole association, though in the eastern parts at least they are more prominent where there are superimposed siliceous sands. The principal mallee species are *Eucalyptus angulosa*, *E. leptophylla*, and *E. Landsdowneana*. There is another mallee which could not be positively identified, but which has affinities with *E. leptophylla*.

Towards the northern limits of this association mallee becomes very prominent, and in addition to the above species *E. Falcata* occurs.

Banksia marginata and *Leptospermum coriaceum* show a marked preference for the lighter and deeper sands in this region.

E. cladocalyx - *C. stricta*—heath association

This association can be considered as an edaphic ecotone. It occurs throughout the dissected peneplain regions north-west of Port Lincoln on podsolised soils associated with underlying gneisses.

E. cladocalyx is often absent from this community and it might be better to recognise more than one association. Amongst the associated sclerophyllous undershrubs *Hakea cycloptera*, *Grevillea aspera*, *Astroloma conostephoides*, *A. humifusum*, *Acacia pycnantha* (golden wattle), etc., are common.

Where the skeletal gneissic soils are less podsolised the tendency is for a straight-out *Casuarina stricta* (pl. xix, fig. 1) or *E. cladocalyx* savannah woodland, and this rather mixed association can be considered an ecotonal link between these communities and the sclerophyll forest and heath associations.

**2 E. CLADOCALYX - CASUARINA STRICTA - E. OLEOSA - M. UNCINATA
CLIMATIC COMPLEX**

E. cladocalyx association and *Casuarina stricta* association

On the slightly podsolised brown and chocolate skeletal soils associated with the gneissic hilly country in the eastern portion of Hundred Louth, much of Hundred Koppio, and in more restricted occurrence elsewhere in the higher rain-

fall regions of Eyre Peninsula, the most important association is a savannah woodland dominated by *Casuarina stricta* (sheoak) (pl. xix, fig. 1).

Much less important on very similar soils is an *E. cladocalyx* savannah woodland.

Little is known of the floristics of these two associations but the latter is restricted to the wetter districts, while the *Casuarina stricta* association also occurs much further north. Interspersed with mallee and broombush (*Melaleuca uncinata*), it is still found on the skeletal soils of the rough hills as far north as Cleve.

Eucalyptus oleosa—*Melaleuca uncinata*—*Triodia irritans* association.

On the high country about Cleve in Central County Jervois the soils are chiefly skeletal, derived from metamorphic rocks, and apart from the *Casuarina stricta* associations much of the region is mallee scrub and broombush. The principal species are *E. oleosa* and less prominently *E. dumosa*, while *E. anceps* and *E. gracilis* have been recorded. The principal associated shrubs are *Melaleuca uncinata*, *Pomaderris racemosa*, *Dodonaea hexandra*, *Bursaria spinosa*, *Hakea* sp., *Rhagodia* sp., *Cassia eremophila* and *Melaleuca pubescens*.

Another species which occurs in the mallee-broom communities in this region is *E. brachycalyx* var. *Chindoo*. It does not appear, however, to be as widespread as the other eucalypts.

The most prominent grasses are the perennial native grasses, especially *Danthonia semiannularis* and *Stipa eremophila*.

In many of the valleys on alluvial and deeper soils *Eucalyptus calricultrix* (water mallee) often associated with *Lomandra* sp. (probably *L. dura*), *Stipa* sp. and *Danthonia* spp. occurs.

On some of the more stony hills *Triodia irritans* is particularly conspicuous.

In Hundred Campoona, coarse pinkish sands are quite a feature and *E. dumosa*, *E. brachycalyx* var. *Chindoo* and more sparingly *E. leucoxylon* (almost a mallee form) occur associated with *Lasiopetalum* sp., *Acacia* sp., *Triodia irritans*, *Daviesia brevifolia* and *Melaleuca uncinata*.

This association is closely allied to several other mallee communities in its floristics. The *M. uncinata* which gives quite a particular physiognomy to the community, shows a very marked preference for sandy soils or shallow skeletal soils. Wherever soils approaching the normal solonised brown soils occur, this association is replaced by another community.

3 EUCALYPTUS ODORATA—C. STRICTA EDAPHIC COMPLEX

E. odorata association (pl. xix, fig. 2)

A very limited area of red-brown earths flank the ranges north of Port Lincoln on the Spencer Gulf side. Elsewhere they are of restricted occurrence. These soils grade rather gradually into skeletal chocolate and brown gneissic soils, which carry a *C. stricta* savannah.

The red-brown earths carry a *E. odorata* savannah woodland, which reaches its maximum development on the range footslopes at Yalluna, west of Tumby Bay. In its edaphic, physiographic and climatic relationships the association can be paralleled with that occurring along the western footslopes of the Adelaide hills, on a similar soil type.

From a little north of Yallana the association follows the footslopes to as far south as Poonindie Plains, where there is a little admixture with *Casuarina*

stricta and *E. calcicultrix*. The principal grasses are *Danthonia semiannularis* and *Stipa* spp.

4 E. DIVERSIFOLIA - C. STRICTA - M. PUBESCENT EDAPHIC COMPLEX

This is the complex which is associated with the extensive occurrences of calcareous aeolianite, on the travertinised surface of which have developed terra-rossa-rendzina soils.

It is of some interest that the same associations are to be found on genetically related soils in the Lower South-East of South Australia (4), and Yorke Peninsula. On Kangaroo Island, on these soils, occurs the closely related *E. diversifolia* - *E. rugosa* association.

E. diversifolia association (pl. xx, fig. 1 and 2)

This association occurs over a very large portion and discontinuously extends from the southern-most portions of Eyre Peninsula to the neighbourhood of Streaky Bay. The dominant species is *E. diversifolia* (white mallee) and associated with it, particularly in County Flinders, is a large number of sclerophyllous shrubs and undershrubs. The soils are very shallow terra rossas developed on the travertine horizons of the old dunes.

Immediately behind Port Lincoln, where the aeolianite limestone has encroached upon both lateritic gravels and the older gneissic rocks and over which they may frequently rest as a relatively thin mantle, there is a large number of other eucalypts associated with *E. diversifolia*. Chief amongst these are *E. rugosa* and *E. conglobata*, but *E. angulosa*, *E. transcontinentalis* and *E. Landsdowneana* occur, especially where the ironstone gravel is more apparent.

E. dumosa occurs with *E. diversifolia* at times on these soils.

In the region immediately behind Port Lincoln the associated sclerophyllous shrubs include *Pomaderris obcordata*, *Templetonia retusa*, *Grevillea aspera*, *Acacia Gillii*, *A. armata* (chiefly marginal to gneissic outcrops), *Dodonaea cuneata*, *D. attenuata* (?), *Lasiopetalum Schulzenii*, *Hakea rugosa*, *H. vittata*, *Pultenaea acerosa* var. *acicularis*, *Holmgrenia cyanea*, *Scutellaria aemula*, *Pimelia stricta*, *Hibbertia stricta* var. *glabriuscula*, *Goodenia* sp. (aff. *affinis*), *Stackhousea monogyna* and *Xanthorrhoea Tuncana* (rare on aeolianite).

The principal perennial grasses are *Danthonia setacea*, *Stipa* sp. (probably *S. eremophila*) and *S. semibarbata* var. *gracilis*.

E. diversifolia and *E. rugosa* (?) both occur, but again discontinuously, on recent systems of unconsolidated dunes of calcareous aeolianite, which lie adjacent to the coast in some parts. It will probably be possible in future to recognise two distinct associations—an *E. diversifolia* association and an *E. diversifolia* - *E. rugosa* association.

E. calcicultrix association.

This rough-barked mallee is frequently known as "water mallee" and though not restricted entirely thereto, it is most widespread on some of the terra rossas associated with aeolianite travertine in the western portion of County Robinson. In much of this region, as about Chandada, it is sufficiently important to reach the rank of an association dominant.

The association is fairly open and approaches savannah woodland. Associated sometimes are *Melaleuca pubescens* (dry-land titree) and *Callitris propinqua*, while *Acacia ligulata*, *Geijera linearifolia* and *E. diversifolia* may occur. The principal grasses are *Stipa eremophila* and *Danthonia semiannularis*.

Casuarina stricta - *Melaleuca pubescens* association.

This association, another associated with the terra rossa - rendzina complex of the aeolianite travertine, is probably the most widespread on Eyre Peninsula. It occurs interspersed with the former two associations, and although it is intimately connected with the *E. diversifolia* association in distribution both on Eyre Peninsula and elsewhere in South Australia, it is floristically (and hence structurally) very different.

The association is essentially an open savannah woodland. The principal dominant species is *Casuarina stricta* (sheoak), and over wide areas may be sole dominant (pl. xxi, fig. 1). *Melaleuca pubescens* is, however, frequently associated and in restricted localities may be sole dominant. It will probably be better in more detailed work to further subdivide this community.

The most prominent perennial grasses are *Danthonia semiannularis* (wallaby grass), *Stipa eremophila* (spear grass) and *S. falcata* (spear grass), while *Bromus rubens* is often a conspicuous annual grass. *Gahnia lanigera* (black rush) is quite a feature in parts of County Robinson, and probably elsewhere.

Casuarina stricta association.

On some of the large calcareous dune systems along the coast a closely allied association occurs. One such system was examined in Sections 292 and 297, Hundred Ripon, and another near Perlubie, Hundred Finlayson, County Robinson. In both localities the sandhills were very unstable and poorly vegetated. The dominant tree was *C. stricta*, which was very dispersed; associated were a number of shrubs, chief of which were *Eremophila crassifolia*, *Lasiopetalum discolor*, *Beyeria Leschenaultii*, *Thryptomene Miquelianae*, *Fusanas acuminatus* and *Lomandra leucocephala*. The most prominent grasses were *Danthonia semiannularis*, *Stipa eremophila*, *S. barbata*, *Stipa* sp., *Puccinellia stricta*, *Bromus rubens* and *B. rigidus*. On the dunes nearer the coast *Olearia* sp., *Spinifex hirsutus* and *Scirpus nodosus* are most important.

5 E. ANGULOSA var. - E. LEPTOPHYLLA - E. FLOCTONIAE EDAPHIC COMPLEX

E. angulosa var. - *E. leptophylla* - *Melaleuca uncinata* association

On the solonised siliceous sands of the Nullarbor-Spence dune system which cut across the north of Eyre Peninsula is a typical low mallee-broombush scrub. There are perhaps modifications at the north-eastern edge of the system, but generally speaking *E. angulosa* var. (possibly var. *ceratocorys*) and *E. leptophylla* (narrow-leaved mallee), together with *Melaleuca uncinata* (broombush), give a characteristic facies to the vegetation.

Other mallees occur, and of these *E. oleosa*, *E. dumosa* and *E. Floctoniae* are the more important, and they all show a preference, at least in the more heavily leached dunes, for the lower slopes of the sandrises.

Associated with the broombush on the more highly leached dunes are a large number of other sclerophyllous shrubs—*Hakea cycloptera*, *H. ulicina*, *Casuarina Muelleriana* (oakbush), *Acacia spinescens*, *A. farinosa*, *Leptospermum coriaceum*, *Phebalium pungens*, *P. bullatum*, *Baeckia crassifolia*, *Thryptomene calycina*, *Grevillea pterosperma*, *Hakea multilineata*, *Spyridium bifidum*, *S. subochreatum*, *Calythrix tetragona*, *Gyrostemon ramulosus*, *Astroloma conostephioides*, *Boronia caeruleascens*, *Hibbertia stricta*, *Loudonia Behrii*, *Homoranthus Wilhelmii*, *Exocarpus sparteus*, *Aotus villosa*, and *Triodia irritans*.

At times the oakbush (*C. Muelleriana*) is so abundant as to give a characteristic facies to the association.

In the drier regions, where the sands are not so heavily leached, as north of Minnipa, the greater part of these sclerophyllous shrubs do not persist, but *M. uncinata*, *Triodia irritans*, *Leptospermum coriaceum* and *Exocarpus sparteus* are all very prominent (pl. xxi, fig. 2).

E. oleosa—*M. uncinata* association.

On some of the solonetzic sandrises *E. oleosa* may be so prominent as to be the dominant tree in the community. This occurs in the sandy regions north-east of Cowell. *E. transcontinentalis*, *E. dumosa*, *E. angulosa* var. and *E. leptophylla* also occur, but to much less extent. Other species include *Myoporum platycarpum*, *Melaleuca uncinata*, *Acacia rigens* and *Baeckia crassifolia*.

E. Flockoneae—*E. dumosa*—*M. uncinata* association

This association is widespread in the Cummins-Yeelanna region, where there is an interesting pattern of grey sands and sandy loams (with red-brown clay subsoils), and red-brown loams. It occurs on the former soil types. It can be considered analogous to the foot-slope community of the solonised dunes.

In addition to *E. Flockoneae* and *E. dumosa*, *E. leptophylla*, *E. oleosa* and *E. calycogona* occur. The latter appears to be particularly prevalent in this region where ferruginous gravel (not pisolithic—possibly fossil orstein) occurs in the soils.

Associated with the mallees are a number of sclerophyllous shrubs, including *Melaleuca uncinata*, *M. pubescens*, *Grevillea ilicifolia*, *Exocarpus sparteus*, *Lasiopetalum Behrii*, *Daziesia ovata*, *Dodonaea Baueri*, *Leptomeria aphylla*, *Astroloma conostephioides* and *Baeckia crassifolia*.

6 *E. OLEOSA*—*E. DUMOSA*—*E. GRACILIS* EDAPHIC COMPLEX

This complex includes all those associations that occur on the major types of what have usually been considered brown solonised soils. Some of the soils are red-brown shallow sandy loams over travertine limestone, others merely contain large amounts of lime rubble in the B₁ horizon, while others are fairly deep light to medium textured soils allied to Murray Valley types like the Barmera sand.

E. dumosa—*E. incrassata* (?) association

In many of the inter-ridge areas associated with the system of solonised dunes there is a community dominated by *Eucalyptus dumosa*, and a closely allied species which may be *E. incrassata*. Many of the species which occur on the dunes also occur in this association.

The following species were prominent on a shallow red-brown loam over travertine limestone in this association near Rudall—*Melaleuca uncinata*, *Eucarya acuminata*, *Acacia spinescens*, *Cryptandra tomentosa*, *C. amara*, *Lasiopetalum Baueri*, *L. Behrii* (?), *Dampiera lanceolata*, *Grevillea ilicifolia*, *Exocarpus aphylla*, *Baeckia crassifolia*, *Phebalium bullatum*, *Brachyloma ericooides*, *Brachycome ciliaris*, *Dampiera rosmarinifolia*, *Boronia inornata* and *Hibbertia stricta*. The rainfall in this region approximates 14 inches per annum.

E. oleosa—*E. brachyacalyx* association

In some of the drier regions, as about Mitchellville (rainfall 11 inches per annum), on brown sandy loams and loams usually underlain by travertine, there is an association in the inter-ridge areas dominated by *E. oleosa* and *E. brachy-*

calyx var. *Chindoo*. The other species present have a more arid facies than the previous association and include many members of the Chenopodiaceae. The following record made at Section 12, Illundred Wilton, can be taken as an example of the floristics of this association. *Melaleuca pubescens*, *Geijera linearifolia*, *E. gracilis*, *Grevillea Hueglii*, *Pittosporum phillyreoides*, *Exocarpus aphylla*, *Daviesia* sp., *Myoporum deserti* (?) *Dodonaea stenozyga*, *Rhagodia spinescens*, *R. crassifolia*, *Kochia tomentosa* var. *appressa*, *K. triptera* var. *pentaptera*, *Atriplex stipitatum*, *Enchylaena tomentosa* and *Cratystylis conocephala*. Amongst the annuals *Mesembrianthemum acquilaterale*, *M. australis*, *Bassia sclerolaenoides*, *B. obliquicuspis*, *Angianthus tomentosus*, and *Zygophyllum fruticulosum* are prominent. The principal grasses are *Danthonia semiannularis* and *D. setacea*, *Stipa Drummondii*, *S. eremophila*, and *Schismus barbatus* (especially on small sand shadows, where *Mesembrianthemum crystallinum* is also often associated).

In restricted area where the soils are heavier *Atriplex vesicarium* occurs.

E. oleosa—*E. gracilis* association (pl. xxii, fig. 2)

This is the most dominant and widespread of the mallee communities and very closely allied to the previous association. It is the principal mallee association in the Minnipa, Warramboo and Kimba regions, and also occurs in the Cowell district. *E. dumosa* and *Myoporum platycarpum* may also be associated, but the two important mallées are *E. oleosa* (red mallee) and *E. gracilis* (Kong mallee). The subdominant low tree-shrub stratum includes *Melaleuca pubescens*, *Geijera linearifolia* (candlebush), *Acacia Oswaldii*, *A. ligulata*, *Eremophila scoparia*, *Grevillea Hueglei*, *Exocarpus aphylla*, *Pittosporum phillyreoides*, and usually where the soils are lighter and deeper, odd *Callitris propinqua* (native pine).

In the lower shrub stratum the composite *Cratystylis conocephala* (locally called bluebush) is very prominent, and may give a particular facies to the community. *Atriplex stipitatum*, *Rhagodia spinescens* and *Enchylaena tomentosa* also frequently occur, and the chief grasses are *Danthonia semiannularis*, *Stipa eremophila* and *S. variabilis*.

Between Yaninee and Minnipa, *Casuarina lepidophloia* occurs as a dispersed dominant in this association.

Casuarina lepidophloia association

On some of the lighter and deeper types of the solonised brown soils occurs a more or less open savannah woodland dominated by *Casuarina lepidophloia* (black oak, or belar). There is a notable occurrence about a mile north of Yaninee. Associated with the belar are a number of other small trees, of which *Myoporum platycarpum*, *Eucarya acuminata*, *Exocarpus aphylla* are most important, while the smaller shrubs include *Cassia eremophila*, *C. Sturtii* and *Acacia ligulata*.

Callitris propinqua association

Associated with outcrops of granite on Eyre Peninsula are soils of higher fertility status, and they frequently carry a *Callitris propinqua* (native pine) woodland.

The same, or a very closely allied association occurs on deep red-brown sands, as about Kimba, or at other times on shallow soils over travertine limestone.

It is not infrequent, where the soils are light-textured and deep, for a community dominated by *Casuarina lepidophloia* and *Callitris propinqua* to occur. This community should perhaps be given association rank.

Stipa eremophila—*Danthonia semiannularis* association.

Throughout the mallee regions on Eyre Peninsula, and especially in north-western County Robinson and County Dufferin occur open grass savannah regions which have always been tree-less.

The most prominent grass is one of the so-called spear grasses, *Stipa eremophila*, but also present to some degree are other species, of which *Danthonia semiannularis* appears to be the most important.

The areas occupied by this association are usually small and dispersed, though from the grazing point of view they are very important, and the total area is considerable.

7 ACACIA SOWDENII—CASUARINA LEPIDOPHLOIA EDAPHIC COMPLEX

This complex is important on the arid side of the mallee communities and occurs on very closely allied soils of the brown solonised soils group.

Acacia Sowdenii—*Myoporum platycarpum* association.

In the Whyalla region the most important association is a tree-steppe community dominated by *Acacia Sowdenii* (myall) and *Myoporum platycarpum* (sandalwood). The taller woody shrubs occurring are *Heterodendron oleifolium*, *Eremophila scoparia*, *Eucarya acuminata*, *Acacia Oswaldii*, *Geijera linearifolia*, *Cassia Sturtii* and *Exocarpus aphylla*, but they are fairly sparse and a particular physiognomy is given to the association by the more or less continuous lower shrub stratum. The principal species in this are *Atriplex vesicarium* (saltbush) and/or *Kochia sedifolia* (bluebush). Other species occurring, however, include *Kochia pyramidata*, *Enchylaena tomentosa*, *Atriplex stipitatum* and *Kochia triptera* var. *pentaptera*.

Where the soils are a little lighter, *Hakea leucoptera* and *Lycium australe* are often present.

The ground flora is comprised chiefly of various species of *Bassia*, of which *obliquicuspis* is the most prominent, and sparse grasses such as *Stipa variabilis*, *Danthonia semiannularis* and *Enneapogon nigriceps*.

This association has already been described north of this region on Yudnapinna Station (7).

Casuarina lepidophloia—*Kochia sedifolia* association

It is not unusual for occasional trees of *C. lepidophloia* (black oak) to occur in the previous association, but at other times an association dominated by this species and with a continuous shrub-steppe stratum occurs. The principal shrub is *Kochia sedifolia*, but *Atriplex vesicarium* and other species also occur.

Associated with the black oak may be occasional *Myoporum platycarpum* and *Acacia Sowdenii*. The soils frequently contain a good deal of lime-rubble or travertine in the sub-soil.

Atriplex vesicarium—*Kochia planifolia* association.

This association is very restricted on the area under consideration and has already been described in the Yudnapinna region.

Kochia sedifolia association

This shrub-steppe association, which may at times be almost monospecific so far as the dominants are concerned, occurs in places. It is most probably associated with soils containing a good deal of free lime. Associated with the

K. sedifolia may be *Atriplex vesicarium*, and occasionally *Kochia planifolia* and *Kochia Georgei*. *Eremophila scoparia*, *Cusuarina lepidophloia*, *Myoporum platycarpum* and *Heterodendron olcifolium* may occur very sparsely.

Other Communities

Two communities of some local interest are the *Eucalyptus camaldulensis* association, which is probably most important in the neighbourhood of the Big Swamp and Little Swamp on southern Eyre Peninsula, and the *Eucalyptus leucoxylon* association. The latter association has only been observed as a very limited one in some of the valleys in the dissected peneplain behind Port Lincoln and on some of the skeletal soils west of Yallana.

E. camaldulensis association, in addition to fringing swamps, also occurs as a fringing forest along some of the creeks.

THE MAPS

Soil Map—This map has been compiled from a recognition of the main types in the field during several visits to Eyre Peninsula, and subsequently following out their distribution with the aid of all the information available. Of great value were data contained in the original survey records.

No attempt has been made on the map to indicate that in the sand-dune system associated with the solonised siliceous sands, the soils of inter-dune areas are normally brown solonised (mallee) soils, frequently shallow over travertine limestone. The red and red-brown soils in these latter cases have distinct affinities with the terra rossas. Nor has any attempt been made to indicate separately the major areas of skeletal soils. Their distribution is obvious by reference to the physiographic map, pl. xxiii. They are a most important feature in the Cleve-Millalie region in Central County Jervois.

Vegetation Map—After field differentiation of the major communities and their inter-relationships, their distribution has been defined with the assistance of the original survey diagrams. In most cases no attempt has been made to map associations, though where there are large floristic differences between some associations within the same edaphic or climatic complex, they have been mapped separately.

SUMMARY

The most important features of the geology, physiography, soils, and climate which influence the distribution of the major plant communities of Eyre Peninsula are described, and soil and vegetation maps presented. The area concerned is approximately 15,000 square miles and includes Counties Flinders, Jervois, Musgrave, Buxton, Le Hunte, Robinson and York.

Twenty-three plant associations have been defined, and these are grouped for convenience into seven edaphic and climatic complexes.

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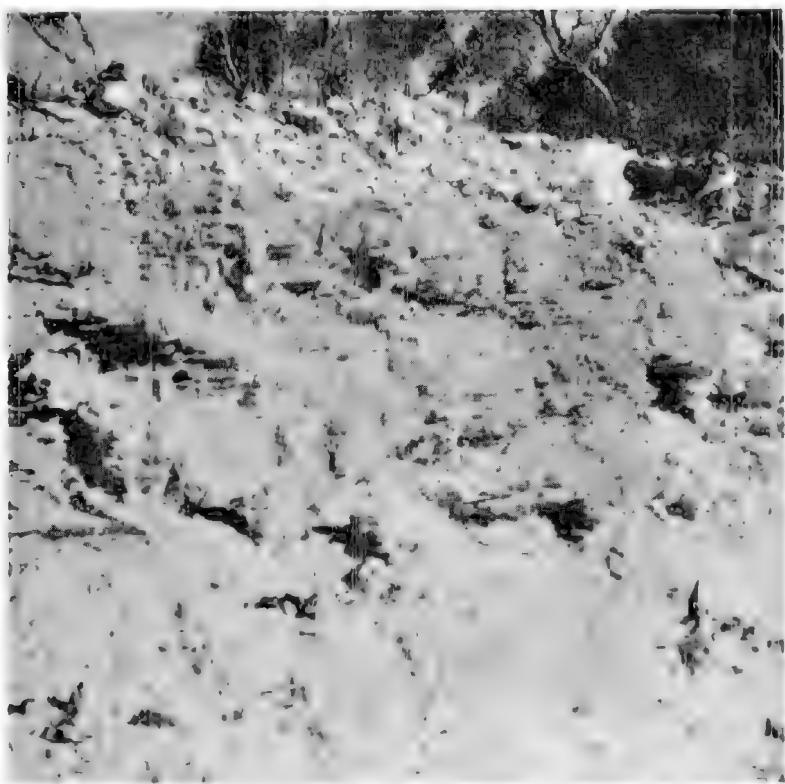


Fig. 1



Fig. 2



Fig. 1



Fig. 2



Fig. 1



Fig. 2



Fig. 1



Fig. 2



Fig. 1



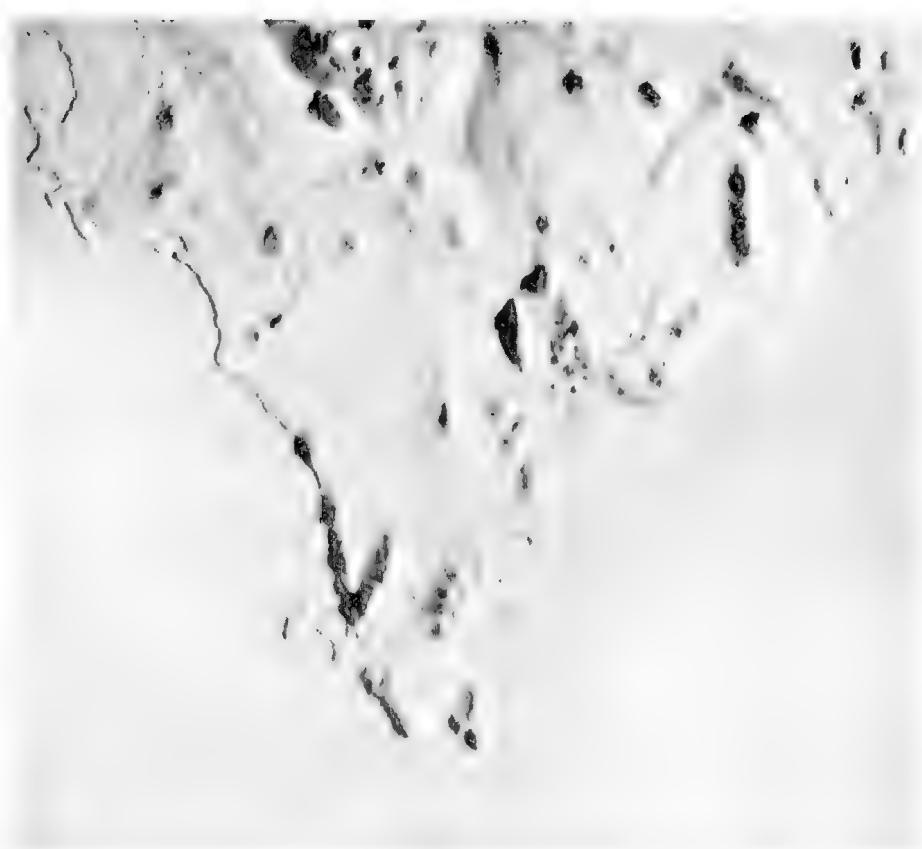
Fig. 2



FIG. 1



FIG. 2



Relief Map of Eyre Peninsula

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EXPLANATION OF PLATES XVII TO XXIII

PLATE XVII

Fig. 1 Consolidated calcareous aeolianite exposed in a road cutting near Calca, County Robinson. The old accretion layers are faintly visible.

Fig. 2 Climbing sandridges passing over the high country between Cowell and Kimba.

PLATE XVIII

Fig. 1 Calcareous aeolianite—an unstable dune system near Perlubie, County Robinson.

Fig. 2 *Eucalyptus cladocalyx* association near Wanilla. *Xanthorrhoea Tateana* is very prominent as an undershrub.

PLATE XIX

Fig. 1 *Casuarina stricta* association on a gneissic hill near Wanilla.

Fig. 2 *Eucalyptus odorata* savannah woodland.

PLATE XX

Fig. 1 *Eucalyptus diversifolia*—*Eucalyptus rugosa* association on aeolianite limestone near Port Lincoln.

Fig. 2 *Eucalyptus diversifolia* association on shallow terra rossa soil developed from aeolianite travertine behind Port Lincoln.

PLATE XXI

Fig. 1 *Casuarina stricta* savannah on shallow terra rossa soils, Hundred Rounsevell, County Robinson.

Fig. 2 *Eucalyptus angulosa* var.—*E. leptophylla*—*Melaleuca uncinata* association north of Minnipa.

PLATE XXII

Fig. 1 *Eucalyptus oleosa* (red mallee) on a brown solonised soil which contains travertine limestone and rubble. Near Mitchelville.

Fig. 2 *Eucalyptus oleosa*—*E. gracilis* association, Kimba. *Cratystylis conocephala* (blue-bush) is an important undershrub.

PLATE XXIII

Relief Map of Eyre Peninsula.

**NOTES ON A RECENT RAISED BEACH AT POINT BROWN,
YORKE PENINSULA, SOUTH AUSTRALIA**

BY R. L. CROCKER

Summary

With greater interest being shown in the geological Recent, the occurrence of raised beaches is especially important. The elevated beach deposit described in this paper is at Point Brown, a small bluff some 4-5 miles south of Port Rickaby, on Spencer Gulf.

**NOTES ON A RECENT RAISED BEACH AT POINT BROWN,
YORKE PENINSULA, SOUTH AUSTRALIA**

By R. L. CROCKER

[Read 11 April 1946]

PLATES XXIV AND XXV

INTRODUCTION

With greater interest being shown in the geological Recent, the occurrence of raised beaches is especially important. The elevated beach deposit described in this paper is at Point Brown, a small bluff some 4-5 miles south of Port Rickaby, on Spencer Gulf.

GENERAL COASTLINE FEATURES

The coast features at Point Brown are very interesting. The Point is composed of cliffs some 12-16 feet above sea level, which form a small though prominent bluff. On either side, that is, both north and south, the cliffs rapidly disappear as they become both lower and covered with calcareous coastal dunes. These latter are practically absent at the Point itself.

The cliffs are entirely composed of travertine limestone. This is hard and dense and has been built up by the cementation of pisolithic lime rubble. These rubble units are readily detectable and, being more resistant to weathering than the matrix, frequently stand out prominently.

Towards the base of the cliffs there appears much less lime rubble, and the whole rock is more clayey and more weakly cemented. The result is a good deal of undercutting from occasional high seas, and a tendency for the formation of caves. Unfortunately, this lower portion of the cliffs is mostly obscured by fallen blocks of the overlying travertine, and cannot be traced right to sea level.

Flanking the whole coastline for some miles in either direction is a limestone reef some 4-6 chains wide. This reef, only broken by occasional small rock-free areas, is very flat, and drops away suddenly on its sea-ward margin. It is submerged by 2-4 feet of water at high tide and is normally completely uncovered at low tide, though limited areas of it may be covered by a few inches of water. The limestone of which the reef is formed is a typical travertine in which lime rubble nodules are obvious. The general features of the coastline are shown in fig. 1 and in pl. xxiv and xxv, fig. 1 and 2.

THE RAISED BEACH

The travertine cliffs exhibit the development of two or three hard pavement-like surfaces which are horizontal and apparently extend back into the cliff. The travertine immediately underlying these pavements is normally much more resistant than the material either above or below and tends to form a projecting shelf. Towards the very top of the cliff, above one of these hard pavements, occurs a raised beach deposit. This is normally 6-8 inches thick and, though lime-cemented and with a thin pavement capping, is very much softer than the underlying travertine, which is more or less sheet stone.

The deposit contains numerous shells chiefly of a reef suite; the dominant species is the black winkle *Nerita melanotragus*. The shell bed is practically free of any of the lime-rubble so conspicuous in the underlying travertine, which



Fig. 1 Travertine limestone exposed in the cliffs at Point Brown.



Fig. 2 Limestone rubble concretions in the travertine cliffs at Point Brown.

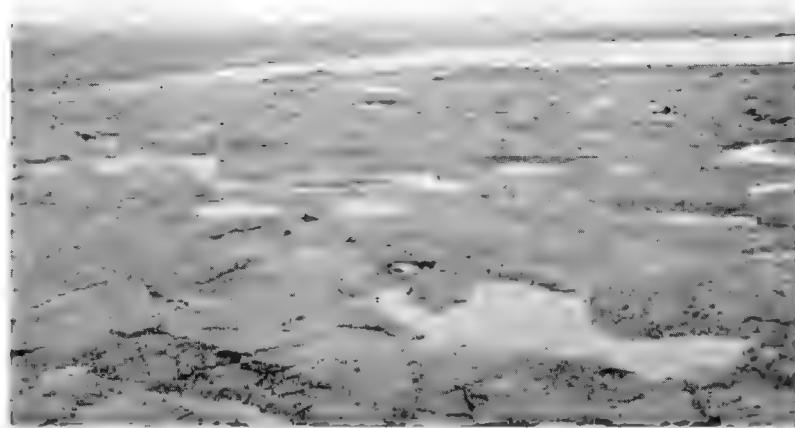


Fig. 1 The travertine reef exposed at low tide.



Fig. 2 The raised beach at Point Brown.

it has post-dated. Its more recent origin is apparent from the manner in which the deposit has filled vertical cracks in the travertine. The material in these fissures can be traced up to the overlying shell bed, from which it is indistinguishable.

It is interesting that a raised beach has already been described some 15 miles further south at Point Turton by Clark (1). Here the upper limit of the bed was only 5-6 feet above high water mark, but as the high water limits are rather indefinite, it is probable that the two deposits bear approximately similar relationships to sea level. The Point Turton deposit could be traced for some two miles and was overlying Miocene marine limestone. It is most likely that the two deposits were formed at the same period when the sea, relative to the land, must have been at least 10-12 feet higher than at present.

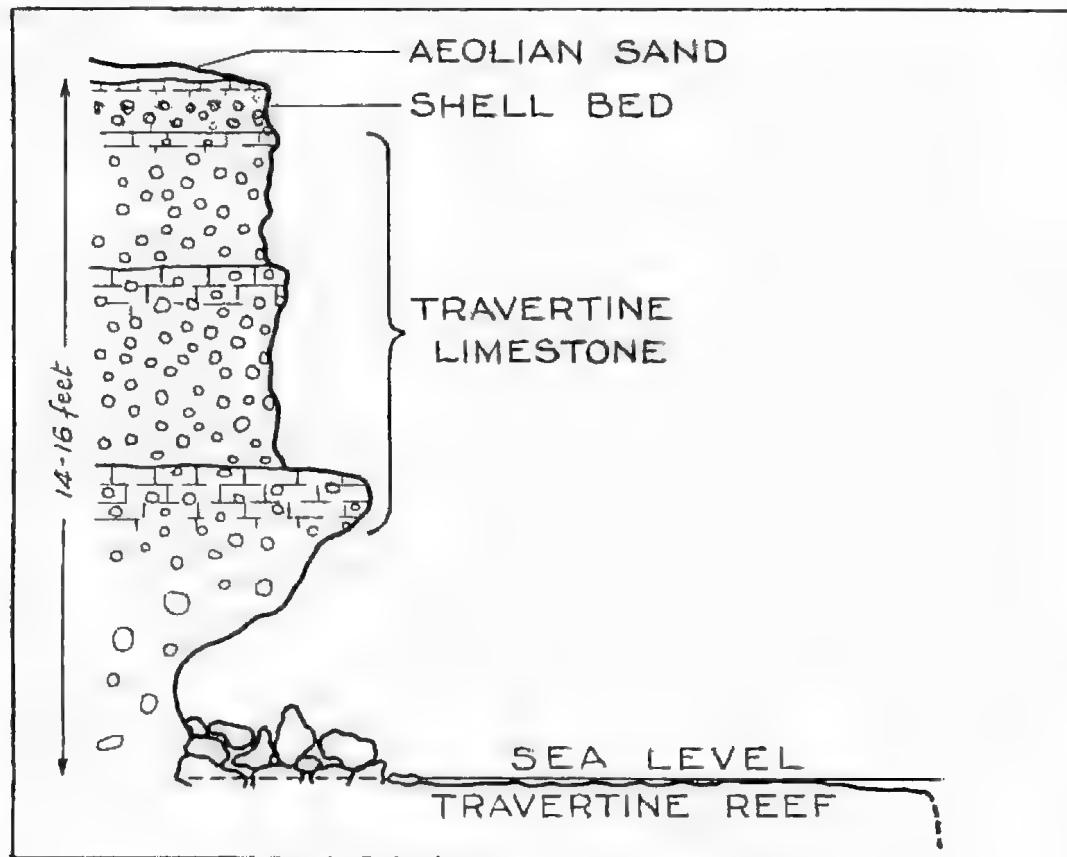


Fig. 1

Sketch section showing the main coastal features at Point Brown.

Most of the shells are represented on the beach adjacent to the site today, and include⁽¹⁾ *Nerita melanotragus*, *Zeacumantus diemenensis* and *Emozamia flindersi*.

In addition to the species still living in this region there is also *Euplica bidentata*, which evidently became extinct in South Australia about the same time as *Anadara trapezia*, although still living in Western Australia today.⁽²⁾.

REFERENCE

- (1) CLARK, E. V. 1928 Trans. Roy. Soc. S. Aust., 52, 189-190

⁽²⁾ Identified by B. C. Cotton, Conchologist, S.A. Museum.

⁽¹⁾ B. C. Cotton—Personal communication.

GERMINATION STUDIES OF AUSTRALIAN CHENOPODIACEAE WITH SPECIAL REFERENCE TO THE CONDITIONS NECESSARY FOR REGENERATION

BY NANCY T. BURBRIDGE, M.Sc., WAITE AGRICULTURAL RESEARCH INSTITUTE

Summary

The characteristics of the germination of *Atriplex vesicarium* Hew. were described in a previous paper (1) which is now followed by a similar study of three species of a genus which, in South Australia at least, is of comparable importance. Over the last few decades the condition of the arid pastoral area has deteriorated. For various reasons the natural vegetation has proved unstable under stocking and as a result increasing attention is being given to the remaining shrubs and to the remainder of the shrub country. Much of the latter carries the palatable but longer-lived bluebushes. Of these *Kosia sedifolia* (Black Bluebush) are very long-lived, but the life-span of *K. georgei* (George's Bluebush) is probably comparable with that of *Atriplex vesicarium*, which Wood (4) gives as about 12 years. In all species longevity is likely to be dependant on the particular incidence of good and bad seasons.

**GERMINATION STUDIES OF AUSTRALIAN CHENOPodiACEAE
WITH SPECIAL REFERENCE TO THE CONDITIONS NECESSARY
FOR REGENERATION. II — (a) *Kochia sedifolia* F. v. M., (b) *K. pyramidalis* Benth, (c) *K. georgei* Diels**

By NANCY T. BURDIDGE, M.Sc., Waite Agricultural Research Institute

[11 April 1946]

PLATE XXVI

The characteristics of the germination of *Atriplex vesicarium* Hew. were described in a previous paper (1) which is now followed by a similar study of three species of a genus which, in South Australia at least, is of comparable importance. Over the last few decades the condition of the arid pastoral areas has deteriorated. For various reasons the natural vegetation has proved unstable under stocking and as a result increasing attention is being given to the remaining shrubs and to the remainder of the shrub country. Much of the latter carries the less palatable but longer-lived bluebushes. Of these *Kochia sedifolia* (Bluebush) is one of the most important. Both this species and *K. pyramidata* (Black Bluebush) are very long-lived, but the life-span of *K. georgei* (George's Bluebush) is probably comparable with that of *Atriplex vesicarium*, which Wood (4) gives as about 12 years. In all species longevity is likely to be dependent on the particular incidence of good and bad seasons.

The present study was an attempt to obtain information of value in the search for methods of preserving the natural shrub vegetation which is in real danger of complete destruction. The general features of germination are much the same in all three species. As compared with *Atriplex vesicarium* development is extremely rapid and the optimum temperature is higher. These characteristics are believed to hold for the whole genus.

THE SPECIES

The plants are monoecious. The perianth is five-lobed, the lobes being imbricate. This structure becomes enlarged and a scarious wing is developed during the maturing of the seed. Owing to the wing, transportation of the seed is by wind.

The seed is similar to that of *Atriplex*, i.e., a small disc-shaped structure, but it is placed horizontally in the ovary, not vertically. The point of the radicle is towards the junction of the outer and inner perianth lobes (pl. xxvi, fig. 4). It is from between these lobes that the young root emerges at the time of germination. The seed is loose within the ovary. As in *Atriplex* it is normally retained within the fruit though in *K. pyramidata*, where the fruit as well as the wing becomes scarious, the structure may split and release the seed. In the field the fruits, found lying under bushes or in debris, are often empty, due to insect depredations. Ants are the most destructive, and their holes are commonly surrounded by discarded fruits.

The seeds of *K. sedifolia* used in the test were collected at Yudnapinna Station near Port Augusta, in October 1943 (No. 4,168) and March 1945 (No. 4,269). Despite the incidence of poor seasons this species has produced seed four times in the last three years. This is not in accordance with the observations of other workers (4). The flowers appear after rains occurring during the warm season. *K. pyramidata* flowers in late winter, the seeds falling in spring or early summer. It is a heavy seeder whenever there are winter or

autumn rains. Seeds used in these experiments were collected at Yudnapinna in December 1942. *K. georgii* seeds about the same time as *K. pyramidata*, but may also flower after summer rain. The seed used was collected at Pallamana in June 1944.

METHODS

The methods employed were the same as those used for *Atriplex vesicarium* and already described (1). The only difference was that tests ran for two weeks instead of three. Unless stated otherwise, the medium used was sand moistened to 60% saturation.

RESULTS

A. EFFECTS OF TEMPERATURE

(a) *Optimum Temperature*

The optimum temperature was sought first in *Kochia sedifolia* (4,168). The 14 cabinets of the multiple temperature incubator varied from 6-41° C. In a preliminary test the seeds were removed from their fruits and placed on moist filter paper in 9.0 x 1.5 cm. petri dishes. In less than 24 hours, at all except the lowest temperatures, 50% of the embryos had burst out from their seeds. In three days germination was complete.

This escape of the embryos from the seed a few hours after moistening can hardly be called true germination, which is a process involving actual growth of tissue. It seems more probable that, because of imbibition and increased turgor, pressure in the curved embryo results in a rupturing of the testa. The process is analogous to the escape of a coiled spring.

Embryos which had appeared at 41.5° C. were already blackened at 24 hours, so that it was clear that, as in *A. vesicarium*, actual damage to the tissues or rapid attack by pathogens occurred at high temperatures.

In all other tests the medium used was sand which had been passed through a 1 mm. sieve. This medium delayed the assessment of results owing to the burial of the seed, but rapid germination was found to be characteristic of all species.

In the next test *K. sedifolia* (4,168) was again used. Half the seeds were removed from their fruits, and the remainder were untreated. The results are shown in Table I. Similar results were obtained with *K. pyramidata* and *K. georgei*. (See Tables II and III.)

TABLE I

Kochia sedifolia germinated in multiple temperature incubator.

50 seeds per petri dish with sand at 60% saturation. Sum of two replications.

| A. | °C. | Increase per Day | | | | | | | | | | | | | % Germination |
|----|------|------------------|----|----|----|----|----|----|----|----|----|----|----|----|---------------|
| | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | |
| | 41·0 | .. | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | 36·0 | .. | 43 | 11 | 1 | 1 | — | — | 1 | — | — | — | — | — | 57 |
| | 30·5 | .. | 58 | 8 | 4 | 1 | — | 1 | — | — | — | — | — | — | 72 |
| | 26·5 | .. | 65 | 12 | 3 | — | 1 | — | — | — | — | — | — | — | 81 |
| | 24·5 | .. | 72 | 2 | 3 | 1 | 1 | — | — | — | — | — | — | — | 79 |
| | 22·5 | .. | 69 | 2 | 2 | — | — | — | — | — | — | — | — | — | 73 |
| | 20·0 | .. | 70 | 6 | — | — | 1 | 1 | — | — | — | — | — | — | 78 |
| | 18·5 | .. | 67 | 7 | 1 | 1 | 1 | 1 | — | — | — | — | — | — | 75 |
| | 16·5 | .. | 52 | 11 | 7 | 3 | 2 | — | — | — | — | — | — | — | 75 |
| | 14·5 | .. | 38 | 38 | 7 | 2 | 1 | 4 | — | — | — | — | 2 | — | 92 |
| | 13·5 | .. | 17 | 29 | 23 | 10 | 2 | 3 | — | — | — | — | 1 | — | 85 |
| | 11·5 | .. | 7 | 9 | 22 | 13 | 19 | 8 | 3 | 1 | — | — | — | — | 82 |
| | 9·0 | .. | 4 | 2 | 6 | 3 | 16 | 15 | 14 | 14 | 1 | 9 | — | 1 | 76 |
| | 6·0 | .. | — | — | 1 | — | 1 | 7 | 8 | 5 | 2 | 3 | — | 10 | 37 |

| °C. | 3 | 4 | 5 | 6 | Increase per Day | | | | | | 11 | 12 | 13 | 14 | % Germination |
|-----------------------------------|----|----|----|----|------------------|----|----|----|----|----|----|----|----|----|---------------|
| | | | | | 7 | 8 | 9 | 10 | 11 | 12 | | | | | |
| B. Not removed from fruit: | | | | | | | | | | | | | | | |
| 41.0 | .. | — | — | — | — | — | — | — | — | — | — | — | — | — | .. — |
| 36.0 | .. | 1 | 2 | 2 | 1 | — | — | — | — | — | — | — | — | — | .. 6 |
| 30.5 | .. | 4 | 5 | 9 | 6 | 3 | 2 | — | 1 | 1 | — | — | — | — | .. 31 |
| 26.5 | .. | 14 | 12 | 8 | 7 | 6 | — | 1 | — | — | — | — | — | — | .. 48 |
| 24.5 | .. | 19 | 9 | 4 | 6 | 2 | — | — | — | — | — | — | — | — | .. 40 |
| 22.5 | .. | 19 | 19 | — | 2 | 1 | — | 1 | — | — | — | — | — | — | .. 42 |
| 20.0 | .. | 16 | 23 | 5 | 3 | — | 1 | — | — | — | — | — | — | — | .. 48 |
| 18.5 | .. | 8 | 21 | 15 | 3 | 3 | 2 | — | 1 | — | — | — | — | — | .. 53 |
| 16.8 | .. | 4 | 25 | 17 | 4 | 1 | — | 2 | 1 | — | — | — | 1 | .. | .. 54 |
| 14.5 | .. | — | 8 | 17 | 16 | 4 | 2 | 1 | 1 | — | — | — | — | — | .. 49 |
| 13.5 | .. | — | — | 8 | 15 | 11 | 3 | — | 1 | — | — | — | — | — | .. 38 |
| 11.5 | .. | — | — | 3 | 3 | 20 | 11 | 1 | 2 | — | 3 | 3 | — | — | .. 46 |
| 9.0 | .. | — | — | — | — | 6 | 4 | 2 | 3 | 10 | 5 | 1 | 6 | .. | .. 37 |
| 6.0 | .. | — | — | — | — | — | — | 1 | — | — | 1 | 4 | .. | .. | .. 6 |

TABLE II

Kochia pyramidata germinated in multiple temperature incubator.
50 seeds per petri dish with sand at 60% saturation. Sum of two replications.

| °C. | 3 | 4 | 5 | 6 | Increase per Day | | | | | | 11 | 12 | 13 | 14 | % Germination |
|-----------------------------------|----|----|----|----|------------------|---|----|----|----|----|----|----|----|----|---------------|
| | | | | | 7 | 8 | 9 | 10 | 11 | 12 | | | | | |
| B. Not removed from fruit: | | | | | | | | | | | | | | | |
| 40.0 | .. | — | — | — | — | — | — | — | — | — | — | — | — | — | .. — |
| 35.5 | .. | 12 | 3 | 2 | 1 | 2 | — | 1 | 3 | 1 | — | — | — | — | .. 25 |
| 29.5 | .. | 35 | 10 | 7 | 2 | 2 | 8 | 2 | 2 | — | — | 1 | 1 | .. | .. 70 |
| 25.5 | .. | 36 | 15 | 5 | 3 | 3 | — | — | — | — | — | — | — | — | .. 62 |
| 22.5 | .. | 45 | 14 | 4 | 1 | — | 1 | — | — | — | — | — | — | — | .. 65 |
| 20.5 | .. | 40 | 19 | 8 | 1 | 2 | — | — | — | — | — | — | — | — | .. 70 |
| 18.0 | .. | 22 | 27 | 7 | 5 | — | 2 | — | — | — | — | — | — | — | .. 63 |
| 16.0 | .. | 6 | 24 | 16 | 5 | 5 | — | — | — | — | — | — | 1 | .. | .. 55 |
| 14.5 | .. | 3 | 22 | 17 | 16 | 4 | 3 | 1 | 3 | — | — | — | — | — | .. 69 |
| 12.5 | .. | 1 | 8 | 13 | 19 | 9 | 2 | 4 | 2 | — | 1 | — | — | — | .. 59 |
| 11.5 | .. | — | 5 | 6 | 2 | 5 | 13 | 6 | — | 2 | 1 | — | 2 | .. | .. 42 |
| 9.5 | .. | — | — | 1 | — | 9 | 10 | 6 | 9 | 11 | — | 2 | 3 | .. | .. 51 |
| 7.0 | .. | — | — | — | — | — | 1 | — | 3 | 9 | 8 | 1 | 3 | .. | .. 25 |
| 4.0 | .. | — | — | — | — | — | — | — | — | — | — | — | — | — | .. — |

TABLE III

Kochia georgei germinated in multiple temperature incubator.
50 seeds per petri dish with sand at 60% saturation. Sum of two replications.

| °C. | 3 | 4 | 5 | 6 | Increase per Day | | | | | | 11 | 12 | 13 | 14 | % Germination |
|-----------------------------------|----|----|----|----|------------------|---|----|----|----|-----|----|----|----|----|---------------|
| | | | | | 7 | 8 | 9 | 10 | 11 | 12 | | | | | |
| B. Not removed from fruit: | | | | | | | | | | | | | | | |
| 40.0 | .. | — | — | — | — | — | — | — | — | — | — | — | — | — | .. — |
| 35.5 | .. | — | — | 4 | 2 | 5 | 3 | 6 | 8 | 4 | — | — | 1 | .. | .. 33 |
| 29.5 | .. | 14 | 6 | 4 | 4 | 8 | 6 | 4 | 4 | — | — | 1 | — | .. | .. 51 |
| 25.5 | .. | 24 | 10 | 4 | 5 | 4 | 2 | 1 | — | 2 | 1 | — | — | .. | .. 53 |
| 22.5 | .. | 26 | 8 | 1 | 5 | 2 | 1 | 2 | 1 | — | — | — | — | .. | .. 46 |
| 20.5 | .. | 39 | 16 | 3 | — | — | — | 1 | — | — | — | — | — | .. | .. 60 |
| 18.0 | .. | 17 | 32 | 4 | 5 | 1 | — | — | — | — | — | — | — | .. | .. 59 |
| 16.0 | .. | 3 | 29 | 14 | — | — | — | — | — | — | — | — | — | .. | .. 46 |
| 14.5 | .. | — | 25 | 13 | 6 | 5 | 1 | 2 | 2 | — | — | — | — | .. | .. 54 |
| 12.5 | .. | — | 7 | 14 | 11 | 6 | 2 | 4 | 1 | 1 | — | — | — | .. | .. 46 |
| 11.5 | .. | — | — | 8 | 12 | 8 | 9 | 8 | — | 1 | — | — | 1 | .. | .. 47 |
| 9.5 | .. | — | — | — | 14 | 4 | 10 | 8 | 4 | 7 | — | 2 | 2 | .. | .. 51 |
| 7.0 | .. | — | — | — | — | 4 | 3 | 1 | 3 | 29* | — | — | 1 | .. | .. 41 |
| 4.0 | .. | — | — | — | — | — | — | — | — | 17 | 5 | 4 | 1 | .. | .. 29 |

* Sand disturbed and all seedlings counted.

It will be noticed that, as in *Atriplex vesicarium*, removal of the seeds of *K. sedifolia* from their fruits greatly improved the rate and amount of germination. In all species a wide temperature range is tolerated. This range is higher than that for *Atriplex vesicarium*. No germination took place at 41° C., while at the lower temperatures there was retardation.

(b) Maximum Temperature

The optimum temperature tests were followed by maximum temperature experiments designed on the same lines as those for *Atriplex vesicarium*. It is to be regretted that, owing to the smallness of the cabinets in the multiple temperature incubator, it was not possible to run concurrent tests using all species. All seeds were tested in their fruits.

In the first test *K. pyramidata* was subjected to a 41° C. maximum. The schedules used were:

- A₁ up to 41° C. daily for one hour, down to 16° C. at night;
 - B₁ up to 36° C. daily for one hour, down to 16° C. at night;
 - C₁ up to 30° C. daily for one hour, down to 16° C. at night;
 - D₁ up to 41° C. every third day commencing third day of incubation. Up to 30° C. on remaining days. Down to 18° C. at night;
 - E₁ up to 41° C. every fifth day commencing fourth day. Otherwise as for D;
 - F₁ up to 36° C. every third day commencing third day. Otherwise as for D.
- Controls were kept at 27° C., 25° C., 23° C. and 22° C. There were two replicates of 50 seeds.

The test was done twice and the results are shown in Table IV. There is no indication that maximum temperatures up to 41° C. have a detrimental effect on germination.

TABLE IV

| Maximum temperature test in <i>K. pyramidata</i> . | | | | | | % germination | | | | |
|--|----------------|----------------|----------------|----------------|----------------|----------------|--------|--------|--------|--------|
| | A ₁ | B ₁ | C ₁ | D ₁ | E ₁ | F ₁ | 27° C. | 25° C. | 23° C. | 22° C. |
| 1st | 54 | 41 | 33 | 45 | 40 | 33 | 43 | 36 | 45 | 34 |
| 2nd | 31 | 34 | 26 | 27 | 25 | 34 | 39 | 33 | 25 | 32 |

A maximum temperature of 41° C. was also tried for *K. sedifolia* (4,269) following Schedule A. described above, except that the night temperature was 18° C. There were control dishes at 25° C., 23° C. and 21.5° C. Four replicates were used.

The dishes under treatment showed a lower germination than the controls. Best results were obtained at 21.5° C., and on a *t* test the schedule germination rate differed significantly at the 5% level. Differences in the remaining results were not significant. They were as follows: Schedule A.: 18.5%; Controls at 25° C.: 30.0%; 23° C.: 24.5%; 21.5° C.: 32.0%.

Only one test with *K. georgei* was possible owing to scarcity of seed. The schedules used were: A₂: Up to 35° C. for one hour daily, night temperature 14° C. B₂: Up to 42.5° C. for one hour daily, night temperature 16.5° C. C₂: Up to 42.5° C. for one hour on alternate days, night temperature 16.5° C. Control dishes were held at 18.5° C. The results were: A₂: 20%, B₂: 12%, C₂: 22.6%, Control: 34.6%. These indicate that *K. georgei* has a maximum temperature tolerance rather lower than that of *K. pyramidata*.

It seemed likely that all species would survive a greater maximum temperature than 41° C. Accordingly the multiple temperature incubator was adjusted so that the compartments registered as follows: 1: 50.0° C., 2: 43.5°, 3: 36.0°, 4: 31.5°, 5: 27.5°, 6: 25.0°, 7: 22.5°, 8: 20.0°, 9: 18.0°, 10: 16.0°, 11: 15.0°, 12: 12.5°, 13: 10.0°, 14: 7.0°.

K. sedifolia (4,269) and *K. pyramidata* were then tested with the following schedules: A₃: Up to 50° C. for two hours per day, down to 20° C. at night. B₃: Up to 43·5° C. for two hours per day, down to 18° C. at night. C₃: Up to 36° C. for two hours per day, down to 16° C. at night. Control dishes were held at 22·5° C. There were four replicates of 50 seeds each.

No germination occurred for either species under A₃. B₃ and C₃ effected *K. pyramidata* but not *K. sedifolia*. The results are shown in Graph 1. The germinative period is typical for *Kochia*. It may be contrasted with the longer period found in *Atriplex vesicarium*.

The results for *K. pyramidata* were unexpected after the first tests. Apparently the duration of the maximum temperature period was likely to be significant. Using 43·5° C., the effect on *K. pyramidata* of a one-hour maximum period was tested against a two-hour period. The schedule followed was similar to that of B₃ described above. The germination was: one-hour maximum 20·0%, two-hour maximum 6·5%.

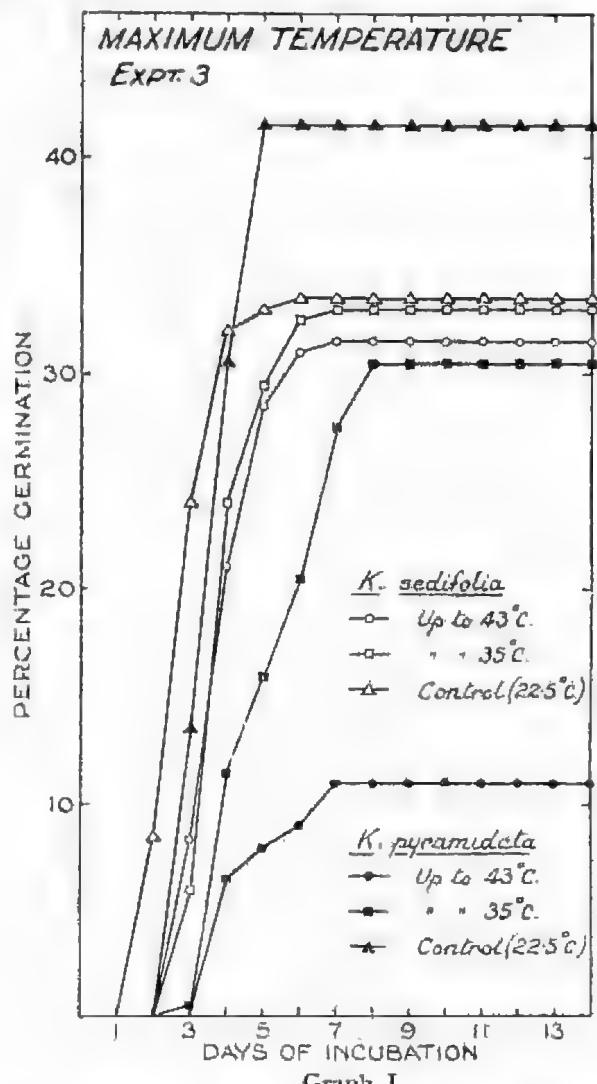
Since it had been found that a 50° C. daily maximum was lethal, a further test was made with *K. sedifolia* in which the seeds were subjected to this maximum every third day. There were three treatments, A₄, with maximum temperature 50° C. on 1st, 4th,

7th and 10th days, B₄ up to 50° C. on 2nd, 5th, 8th and 11th days, C₄ up to 50° C. on 3rd, 5th, 9th and 12th days. The control dishes were held at 20° C. The test was carried out three times; once with a two-hour maximum period and twice with a one-hour period. The results are shown in Table V.

TABLE V
Kochia sedifolia: effect of 50° C. maximum every third day, % germination.

| | A ₄ | B ₄ | C ₄ | Control (20° C.) |
|------------------------|----------------|----------------|----------------|------------------|
| 2 hour maximum ... | ... 13·5 | 4·5 | 6·5 | 39·0 |
| 1 hour maximum (a) ... | 13·5 | 20·5 | 10·5 | 18·5 |
| 1 hour maximum (b) ... | 32·5 | 24·5 | 30·0 | 48·5 |

These results provide further evidence of the importance of the duration of the maximum temperature period and suggest that heat penetration into the dishes is rapid.



Graph I

Subsequently the incubator was adjusted so that the top compartment registered 47° C., and *K. sedifolia* (4,269) was tested under the following treatments: A₅: Up to 47° for one hour daily, down to 19.5° C. at night. B₅: Up to 47° C. on 2nd, 5th, 8th and 11th days, night at 19.5° C. C₅: Up to 47° C. on 3rd, 6th, 9th and 12th days, night at 18° C. Control dishes were held at 21.5° C. The results were: A₅: 23.5%, B₅: 34.5%, C₅: 33.0%, Control 47%.

This test was repeated with *K. pyramidata*. More than six months had elapsed since the previous test with this species, but it was disappointing to find that the seed was no longer viable and the experiment had to be abandoned. This is further discussed under longevity.

The information obtained in the maximum temperature tests is summarised in Table VI. According to this soil temperatures of 45° C (113° F.) or higher immediately following heavy summer rains would adversely affect germination of these *Kochia* spp. with the possible exception of *Kochia sedifolia*.

TABLE VI
Summary of results in maximum temperature experiments.

| Temperature | <i>K. sedifolia</i> | <i>K. pyramidata</i> | <i>K. georgei</i> |
|---------------|---|--|---|
| 30° C. | No adverse effect | No adverse effect - cf. Tables I-III | |
| 35-36° C. | No adverse effect | Slight effect if daily maximum period is two hours. | Slight effect even with one hour maximum period. |
| 41° C. | Some effect which is increased if the maximum period is two hours. | Effect not significant with one hour maximum period, but significant with two hour period. | |
| 42.5-43.5° C. | Some effect with two hour maximum period. | Some effect with one hour and strong effect with two hour period. | Definite effect with one hour maximum period. With alternate day treatment effect lessened but still evident. |
| 47° C. | Definite effect which is much lessened when maxima occur every third day. | | |
| 50° C. | No development with continuous maximum. With maximum every third day effect less with one hour than two hour max, but always significant. | No development with continuous maximum treatment. | |

B. EFFECTS OF SOIL SATURATION

All three species were germinated at 23.5° C. under the following conditions of soil saturation: 20%, 40%, 60%, 80%, 100%. The results are shown in Table VII.

TABLE VII
% germination under varying conditions of soil saturation.

| Species | 20% | 40% | 60% | 80% | 100% |
|-------------------------|-----|-----|-----|-----|------|
| <i>Kochia sedifolia</i> | 17 | 67 | 75 | 69 | 68 |
| <i>K. pyramidata</i> | 61 | 61 | 73 | 70 | 58 |
| <i>K. georgei</i> | 37 | 48 | 57 | 50 | 40 |

It will be noted that there is toleration of a wide range of moisture conditions. This with the equal toleration of temperature suggests that *Kochia* spp. are capable of germinating under a wide range of field conditions.

In *Kochia sedifolia* (4,168) removal of the seeds from their fruits resulted in > 80% germination at all saturation levels under incubator conditions.

Kochia sedifolia (4,168) was also used in a glasshouse experiment run concurrently with one on *Atriplex vesicarium* which was described in the first paper of this series. The seeds (100) were planted in flat tins 15 x 6 cms., each holding one kilogram of soil. The treatments were as follows:—

Series 1. watered to 70% saturation continuously.

- „ 2. watered to 70% saturation 2 weeks, then left dry 3 weeks.
- „ 3. 10 ccs. water per week.
- „ 4. left dry.

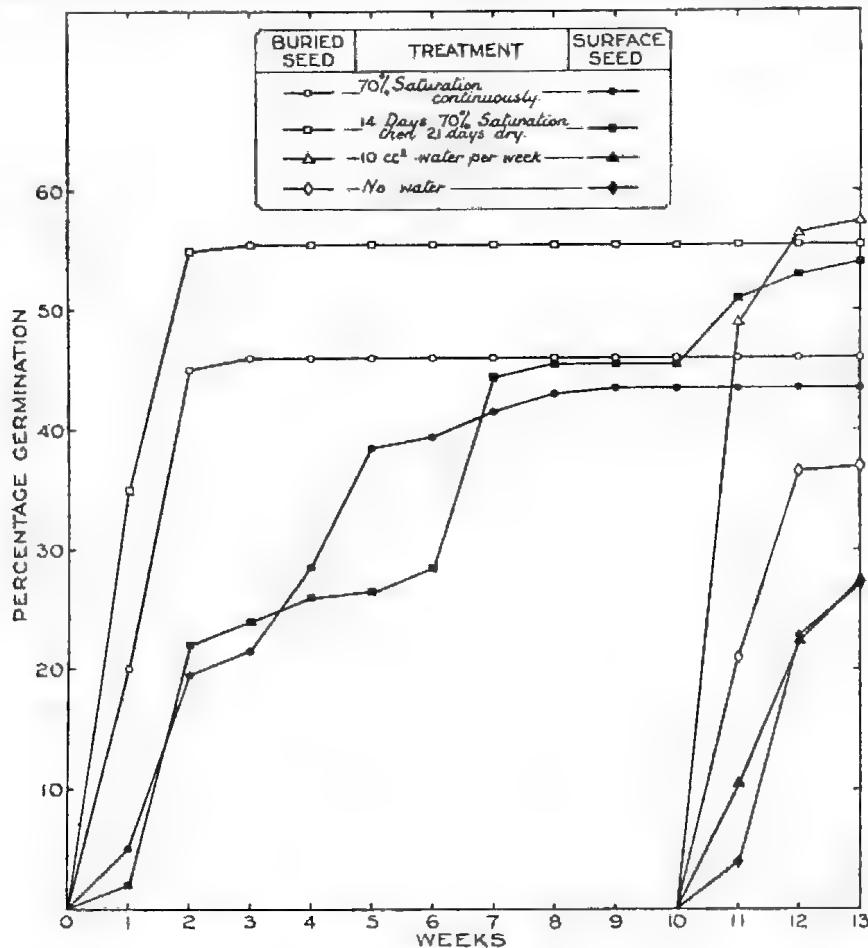
In each series half the tins had buried seeds and in the other half the seeds were scattered on the surface. There were three replications.

Treatment continued for ten weeks (9 June - 10 August), after which all tins were brought to the 70% saturation level for three weeks. The results are shown in Table VIII and Graph II.

TABLE VIII

| Treatment | 1st week | 2nd week | 3rd week | 4th-10th week | 11th week | 12th week | 13th week | Total % |
|---|----------|----------|----------|---------------|-----------|-----------|-----------|---------|
| Cont. 70% saturation Buried Seed | 18.3 | 25.7 | 0.9 | — | — | — | — | 44.9 |
| Cont. 70% saturation Surface Seed | 4.4 | 17.3 | 1.7 | 19.6 | — | — | — | 43.1 |
| 14 days 70% 21 „ dry Buried Seed | 30.7 | 17.7 | 0.9 | 0.4 | — | — | — | 49.7 |
| 14 days 70% 21 „ dry Surface Seed | 1.7 | 17.7 | 1.7 | 20.9 | 4.9 | 1.7 | 0.9 | 49.5 |
| 10 ccs. water per week Buried Seed | — | — | — | — | 43.6 | 7.1 | 0.9 | 51.6 |
| 10 ccs. water per week Surface Seed | — | — | — | — | 9.3 | 10.7 | 4.0 | 24.0 |
| No water Buried Seed | — | — | — | — | 18.7 | 13.7 | 0.4 | 32.8 |
| No water Surface Seed | — | — | — | — | 3.6 | 16.4 | 4.0 | 24.0 |

It will be noted that in the first two series buried seed started more rapidly than surface seed, but the latter finished at the same level. There was a distinct periodicity owing to intermittent watering in the case of the surface seed, but the final result was not affected. This is contrasted with the results in *Atriplex vesicarium*, where cessation of watering after the second week had a detrimental effect on the result. In series 3 and 4 no effect of treatment was evident.



Graph II

C. EFFECT OF SATURATION X TEMPERATURE

The test was made with *K. pyramidata*. The results are shown in Table IX. As in *Atriplex vesicarium* higher saturations gave better germination than lower when the incubating temperature was either above or below the optimum range.

TABLE IX
Effect of saturation temperature for *K. pyramidata*. — % Germination

| Temperature °C. | Saturation | | | | — % Germination | |
|-----------------|------------|-----|-----|------|-----------------|----|
| | 40% | 60% | 80% | 100% | | |
| 36.5 | ... | ... | — | 2 | 1 | 6 |
| 29.0 | ... | ... | 31 | 25 | 41 | 34 |
| 25.5 | ... | ... | 35 | 30 | 32 | 39 |
| 22.5 | ... | ... | 39 | 40 | 35 | 35 |
| 17.5 | ... | ... | 32 | 38 | 41 | 39 |
| 14.0 | ... | ... | 20 | 25 | 25 | 35 |

D: DEPTH OF PLANTING

Seeds of all three species were planted at various levels in 600 cc. beakers, whose sides were covered with black paper to exclude light, and incubated at 23.0°C. The results are shown in Table X.

| Depth of planting | Effect of depth planting. — % Germination | | |
|--------------------|---|----------------------|-------------------|
| | <i>K. sedifolia</i> | <i>K. pyramidata</i> | <i>K. georgei</i> |
| Surface | 33.3 | 28.0 | 16.0 |
| at $\frac{1}{2}$ " | 16.0 | 16.0 | 12.0 |
| at 1" | — | 1.3 | 4.0 |
| at 2" | — | — | — |
| at 3" | — | — | — |

A comparison of Tables X and VIII shows that the moist atmosphere conditions in the incubator favoured the seeds on the surface. In the field a shallow burial would provide less variable moisture conditions than the surface, and hence a more propitious habitat.

E. LONGEVITY OF SEED

K. sedifolia (4,168) was collected, in October 1943, from the bushes and stored in airtight tins. Germination tests have given consistently good results. No. 4,269 was collected in March 1945 and also stored. In June there was a rain of 180 points on the collecting area, which brought up a number of seedlings. A week later a collection was made of seed still lying under bushes and seed remaining attached to the plants. This material was tested for viability at 22.5°C. The seed from the ground proved quite unviable while that from the bushes gave 2% germination. From this it appears that seeds remaining ungerminated after the first heavy rains may have a very low viability. Such a conclusion is consistent with the results of the glasshouse experiment (Table VIII).

The seeds of *K. pyramidata* were collected in December 1942 from the ground beneath the bushes. Up till June 1945 viability showed a gradual falling off. No further test was made until January 1946, when no seeds germinated. As there had been no alteration in methods of storage this was probably due to a change in the seeds themselves. It remains to be seen whether the viability in *K. sedifolia* 4,168, collected a year later, will decrease rapidly in 1946.

DISCUSSION

The optimum temperature being higher for *Kochia* spp. than it is for *Atriplex vesicarium*, it is not surprising to find that there is toleration of higher daily maxima. The rapidity of germination and the toleration for a wide range of temperature and saturation conditions demonstrate the adaptability of the species under the prevailing climatic conditions which are so characterised by irregularity of both intensity and incidence of precipitation (2) (3). Germination and establishment of *K. sedifolia* would be possible after rains in almost any month of the year though January might, in some seasons, be unpropitious. *K. pyramidata* and *K. georgei* would probably be affected by high temperatures in January but the limiting factor for all species, during the hot season, would be the rapidity of the drying out of the soil rather than the occurrence of dangerously high daily maxima. In view of the shallow planting favoured by the seeds it would be interesting to know what diurnal changes in moisture content take place in the top half inch of soil in arid country.

The structure of the light-winged fruit has considerable influence on the possibility of regeneration of denuded land because, owing to the winds so prevalent in open arid country, there is little chance of the fruits finding an anchorage on a bare surface. Similarly the results of the tests on depth of planting show that the seedlings are unlikely to be prominent among the pioneers colonising a sand drift. Again, if the great majority of viable seeds germinate following the first heavy rain after seeding, then there will be no important seed reserve in the soil over a long period. Hence the species can only be maintained in places where there are enough mature bushes to provide both a regular supply of seed and enough litter to catch the blown seed. A denuded area adjacent to land carrying mature bushes would be regenerated, though with great slowness, if there was a covering of dead or living ephemerals to hold the blown seed. In other words, *Kochia* spp. are not important during the early stages of the ecological sere.

SUMMARY

Germination in *Kochia* spp. is rapid and complete in a few days.

A higher optimum and a wider range of temperature is tolerated than is the case in *Atriplex vesicarium*.

It follows that a higher daily maximum temperature can be endured without adverse effect on the rate of germination.

Kochia sedifolia can withstand higher maxima than either *K. pyramidata* or *K. georgei*.

A wide range of soil moisture conditions is tolerated by all species.

Planting deeper than $\frac{1}{2}$ inch severely reduces the number of seedlings.

Seeds under field conditions are not likely to remain viable for any long period.

None of the species is likely to be important during the early stages of regeneration of denuded areas under natural conditions.

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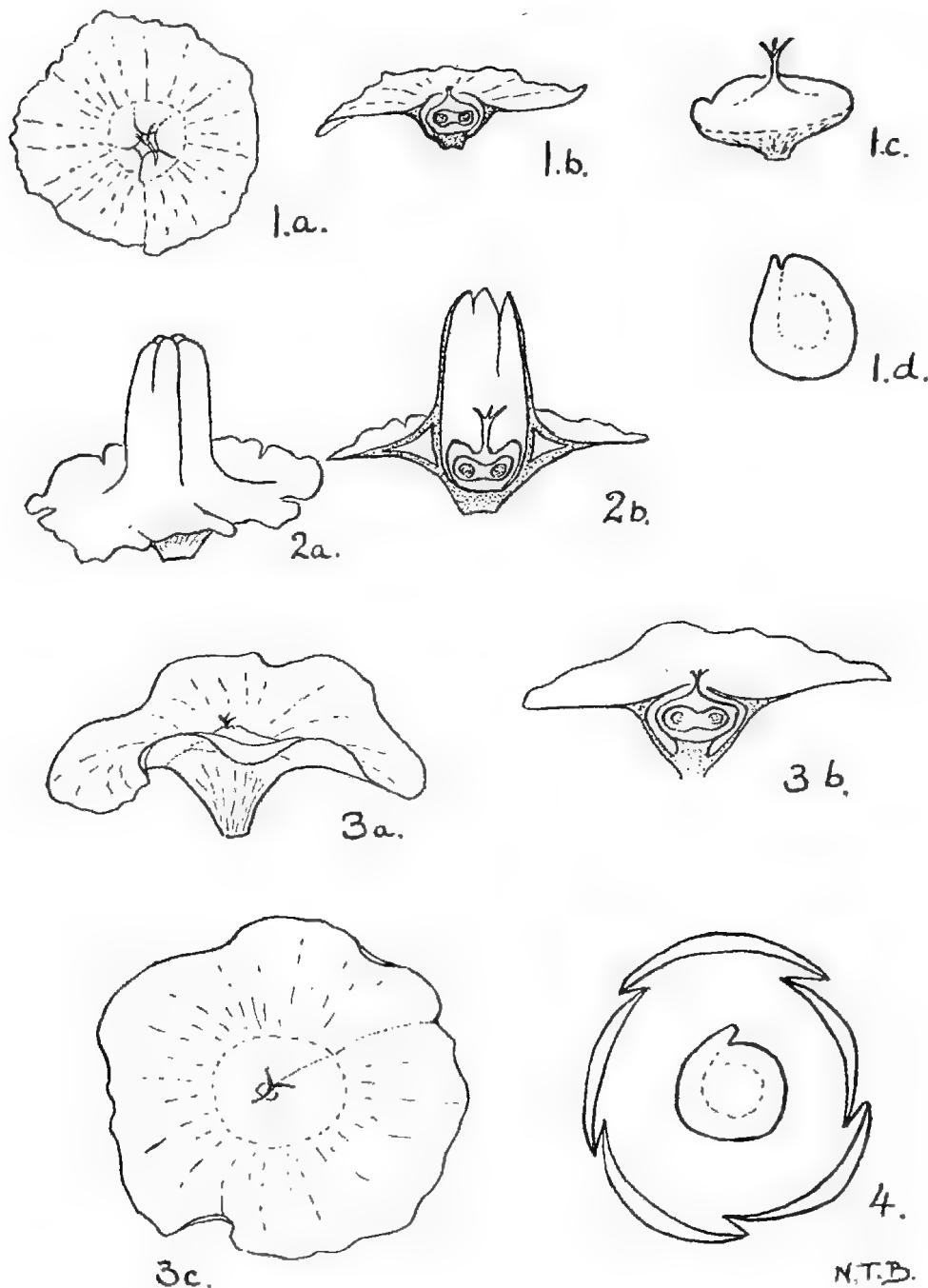


Fig. 1. *Kochia sedifolia*: a, fruit from above; b, vertical section of fruit; c, ovary with seed; d, seed. a. and b. $\times 4$, c. and d. $\times 10$.

Fig. 2. *K. pyramidata*: a, fruit; b, vertical section of fruit. $\times 4$.

Fig. 3. *K. georgei*: a, fruit; b, vertical section of fruit; c, fruit from above. $\times 4$.

Fig. 4. Floral diagram showing the relation between seed and perianth lobes.

THE LIFE CYCLE OF THE SHEEP LIVER FLUKE IN SOUTH AUSTRALIA

BY T. HARVEY JOHNSTON AND ANNE C. BECKWITH, UNIVERSITY OF ADELAIDE

Summary

The sheep liver fluke, *Fasciola hepatica*, is not common in South Australia. It is found from time to time in sheep slaughtered at the Metropolitan Abattoirs, as well as at some country centres, such as the South-East. Attempts by us to ascertain from what particular localities such infected animals are derived have not been successful, because sheep may have been bred in one district and sold elsewhere before reaching slaughterhouses. Mitton (1944, 202; 1945, 13) has stated recently that the parasite is not widespread in this State, but occurs in sheep in the South-East, along the River Murray swamps, and in the Southern Hills, and is liable to be found in any locality where creeks and marshy areas along rivers abound and remain wet throughout the year. The markedly seasonal character of the rainfall, which is mainly a winter one, and the hot dry summers play a very important part in limiting the prevalence and distribution of the parasite in South Australia.

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[Read 9 May 1946]

The sheep liver fluke, *Fasciola hepatica*, is not common in South Australia. It is found from time to time in sheep slaughtered at the Metropolitan Abattoirs, as well as at some country centres, such as the South-East. Attempts by us to ascertain from what particular localities such infected animals were derived have not been successful, because the sheep may have been bred in one district and sold elsewhere before reaching the slaughterhouses. Mitton (1944, 202; 1945, 13) has stated recently that the parasite is not widespread in this State, but occurs in sheep in the South-East, along the River Murray swamps, and in the Southern Hills, and is liable to be found in any locality where creeks and marshy areas along rivers abound and remain wet throughout the year. The markedly seasonal character of the rainfall, which is mainly a winter one, and the hot dry summers play a very important part in limiting the prevalence and distribution of the parasite in South Australia.

Until we commenced in 1937 our studies of the life cycles of local trematodes, the only species whose life history in Australia was known was *Fasciola hepatica*, which is not a native of Australia. Before reporting our own observations, we propose to review briefly the earlier attempts to ascertain what kinds of pond snails may serve as the intermediate hosts for the parasite in the Commonwealth. Such investigations were carried out in New South Wales and Victoria because of the prevalence of liver fluke in the moister parts of those States.

The earlier records of the occurrence of the cercaria stage in various pond snails in the eastern States are now regarded as incorrect (Johnston and Cleland 1937, 193), as the genera and species of molluscs mentioned have since been found refractory to infection by the miracidium of *Fasciola hepatica*. Amongst such records are those of Cherry (1895; 1917) and Fielder (1896), as well as members of the Victorian Field Naturalists' Society (1896). Cobb (1897, 459; 1898, 182) reported that *Bulinus brasieri* (now known as *Isidorella brasieri*) was the intermediate host in Australia, basing his statement on his observations near Moss Vale, New South Wales; but Bradley (1926 a) pointed out that Cobb's figures indicated two distinct snails, *B. brasieri* and *Lymnaea brasieri*. Cherry (1917) reported that larval stages of the sheep liver fluke had been found in Victorian species of *Bulinus* and *Planorbis*, but that statement lacks confirmation and, no doubt, was based on incorrect determinations of the larvae.

During 1925 and 1926 a determined effort was made in New South Wales by Bradley and McKay to ascertain the actual transmitter. Bradley (1925) found that 15% of *L. brasieri* examined in the Monaro district were infected with distome cercariae and that that snail was probably the intermediate host of *F. hepatica*. Next year (1926 a) he extended his examinations to other species of freshwater snails, and included the New England tableland in his survey. He reported finding a pigmented type of larva (as well as others) in *L. brasieri*, and stated that, on epidemiological grounds, he considered that snail to be the intermediate host of the sheep fluke in New South Wales. In a short paper (1926 b) he referred to the presence of *L. brasieri* in fluky sheep paddocks in New England, and to its usual absence from paddocks where fluke did not occur in sheep.

In a later paper (1926 c) he referred to the pigmented larva as *Cercaria pigmentosa* and recorded its occurrence in 40% of a small number of *L. brasieri* in an aquarium into which sheep fluke eggs had been introduced; and such cercariae were found during summer in 69 and 72 days after the eggs had been added.

McKay (1926 a, b, c) succeeded in tracing the complete life cycle in *L. brasieri*, in which snail he found three kinds of pigmented larvae, one of which agreed with Thomas' account and figures of that of *F. hepatica*. The cysts were fed to guinea pigs and the adult stage of the liver fluke of the parasite was obtained. Attempts (1926 b) to infect with miracidia of *F. hepatica* other kinds of pond snails, as well as the land snail, *Succinea australis*, proved unsuccessful. In a later paper McKay (1928) published rather more information than was contained in his earlier report (1926 b).

Claties Ross (1928 b) stated that *L. brasieri* was the only Australian snail which had been proved to be an intermediate host for *F. hepatica*; and in the next year, in conjunction with McKay, published a very important paper dealing with the life history and control of the liver fluke, as well as its transmitting snail in New South Wales. Attempts to infect other pond snails (*Bulinus* spp., *Gibbia*, *Segmentina*) were unsuccessful. Specimens of *L. brasieri* were found in the central district of Victoria, and that species was regarded as the transmitter in that State also. Specimens were also received from Tasmania, and though showing certain differences in form from typical *L. brasieri*, were regarded as belonging to the same species (1929, 26-27). Rabbits and guinea pigs were found experimentally to be able to harbour the adult fluke (Ross and McKay 1929).

Bradley (1933) stated that *L. brasieri* was the usual (if not the only) local intermediate host for larval stages of *F. hepatica*, and drew attention to the particular kind of aquatic environment required by the more common pond snails (including *L. brasieri*) in the highlands of New South Wales. Cotton and Godfrey's statement (1932, 160) that *Isidorella brasieri* was the intermediate host is an error due, no doubt, to having confused two different animals bearing the same specific name.

Mitton (1944, 202; 1945, 13), when dealing with fluke in South Australian sheep, gave a brief account of the life cycle of *F. hepatica* and republished figures of *L. brasieri*, stating that the latter was the only one through which the parasite in Australia could undergo its larval stages. There is no evidence that *L. brasieri* occurs in South Australia, but, as we shall indicate, there is a related local species, *L. subagutialis*, which has similar habits, and is capable of transmitting *F. hepatica* in this State.

Our early efforts to infect *Amerianna* spp. and *L. lessoni*, using eggs or miracidia of *F. hepatica*, were unsuccessful. For many years we have attempted, when opportunity offered, to ascertain whether *L. subagutialis*, whose habits closely resemble those of *L. brasieri*, could serve as the intermediate host and thus afford an explanation of the local infestation of sheep. The snails of this species used in our experiments were collected in Hazelwood Park, an enclosed public reserve in a suburb of Adelaide. From this park sheep and cattle are excluded and in it rabbits are rarely seen, hence natural infection of the snails with liver fluke is very improbable; and none of these molluscs has revealed infection with any trematode larvae when tested prior to using them for our experiments. The creek is dry in summer, but its waters enter the Torrens after rain in winter and early spring. We had difficulty in keeping the snails alive in our aquaria until recently, and liver flukes were rarely available at times when this snail could be obtained.

We found that eggs hatched in 27 days in late autumn (May-June). Ross and McKay published information regarding the length of time needed for hatching under different conditions of temperature and under diurnal changes. Their results indicated a minimum of eight days at about 80° F.; 9 days at 77° F.; 10 days in January—midsummer (maximum 86° F. and minimum 64° F.); the period lengthening to 28 days when the daily room temperature was between 64 and 75° F. for 16 hours and 46-52° F. for 8 hours. No hatching took place at about 50° F., but eggs remained viable through the winter and hatched on the advent of warm weather. They stated that it would appear that, with alternating periods of relatively high temperatures during the day, cold conditions during the night checked development only proportionately to the length of the latter. We did not have an opportunity to ascertain the period required during summer in Adelaide where the day and night temperatures have a higher average than in Sydney, but Ross and McKay's observations would suggest about eight or nine days if such eggs had reached a moist environment. The hot dry summers in South Australia must play a very important part in controlling hatching of fluke eggs and the pre-swimming life of the miracidium. Mitton (1945, 14) stated that 9 to 20 days, according to temperature, were necessary in summer, but that in winter hatching might require five or more months.

From one of a few *L. subaquatilis* exposed to miracidia in mid-June some rediae were taken in early August, i.e., 48 days later. On 27 June 1945, eggs obtained by teasing live flukes were added to shallow aquaria containing the same species of snail. Eight of the latter which died during July and August showed no trace of infection, but all snails which died after 10 September contained large numbers of rediae. This indicated that the cold weather had prevented hatching and infection until some time after August. The rediae first detected amongst these dead snails were small, but they already contained daughter rediae. On 2 November cercariae were observed swarming from a dead snail and were identical with those of *F. hepatica*. This observation indicated that from eggs obtained in midwinter, under laboratory conditions, cercariae may be developed and escape from infected snails four months later, i.e., in late spring. These cercariae encysted readily on lettuce leaves (as well as elsewhere), usually within a few minutes after escape. The infected leaves were fed to rabbits on 7 November. On 15 January 1946 one rabbit was killed and a small *F. hepatica* was taken from a bile duct, the worm, though only 20 mm. long, already containing eggs. On 8 February another rabbit was killed and eight flukes were recovered, most of them being a little larger than the first one obtained. Hence adult flukes may be produced in midsummer under Adelaide conditions in 69 days after the ingestion of cysts in late spring. Mitton stated that maturity was reached in 10 to 12 weeks from the time that cysts entered the final host. Ross and McKay (1929, 25) reported that the bile ducts are apparently not reached by the wandering young flukes until after the thirty-ninth day in experimental animals, and that maturity was attained in the bile ducts of an experimental guinea pig in 13 weeks. One of our observations, recorded above, indicates that a shorter period can suffice.

On 19 November 1946 another attempt was made to infect a number of *L. subaquatilis*, but too many eggs must have been used, since all the snails were killed. In one which died on 4 December, i.e., 15 days after eggs had been added to the aquarium, abundant miracidia were found moving in the tissues of the mollusc. In another which survived until 10 December, minute sporocysts were found, i.e., in 21 days after the addition of fluke eggs. In snails which died later (in late December and very early January) typical rediae were recovered, but all snails died by 5 January before cercariae had developed in them. These

observations seem to indicate that a period of 47 days in early summer is insufficient to permit cercariae to be developed and escape from infected snails.

Cotton and Godfrey (1932, 158) mentioned as recorded localities for *L. subaquatilis* Tate—River Torrens at Adelaide and Reedbeds, Henley; Victor Harbour; and Millicent. They also published a figure (pl. ii, fig. 2) which shows a relatively more elongate opening of the shell and a different gradation in the size of the whorls from that figured later by Cotton (1943, pl. xvi, fig. 7-8), the latter illustration resembling more closely our specimens. We have collected the species near Myponga (from a "black bog" due to a spring); near the head of Currency Creek (also in a similar bog); the northern shores of Lake Alexandrina (in ruts and shallow channels amongst the flooded samphire); and in a small pool in black mud in a rich pasture close to the Murray River near Murray Bridge; and in all these localities fluke was present in some of the sheep, though none of the snails taken by us was found to be infected with *F. hepatica*. We should mention that some years ago we were informed that rabbits in the South-East sometimes harboured liver fluke, but unfortunately our notes regarding the locality have been lost.

Iredale (1943, 211-214) reviewed the Australian species of Lymnaeidae and subdivided *Lymnaea* into several genera, including *Peplimnea* for *L. lessoni*, and *Simlimnea* for small Lymnaeids with a short acute spire, large normal (not swollen) body whorls, well developed inner lip, columella not much folded, and shell comparatively stout. He included under *Simlimnea*, *L. brasieri* from New South Wales, *L. gunni* and *L. neglecta* from Tasmania, *L. victoriae* from Gippsland, and *L. subaquatilis* from the Torrens, South Australia. He also mentioned that there were two MS names, *L. viridula* and *L. venustula* applied to snails in western Victoria, and another, *L. tasmanica*, from Tasmania. He suggested that the last-named may have been based on the European *L. peregra*, supposed to have been introduced accidentally. Cotton (1943, 145) accepted some of Iredale's new genera, but rejected *Peplimnea*, retaining *lessoni* under *Lymnaea*. He gave a key to the Australian genera of the family and a more extended diagnosis for *Simlimnea* (146). He listed the five species mentioned by Iredale, noted the chief differences between some of them, and figured *S. subaquatilis* and *S. gunni*.

Since all these species have similar habits and are found in localities where liver fluke occurs, it is reasonable to assume that all of them are likely to serve as transmitters, and that Ross and McKay's *L. brasieri* from Tasmania was actually one or more of the Tasmanian species of *Simlimnea*, and that the Victorian forms belonged to *S. victoriae*. The carrier in south-western Victoria has not been determined, but it is possible that it is *S. subaquatilis*. The habits of *S. brasieri* have been described by Bradley (1926a; 1933, 248) and by Ross and McKay (1928, 27-29).

In 1889 Whitelegge reported that cercariae of *Distoma* sp. occurred commonly near Sydney in local pond snails, amongst which he included *L. brasieri*, but without mentioning any particular species as host (1889, 307). Fielder (1896c) reported finding larval stages of flukes in the same species from southern New South Wales, and figured a heavily pigmented round cyst from it. He also illustrated a minute stylet-bearing cyst from the same host.

Bradley (1926a) found three kinds of cercariae in *L. brasieri* in New South Wales, one of them pigmented (figured, and probably belonging to *F. hepatica*), and two unpigmented, one of which possessed a stylet. Later in the year (1926d) he described these two latter as *Cercaria catellae* (an echinostome larva) and *C. pellucida* respectively. *C. pellucida* was stated to resemble *C. brevicarca* and *C. polyndena*. As Bradley's specific name was preoccupied,

one of us (Johnston 1941, 282) renamed this plagiorchid larva as *C. bradleyi*. In 1927 Bradley discussed the probable life cycle of *C. catellae*, to which species he referred again in 1933. We considered this cercaria to belong to *Echinostoma revolutum* (Johnston and Cleland 1937, 196; Angel 1941, 317).

McKay (1926 a) reported that he found three kinds of pigmented cercariae in *L. brasieri*, one of them being that of *F. hepatica*, the other two being less heavily pigmented and not able to encyst on available material. Ross and McKay (1928, 14) referred to the presence in *L. brasieri* of *C. pellucida* and *C. greeri*. The latter had been described by Bradley (1926 d) as occurring in *Bulinus brasieri*, its author believing the cercaria to be that of a schistosome, but the general form of the body, tail-stem and furcae indicate that it was a Strigeid (Johnston 1941, 282). Bradley (1933, 247) listed it as a parasite of *L. brasieri*.

We have found four different species of cercariae issuing from *L. subaquatilis* from Lake Alexandrina. Two of these were furcocercariae belonging to the Strigeida; the third was *Cercaria parocellata*, a schistosome larva described by us (Johnston and Simpson 1939, 63) from *L. lessoni*; and the fourth was identified as *C. ellisi*, an echinostome, originally described from *L. lessoni* (Johnston and Simpson 1944, 125).

We desire to acknowledge gratefully assistance received from Miss L. M. Angel who made the earlier observations in our laboratory; the following veterinary officers: Messrs. F. V. Collins, Burrage, McKenna, Smith, Pulsford and Gosling; as well as B. C. Cotton of the South Australian Museum.

SUMMARY

Simlimnica subaquatilis is a transmitter of *Fasciola hepatica* in South Australia; and some observations on the developmental stages of the parasite are recorded.

Of four different kinds of cercariae found in *S. subaquatilis*, two (*C. parocellata* and *C. ellisi*) were known previously only from *Lymnaea lessoni* from the lower Murray region.

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STUDIES ON THE MARINE ALGAE OF SOUTHERN AUSTRALIA
INTRODUCTION AND
NO. 1 THE GENERA ISACTIS AND RIVULARIA (MYXOPHYCEAE)

BY H. B. S. WOMERSLEY, DEPARTMENT OF BOTANY, UNIVERSITY OF ADELAIDE

Summary

The history of phycology in Australia is one of an enthusiastic beginning during the years 1840-1890, when numerous collections from the Southern Australian region (including Tasmania) were sent to Europe and described by workers of that time. During this period a considerable proportion of the Australian species was described, chiefly by W. H. Harvey, J. G. Agardh, W. Sonder, T. Reinbold and others, and it is on the work of these men that present-day phycology in Australia is based. A. H. S. Lucas, who was the only Australian worker between 1910 and 1936, has given a more detailed survey of the early work (*Seaweeds of South Australia, Pt. I*), as also has V. Mary (*Journal of the C.S.I.R.*, **18**, No.1, 62).

STUDIES ON THE MARINE ALGAE OF SOUTHERN AUSTRALIA

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INTRODUCTION

The history of Phycology in Australia is one of an enthusiastic beginning during the years 1840-1890, when numerous collections from the Southern Australian region (including Tasmania) were sent to Europe and described by workers of that time. During this period a considerable proportion of the Australian species was described, chiefly by W. H. Harvey, J. G. Agardh, W. Sonder, T. Reinbold and others, and it is on the work of these men that present-day phycology in Australia is based. A. H. S. Lucas, who was the only Australian worker between 1910 and 1936, has given a more detailed survey of the early work (*Seaweeds of South Australia, Pt. 1*), as also has V. May (*Journal of the C.S.I.R.*, 18, No. 1, 62).

For Australian students taking up the study of marine algae this history has certain unfortunate results. The type specimens of most of the species described before 1900 are in Europe (with the exception of those of W. H. Harvey, of which numerous cotypes are present in the Melbourne and Sydney National Herbaria), and not available to Australian workers. This means that determination of species must, in many instances, be based on descriptions alone. Apart from the works of W. H. Harvey, which were usually well illustrated, most authors gave no figures; descriptions were usually inadequate and only in Latin, resulting in the utmost care being necessary to establish an identification today.

Since 1900, practically the only worker on Australian marine algae was A. H. S. Lucas, who published several papers in the Linnean Society of New South Wales, and wrote Part I and the first half of Part II of "*The Seaweeds of South Australia*." Since 1938 keys and notes on New South Wales algae have been published by V. May, and Part II of "*The Seaweeds of South Australia*" should be available by July 1946.

It is evident that at present scarcely a single species from Australian waters does not require a thorough study, and each genus needs detailed revision. In the past details of locality and occurrence have been generally inadequately given.

Although taxonomic studies are of first importance, extensive ecological surveys are needed, for it is such work that brings to light variations in form of many species and indicates how reliable certain taxonomic criteria may be. It is during such ecological studies that associations of economically important species are likely to be found.

This paper is the first of a series on marine algae from the Southern Australian coasts and deals with two genera of the Myxophyceae, family Rivulariaceae, which are common on rocky or tidal flat regions. The Myxophyceae as a whole have been left severely alone by previous workers, although many species are to be found around our coasts.

No. 1 THE GENERA ISACTIS AND RIVULARIA

These two genera belong to the family Rivulariaceae of the blue-green algae. The family is a natural one, distinguished by a combination of false branching and terminal hairs to the trichomes, and usually with heterocysts at the base of the filaments. Both freshwater and marine representatives of the family are common, and several marine species of *Calothrix* and *Lyngbya* occur in South Australian waters.

Genus ISACTIS Thuret 1875

Thuret, Essai Class. Nost., 1875, 376, 382; Bornet and Flahault, Rev. 1, 1886, 343; De Toni, Sylloge Algarum, 5, 646; Rabenhorst, Kryptogamen Flora, 14, 656; Setchell and Gardner, Marine Algae of Pacific Coast of N. America, 104; Newton, Handbook of British Seaweeds, 35.

Filaments erect, parallel, densely crowded and coalescent into a compact layer attached to the substratum, simple or sparsely branched; heterocysts basal; reproduction by spores unknown.

Isactis is a genus differing from *Rivularia* in its more simple trichomes which are crowded and parallel. This gives rise to flattened, more or less orbicular layers instead of hemispherical or more or less convex and lobed expansions.

ISACTIS PLANA (Harv.) Thuret (Fig. 1, A)

Rivularia plana Harvey in Hooker, Brit. Fl., 1833, 2, (1), 394; *Isactis plana* (Harv.) Thuret in Essai, 1875, 382; Bornet and Thuret, Notes Alg. II, 1880, 163, pl. xl; Bornet and Flahault, Rev. II, 344; De Toni, Sylloge Algarum, 5, 646; Rabenhorst, Kryptogamen Flora, 14, 656; Setchell and Gardner, Marine Algae of Pacific coast of N. America, 104; Newton, British Seaweeds, 35.

Fronds 0·4 to 0·9 mm. thick, spread out indefinitely on the surface of rocks, but usually less than 2 cm. across, dark green; filaments densely crowded, mostly simple; trichomes 7-9·5 μ diameter, light blue-green, tapering into a delicate hair above when young; cells not to fairly deeply incised at cross walls, $\frac{1}{2}$ to 1 times as long as broad.

South Australian specimens seem to belong to the var. *plana* B. and F. in which the layer is not zonate, filaments unbranched or nearly so, cohering together.

Hog Bay (on rocks in littoral), Vivonne Bay (edge of rock pools, on mollusc *Cellana*), and Pennington Bay (on reef surface) on Kangaroo Island; Port Noarlunga (on reef in littoral); Port Willunga (on reef in upper littoral).

Atlantic, Mediterranean, coasts of Europe, North America. Apparently not previously recorded from Southern Hemisphere. Probably to be found anywhere in the Southern Australian region, at all times of the year.

The only noticeable difference from descriptions of Northern Hemisphere specimens is in the greater thickness of the frond (0·9 mm. against 0·5 mm.).

Genus RIVULARIA C. Agardh 1812

C. Agardh, Disp. Alg. Suec., 1812, 43, Syn. Alg. Scand., 1817, p. xxxviii, 130-131; Syst. Alg., 1824, 19; Roth, Neue Beitr. z. Bot., 1803, 261; Cat. Bot., 3, 1806, 332; Bornet and Flahault, Rev. Nost. Het. 1, 1886, 345; De Toni, Sylloge Algarum, 5, 648; Rabenhorst, Kryptogamen Flora, 14, 643; Setchell and Gardner, Marine Algae of Pacific coasts of N. America, 105; Newton, British Seaweeds, 38.

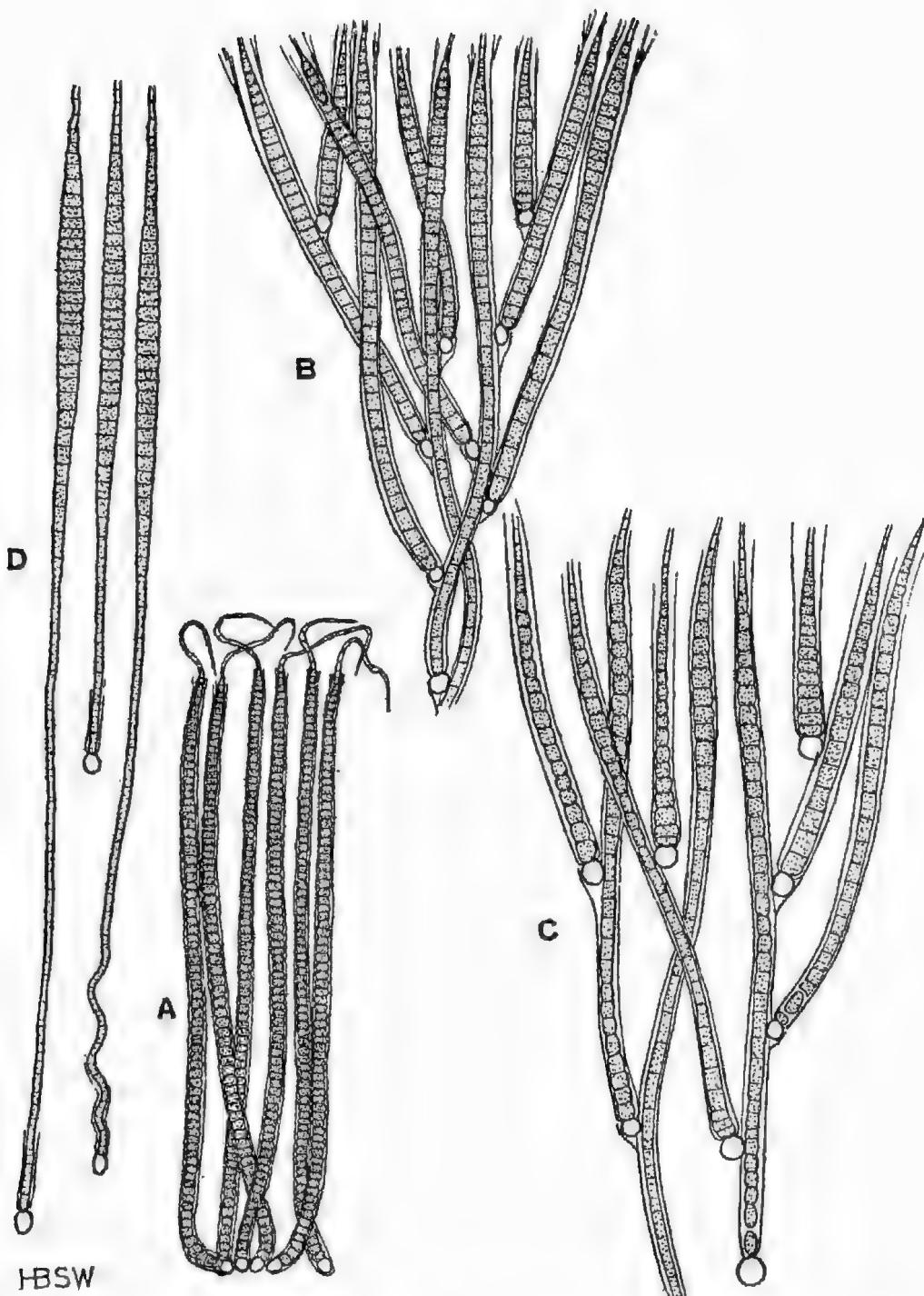


Fig. 1

A, *Isactis plana*, group of trichomes; B, *Rizularia atra*, group of trichomes with two hormogonia; C, *Rizularia nitida*, group of trichomes; D, *Rizularia australis*, three typical trichomes from one of Harvey's specimens.

Thallus hemispherical, globose or irregularly lobed, light to dark green, softly or firmly gelatinous, at times hollow, or confluent into a solid expanded stratum; filaments radiating from the centre or from the base, repeatedly false-branched;

heterocysts basal (or rarely intercalary), some species (sub-genus *Gloeostrichia*) producing cylindrical spores contiguous to the heterocyst.

In view of the presence of intercalary heterocysts, as described below in *R. firma*, *R. polyotis* and *R. australis*, the generic description must be modified slightly, as has been done above.

The species of *Rivularia* are far from satisfactory taxonomically, as considerable variations may be shown in different habitats. In placing any particular specimen, attention should be focussed on all the features used in separating the species rather than any single one. Five species can now be recorded from Southern Australia, of which one is described as new; the other four are considered specifically identical with widespread Northern Hemisphere forms which are probably cosmopolitan.

Staining with gentian violet is often necessary to distinguish details of the sheath. Sometimes if a firm colony is broken up a layer of mucilage may cling to the trichome and appear very similar to an individual sheath, staining faintly blue.

KEY TO THE SOUTHERN AUSTRALIAN SPECIES OF *Rivularia*

| | | | |
|----|---|-----------------------|---|
| 1 | Intercalary heterocysts abundant, thallus very firm. | <i>R. firma</i> n.sp. | 2 |
| 1' | Intercalary heterocysts absent or rare, thallus either small or large and soft. | | |
| 2 | Thallus solid, hemispherical, less than 4 mm. across. | <i>R. alra</i> | 3 |
| 2' | Thallus hollow, expanded, globose or plicate corrugate. | | |
| 3 | Thallus dark olive green, plicate corrugate, usually less than 1 cm. across. | <i>R. nitida</i> | 4 |
| 3' | Thallus light green, hollow, soft. | | |
| 4 | Trichomes 5-7.5 μ thick, sheath thin. | <i>R. australis</i> | |
| 4' | Trichomes 9-14 μ thick, sheath usually wide, lamellate. | <i>R. polyotis</i> | |

Rivularia firma n. sp.

(Fig. 2, A and B)

Thallus caeruleus, hemisphericus, solidus, firmissime gelatinus, 2 cm. latus, copiae 5 cm. latae; corpus qui produci potest, lentus. Trichomatibus confertis, pressione non secendentibus, 2-3 μ latis inferne, superne 6-8.5 μ latis, in pilum attenuatis; vaginis angustis, hyalinis, superne indistinctis, totus in gelatinam amorpham confluens; cellulis superne diam. $\frac{1}{2}$ -1 brevioribus, ad genicula contractis, cellulis inferioribus elongatis. Heterocystis basibus et intercalaribus; basis globosa, 10-18 μ diam.; interclaribus usitatus copiosis, ovatis aut longis linearis, cum crasso muro, 4-8 μ latis, diam. 2-20 brevioribus; basibus heterocystis in concentrica zona dispositis.

Thallus dark blue-green, hemispherical, solid, very firmly gelatinous; individual plants to 2 cm. across, masses formed by union of several to 5 cm. across; substance elastic, not easily torn. Trichomes crowded, not separable by pressure, 2-3 μ thick near basal heterocyst, expanding upwards to 6 to 8.5 μ thick in meristematic region, then tapering to a long narrow hair; sheath thin, hyaline, vanishing above, but the whole in a very firm gelatinous matrix; cells in meristematic region $\frac{1}{2}$ to 1 times as long as broad, slightly to moderately incised at cross walls, lengthening below to 3-6 times as long as broad. Heterocysts basal and intercalary; basal approximately spherical, 10-18 μ diameter; intercalary ones usually abundant, ovoid to elongate linear, thick-walled, 4-8 μ wide, 2 to 20 times as long as wide, rarely causing any bulging of filaments; basal heterocysts usually produced in roughly concentric bands causing a faint zonation in transverse section of the thallus.

Granite Island and Petrel Cove, near Victor Harbour (on rocks, particularly in roughest places, in upper littoral and spray zones). Antechamber Bay, Cape

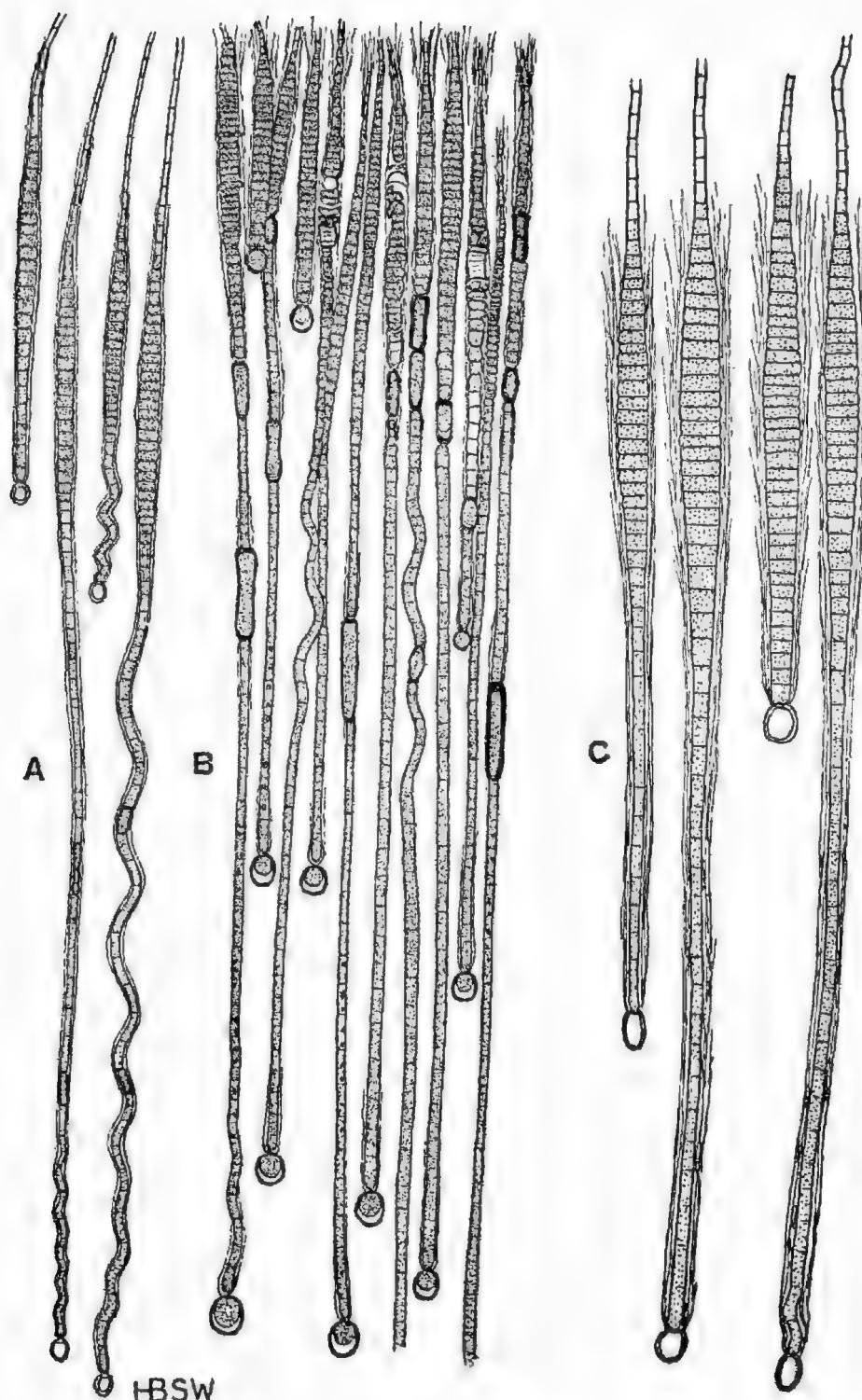


Fig. 2

A and B, *Rivularia firma* n.sp; A, trichomes from young thallus; B, trichomes from older thallus showing intercalary heterocysts and cell arrangement; C, *Rivularia polyotis*, trichomes with wide lamellate sheaths.

Willoughby, Pennington Bay, Vivonne Bay, on Kangaroo Island (in upper littoral, probably all along east, south and west coasts).

Occurring throughout the year, but usually better developed in winter.

In general, *R. firma* forms a zone in the upper littoral on exposed rocky coasts, frequently occurring on otherwise bare rocks and in situations where it is often exposed to desiccation for several hours daily. The firmly gelatinous thallus enables it to withstand considerable exposure.

The presence of abundant intercalary heterocysts distinguishes this species from any previously described. They are usually much elongated, 2 to 20 times as long as broad, lying within the trichome sheath. When much elongated each is often slightly wider at the ends where the walls are somewhat thicker than in the centre, with finely granular colourless contents (see fig. 2, B). Intercalary heterocysts such as these have apparently not been described in any other species. Occasionally, however, they occur in both *R. australis* and *R. polyotis*, though only very rarely.

The very firm and solid nature of the thallus is also a distinctive characteristic.

Hormogonia develop beneath the superficial layers of the thallus, and because of their confinement within the very firm gelatinous matrix often develop into ovoid or elongated masses of compressed, often polygonal, cells instead of the usual cylindrical trichomes. This type of hormogonia development is particularly characteristic of species of *Rivularia* with a firm thallus.

Specimens collected from the south side of Granite Island, Victor Harbour, in December 1943, were brownish, with pitted surfaces, particularly distorted hormogonia, and unusual abundance of intercalary heterocysts. This is attributed to a heat wave and low tides shortly before collection, the specimens probably being dead and atypical when collected.

Type and cotype specimens are catalogued under numbers A 2205 (K.I. 5) and A 2,204 (K.I. 4) respectively, in the Algal Herbarium, Department of Botany, University of Adelaide.

RIVULARIA ATRA Roth (Fig. 1, B)

Roth, Cat. Bot., 3, 1806, 340; Bornet and Flahault, Rev. II, 1886, 353; Harvey Phyc. Britt. t. 239; De Toni, Sylloge Algarum, 5, 664; Rabenhorst, Kryptogamen Flora 14, 645; Setchell and Gardner, Marine Algae . . . 107; Newton, British Seaweeds, 38.

Thallus solitary or confluent, hemispherical or flattened, up to 4 mm. in diameter. Filaments radiating from the centre, densely compacted, abundantly false-branched. Trichomes 2·5-5 μ thick below, expanding slightly to 5-6·2 μ thick above, then tapering to a narrow hair; cells yellowish-green, shorter than broad above, lengthening below to 3-6 times as long as broad, not or very slightly incised at cross walls; cross walls very indistinct below; sheath hyaline, inconspicuous, but often fairly thick. Heterocysts basal, spherical to ovoid, 7-10 μ diameter. Older specimens may show faint zonation of heterocysts in section of the thallus. Hormogonia forming towards ends of outer trichomes.

Port Noarlunga (on reef, littoral); Marino, Moana (on rocks); Port Willunga (on reef, littoral); Vivonne Bay, Kangaroo Island (around edges of littoral pools, south side of Ellen Point). Occurring throughout the year.

Europe, North America, Japan, Australia (previously recorded by Nordstedt). Cosmopolitan.

Two varieties of *Rivularia atra* have been distinguished; var. *hemispherica* (Kütz.) B. and F., with hemispherical colonies, very dark green, and var. *confluens* (Kütz.) Bornet, in which the thallus is a flat confluent mass, deep blue-

green, trichomes 5-7 μ wide. Both varieties seem to be present in South Australia, although many gradations between the two are shown.

The main differences from descriptions of Northern Hemisphere species lie in (a) trichomes expanding slightly to up to 6.2 μ thick. Setchell and Gardner, however, record a width of 5-7 μ for trichomes in var. *confluens* (Kütz.) Bornet. Young outer trichomes, in our specimens, taper evenly from the base, being 5-6.2 μ thick; (b) sheath often quite thick in our specimens, whereas it is given as "thin" in all descriptions.

RIVULARIA NITIDA Ag.

(Fig. 1, C)

C. Agardh, Disp. 44, 1812; Bornet and Flahault, Rev. II, 1886, 357; De Toni Sylloge Algarum, 5, 661; Rabenhorst, Kryptogamen Flora, 14, 646; Setchell and Gardner, Marine Algae . . . 108; Newton, British Seaweeds, 38; *R. plicata* Carm. in Hooker's Brit. Fl. Crypt., 392; Harvey, Phyc. Brit. t, 215; Phyc. Aus. Syn. No. 787.

Thallus usually hollow, variable in outline, expanded and plicate-corrugate, to 2 cm. across, dark olive green in colour. Filaments crowded, usually tapering from the base to a long narrow hair, from 3.5 to 6.3 μ thick below, occasionally to 8.5 μ thick next to heterocyst, tapering evenly to 2 μ thick in the hair, or sometimes expanded slightly upwards; cells olive green, mostly $\frac{1}{2}$ -1 times as long as broad, often longer below, not or slightly incised at cross walls. Sheath usually prominent and distinct, hyaline or yellowish-brown. Heterocysts basal, ovoid to spherical, 6 to 12 μ across.

Pelican Lagoon, American River, Kangaroo Island (on flat rock in littoral). Collected during January 1946, but probably present throughout the year. Specimens from this locality are identical with Harvey's No. 591 B (as *R. plicata* Carm.) from King George Sound, Western Australia.

Britain, North Europe, Mediterranean, Nova Scotia, Alaska.

Only apparent difference from Northern Hemisphere specimens lies in the somewhat thicker trichome (to 6.3 μ thick as against 2.5 μ in descriptions).

RIVULARIA AUSTRALIS Harvey

(Fig. 1, D)

Harvey, Some Acc. Marine Bot. of W. Aust., 566, 1854; Phyc. Aus. Syn., n. 786; Sonder, Alg. Austral. hact. cognitae, 42, n. 1.047; Bornet and Flahault, Rev. II, 362; De Toni, Sylloge Algarum, 5, 658; Newton, British Seaweeds, 40; Rabenhorst, Kryptogamen Flora, 14, 646.

Thallus irregularly globose, soft, always hollow, to 8 cm. across, usually a metallic blue-green in colour; occasionally growing as masses of smaller irregularly united hollow thalli. Trichomes easily separated by pressure, long, almost parallel, expanding in width from 1.3 μ near heterocyst to 5-7.5 μ in meristematic region, then tapering to a fine hair; cells in meristematic region $\frac{1}{2}$ to 1 times as long as broad, slightly to moderately incised at cross walls, becoming longer below. Sheath very thin, hyaline, usually only detectable near heterocyst. Filaments below straight or slightly undulating. Heterocysts ovoid to spherical, 10-13 μ by 7-11 μ ; intercalary heterocysts very rare, ovoid to oblong, similar to those in *R. firma*.

The very soft thallus, trichome width and absence of a sheath distinguish this species reasonably well.

South Australia: Port Willunga (on reef, littoral). Victoria: Port Lonsdale (January 1941); Phillip Island (January 1946); Brighton (January 1853);

Frankston (January 1903)⁽¹⁾; San Remo (February 1929),⁽¹⁾ New South Wales. Eden (January 1910),⁽¹⁾ Tasmania: Tamar Heads (December 1864); Low Head (February 1935)⁽¹⁾; East Beach, Low Head (February 1927⁽¹⁾ and March 1932). Western Australia: Cape Riche (Harvey's 592 C).

Most of these records are during the months of January and February, but the species probably occurs during all months of the year.

Atlantic, Europe, England.

Specimens of Harvey's *R. nitida* Ag., No. 593 I, recorded by Harvey from Brighton, Port Phillip and Georgetown, Tasmania, have been examined and found to belong to *R. australis* Harv. According to De Toni, *Sylloge Algatum*, 5, 660, *R. nitida* Ag. as figured by Harvey in *Phyc. Brit.* t. 68, is a synonym for *R. bullata* (Poir) Berkeley, and Harvey's and Sonder's Australian specimens are referred to the latter species. The only difference in the specimens placed by Harvey under the two species, *R. australis* and *R. nitida* Ag., lies in the external appearance of the thallus. Harvey's *R. australis* was slightly smaller and firmer than his *R. nitida*, but both show trichomes expanding upwards to 5-7.5 μ thick, with the cells $\frac{1}{2}$ -1 times as long as broad, slightly to moderately incised at the cross walls. The sheaths in both are scarcely detectable, very thin and hyaline. Heterocysts are spherical to ovoid, 7-9 μ by 7-11 μ . Intercalary heterocysts are rare, but present, in Harvey's 592 C.

Harvey's *R. nitida* Ag. (*R. bullata* (Poir) Berkeley) must then without any doubt be referred to his own species, *R. australis*. He records *R. australis* as growing on rocks near low water at Cape Riche. Possibly his specimens of *R. nitida* were growing in more sheltered conditions, and this would account for the slight differences in the external thallus structure.

A specimen in the Melbourne National Herbarium, named as *R. nitida* var. *bullata* Kütz., from rocks at Port Phillip, is probably also referable to *R. australis* Harvey. Sonder's specimens of *R. bullata* from "Adelaide" (according to De Toni) may also be referable to *R. australis* Harv.

It appears then that the true *R. bullata* cannot as yet be recorded from Australia.

It should be noted, however, that *R. australis* Harv. and *R. bullata* (Poir) Berkeley are closely related. From descriptions, it appears that the main differences lie in the firm thallus and slightly wider trichomes (to 8.5 or 10 μ) of *R. bullata* compared with the very soft thallus and trichomes to 7.5 μ wide of *R. australis* Harv.

RIVULARIA POLYOTIS (Ag.) Bornet and Flahault (Fig. 2C)

Bornet and Flahault, Rev. II, 360; De Toni, *Sylloge Algatum*, 5, 659; Rabenhorst, *Kryptogamen Flora*, 14, 647. *R. plicatu* Harv. Australian Alg. (1857); Sonder, *Algae Austral.*, 42 (see De Toni, 5, 659).

Thallus light to dark green (darker when young), very soft, hollow except when young, irregularly globose, to 8 cm. across. Trichomes easily separated by pressure, expanding in width upwards from 2.5 μ near heterocyst to 9-14 μ in meristematic region, then tapering to a moderately thick hair; cells in meristematic region $\frac{1}{2}$ to 1 times as long as broad, not or slightly incised at cross walls, becoming longer below. Sheath usually prominent, thick, hyaline, lamellate, expanding above. Heterocysts basal, ovoid to spherical, 10-18 μ by 10-14 μ . Intercalary heterocysts very rare, ovoid to oblong-cylindrical, similar to those in *R. firma*.

⁽¹⁾ These specimens had been identified by A. H. S. Lucas as *Lecithesia difformis* (L.) Aresch., and one specimen from Tasmania, Low Head, as *Codium pannoides* J. Ag.

American River, Kangaroo Island (on *Posidonia*, *Zostera* and algae on tidal flats, often detached and floating. Common throughout the year. West Beach, Port Adelaide River, Port Noarlunga, Port Willunga (on *Hormosira Banksii* Dene, and on reef, littoral). Typically occurring under calm sheltered conditions, such as on tidal flats and inlets.

Europe, Atlantic, Mediterranean, Southern Australia.

The combination of soft, hollow thallus, thick trichome and wide lamellate sheath distinguishes this species. Occasionally, however, a few specimens of an otherwise uniform series from the one locality have failed to show any noticeable sheath.

The records of this species given by De Toni (5, 659) as under "*R. plicata*" Harv. Aus. Alg. (1857), Sond. Algae Austral., 42, non Carmichael, *nec Lloyd*," cannot be discussed as none of these specimens are available for examination.

ECOLOGICAL NOTES ON THE SOUTH AUSTRALIAN SPECIES OF *Rivularia*

The South Australian species of *Isactis* and *Rivularia* are found in the upper littoral or spray zone on rocky coasts, or in littoral regions in tidal inlets, where they are often floating. Although records are still very fragmentary, except for Kangaroo Island, there are probably few places on the coast of Southern Australia where one or more of the above species do not occur.

Rivularia polyotis is characteristic of tidal inlets such as American River and the Port River, where conditions are very calm. This species is usually epiphytic, particularly on *Posidonia australis* Hooker and *Zostera Muelleri* Irmish (American River), or on *Hormosira Banksii* Dene. (Port Willunga); young specimens occur on the reef itself at Port Willunga, and may be solid. *R. polyotis* is often cast up on the beaches of Holdfast Bay during winter months.

Rivularia australis probably favours somewhat similar habitats. Only one specimen of this species has been found in South Australia, but from records available it appears to be common in Port Phillip Bay, Victoria, and the Tamar in Tasmania.

On the rocky exposed south coast of Kangaroo Island, and similar places on the mainland (Granite Island, Petrel Cove), the dark green, very firm blobs of *Rivularia firma* are usually found. This species is confined to the upper littoral and spray zones, where it may have to withstand exposure for several hours each day.

The small blobs of *Rivularia atra* and *Isactis plana* occur usually in littoral situations where they may have to withstand some exposure, but appear to be less hardy than *Rivularia firma*. At Pennington Bay *Isactis plana* occurs in areas of scattered small patches almost anywhere on the reef surface, but invariably where it is always covered with water.

Rivularia nitida occurs on flat rock in the littoral zone at Pelican Lagoon, American River. Here it is subject to severe drying and desiccation during low tide on hot days, for no water is retained near it. It appears to suffer little damage from this.

The Southern Australian species of *Rivularia* and *Isactis* then are typically littoral algae; *R. firma* flourishes under the roughest of conditions, while *R. polyotis*, *R. australis* and *R. nitida* favour calm sheltered places. *R. atra* and *Isactis plana* occur in intermediate conditions. All these species seem to occur throughout the year.

From the literature available, it appears that *Isactis plana* has not been previously recorded from the Southern Hemisphere.

SUMMARY

One species of *Isactis* and five of *Rivularia* (Myxophyceae) are now known from Southern Australia, including one species, *R. firma*, here described as new. The presence of abundant intercalary heterocysts in *R. firma* is considered as distinguishing this species from all others of the genus.

An examination of W. H. Harvey's specimens of *R. australis* and *R. plicata* Carm. (*R. nitida* Ag.) has shown that they are specifically identical, and his *R. plicata* Carm. must be referred to *R. australis* Harv. It appears that records of *R. bullata* (Poir.) Berkeley may be incorrect, the specimens actually being of *R. australis* Harv.

ACKNOWLEDGMENTS

I am indebted to Dr. Francis Drouet, Chicago Museum of Natural History, for confirmation of *Rivularia firma* as being previously undescribed. Specimens of *Rivularia* from the Lucas collection, Division of Plant Industry, C. S. & I. R., Canberra, and the National Herbarium, Melbourne, were examined through the kindness of Mr. W. H. Hartley and Mr. A. W. Jessep respectively. Dr. E. McLennan, Department of Botany, University of Melbourne, also kindly forwarded specimens for examination.

H 2845a

K I 645a

A



B



cm 0 1 2 4

Dasyoopsis clavigera n. sp.

Type specimens: A, from Pennington Bay; B, from Vivonne Bay.

STUDIES ON THE MARINE ALGAE OF SOUTHERN AUSTRALIA
NO. 2 A NEW SPECIES OF DASYOPSIS (FAMILY DASYACEAE)
FROM KANGAROO ISLAND

BY H. B. S. WOMERSLEY, DEPARTMENT OF BOTANY, UNIVERSITY OF ADELAIDE

Summary

Previous to this communication on the genus *Dasyopsis* has been known only from the Northern Hemisphere, where seven species have been described. Five species occur in the European and Mediterranean regions, and two on the western coast of the United States of America. (De Toni, 1,177; Smith, 356).

STUDIES ON THE MARINE ALGAE OF SOUTHERN AUSTRALIA

No. 2 A NEW SPECIES OF *DASYOPSIS* (FAMILY DASYACEAE)
FROM KANGAROO ISLAND

By H. B. S. WOMERSLEY, Department of Botany, University of Adelaide

[Read 9 May 1946]

PLATE XXVII

Previous to this communication the genus *Dasyopsis* has been known only from the Northern Hemisphere, where seven species have been described. Five species occur in the European and Mediterranean regions, and two on the western coast of the United States of America. (De Toni, 1,177; Smith, 356).

The family Dasyaceae comprises a natural grouping of members of the Ceramiales showing sympodial growth of the axis, while *Dasyopsis* is distinguished from other genera of the family by the apparent absence of pericentral cells surrounding the central axis or siphon of the stem. This apparent absence, however, is actually due to separation of the pericentral cells from each other and from the central siphon by corticating cells which penetrate between them. This will be discussed more fully later.

The species described as new in this paper agrees with *Dasyopsis* in all essential aspects, but shows several distinctive differences, as far as can be ascertained from descriptions alone, from all other described species. An alga such as this, being so far removed from other species of the genus in its geographical distribution, forms a most interesting record. It is worth noting, however, that the closely related genus *Dasya* shows a strong Australasian distribution of its species, 25 of 46 described species occurring in the Southern Australian and Tasmanian regions. Other genera of the Dasyaceae are also well represented in these regions.

The range in external form is remarkable in this species (see fig. 1, A and B, pl. xxvii). When first collected only the extreme forms (pl. xxvii) were known and the existence of two species was suspected. A complete range of form between the two extremes has now been found, and the form in any particular habitat appears to be correlated with the roughness and severity of wave action in that habitat.

This alga has been collected during ecological studies on the marine algae of Kangaroo Island. In later papers it is hoped to survey the ecology of the south coast of the island, particularly the Pennington Bay and Vivonne Bay regions.

Dasyopsis clavigera n. sp.

Named after the clavate (club-shaped) form of the branches.

OCCURRENCE AND HABIT

The only known occurrences as yet are on the southern and western coasts of Kangaroo Island. Serial numbers of the specimens deposited in the Algal Herbarium, Department of Botany, University of Adelaide, are given below.

Pennington Bay, 20 and 25 May 1945—Cast up and growing in the *Cystophora*-coralline association in the south-east corner of the main reef. (This reef is the largest of many similar ones in the Pennington Bay region, and is also the most accessible.) Sometimes epiphytic on *Cystophora* sub-

farcinata (Mert.) J. Ag., or with *Ceramium nobile* J. Ag. epiphytic on it. No. A 2,727 (K.I. 527).

15 January 1946—In the *Cystophora*-coralline association and along the eastern edge of reef and to one foot down the vertical side. Often with a heavy epiphytic growth of *Jania* sp. Tetradsporangial, spermatangial and cystocarpic plants present. Nos. A 3,049 (K.I. 849), A 2,845 (K.I. 645).

A 2,845a has been selected as the type specimen (fig. 3, A).

Vivonne Bay, 23 May 1945—On rocks just above the *Cystophora* zone, on the south side of Ellen Point. Only tetradsporangial plants found. No. A 2,726 (K.I. 526).

31 December 1945. From just inside Ellen Point, extending around the point and at least half a mile west, in a region just above the *Cystophora* zone (lower littoral). Plants mainly tetradsporangial. No. A 2,997 (K.I. 797).

West Bay, 6 January 1946—Cast up; epiphytic on *Sargassum* sp. and with *Plocamium* sp. and *Nitophyllum* sp. epiphytic on it. Plants tetradsporangial or sterile. Nos. A 3,199 (K.I. 999), A 3,251 (K.I. 1,051), A 3,253 (K.I. 1,053), A 3,265 (K.I. 1,065).

It seems probable that *Dasyopsis clavigera* occurs generally along the south and west coasts of Kangaroo Island, usually in regions where it is subject to considerable or very heavy wave action. All the habitats in which it has so far been found correspond to the lower littoral or the upper margin of the sub-littoral.

The extreme forms of this variable alga are illustrated in pl. xxvii, A and B. The type specimen, A, from Pennington Bay is the largest found, being 20 cm. high and consisting of numerous erect terete stems from a common base, the main stems being rarely branched but all closely set with short lateral branches 1 to 3 cm. long, giving each frond a narrowly pyramidal outline.

The specimens in pl. xxvii, B, from Vivonne Bay (May 1945) are quite typical of those collected at this time. Each consists of one to five clavate, simple or occasionally branched, stems from a common base, the whole forming a tuft 2 to 5 cm. high.

During January 1946 specimens collected from the end and about half a mile to the west along the south side of Ellen Point, Vivonne Bay, showed all degrees of variation between the specimens shown in pl. xxvii, B, and smaller specimens of the form shown in pl. xxvii, A.

The plants in all cases consist of a terete stem or branch densely clothed with branched, filamentous pseudolaterals, giving the frond a woolly appearance, but usually becoming shrubbier and finally denuded near the base.

The form of this alga shows adaption to the extremely rough conditions under which it grows. At Vivonne Bay, particularly in the habitat where the smaller unbranched specimens grew, waves are continually breaking directly onto the rocks, and the short, stout, terete fronds, with a common adhesive base and little branching, together with the close occurrence of the plants, offer minimum resistance to the breakers. In somewhat less exposed places more branched plants occur, showing gradation to the forms met with on the Pennington Bay reef.

On the reef studied at Pennington Bay, *D. clavigera* occurs in the south-east corner (*Cystophora*-coralline association) and along the eastern edge of the reef. All the plants in these regions show profuse laterals, but vary from one to

numerous main stems from the common base. Owing to the very flat and horizontal nature of the reef, and the sudden vertical drop into deep water at the edge, the breakers tend to surge over the edge and along the side of the reef, rather than breaking onto it. These conditions are clearly less violent than at Vivonne Bay, and allow greater development in size and lateral branching of the alga. A dense covering of other algae on the reef also affords mutual protection for each.

Branched forms of *D. clavigera* are uniformly of a yellowish-brown colour, with the extreme tips often a rose red. The Vivonne Bay plants of May 1945 (pl. xxvii, B), however, were all deep rose red in colour. It seems that with greater development only the youngest parts retain the red colour.

The forms of *D. clavigera* met with so far in different localities, therefore, appear to be closely related to the forces of wave action which they have to withstand. The importance of physical factors in determining the form of an alga is quite clear in this case; such criteria as degree of branching, and particularly size, are of little value taxonomically, and it is more than likely that forms previously separated on such criteria will have to be united when their full range of form becomes evident.

VEGETATIVE STRUCTURE

Dasyopsis clavigera shows the sympodial type of growth that is characteristic of all the Dasyaceae. The growing region, illustrated in fig. 1 D, shows clearly the development of pseudolaterals. A lateral, arising from the base of the previous generation, continues the growth of the axis, while the upper parts, which become displaced, form the successive units of the sympodium (3, 2, 1 in fig. 1 D) and develop as branched, apparent laterals (pseudolaterals). These pseudolaterals develop in spiral sequence, densely covering the stem and branches except for the lower parts and base which usually become denuded. The stem between the pseudolaterals is bare, and where they are not too dense the spiral arrangements can be readily distinguished. Fritsch (p. 572), however, refers to the pseudolaterals in other species of *Dasyopsis* as being distichously arranged, although they are spiral in the genus *Dasya*.

The genus *Dasyopsis* differs from *Dasya* essentially in that the pericentral cells become separated from the central siphon by large corticating cells which penetrate between the original pericentra. The presence of pericentral cells has often been denied, but Fritsch (p. 574) points out that their apparent absence is due to intermixture with cortical cells and separation from the central siphon.

Fig. 1 D illustrates the method of cortication of the main axis. At the bases of the pseudolaterals which have just been displaced small elongate cells develop and rapidly form a thick cortex to the stem. Fritsch (p. 572) records five pericentral cells generally for *Dasyopsis*, but in this species no definite number could be distinguished. At the base of each apical tuft of the filaments the structure is clearly polysiphonous, but cortication commences so early, with the corticating cells penetrating between the original ones, that a cross section just below the apex shows a ring of cells, some of which may be larger than others, surrounding a large central siphon (see fig. 1 E). The cortex rapidly becomes many cells thick, but often in the younger parts four to six cells are larger and stand out from the others (fig. 1 F). In older stems no distinctive cells are apparent, though the central siphon is always evident, being several times larger than any other cells in the stem. It may well be that the number of pericentra is five, but this could not be established in any of the plants examined. The adult stem is 1-2 mm. thick, and the cells have rather thick walls.

Fritsch (p. 572) refers to the pseudolaterals of *Dasyopsis* as uniserial, though noting that in *Heterosiphonia* the three basal segments of the pseudolaterals

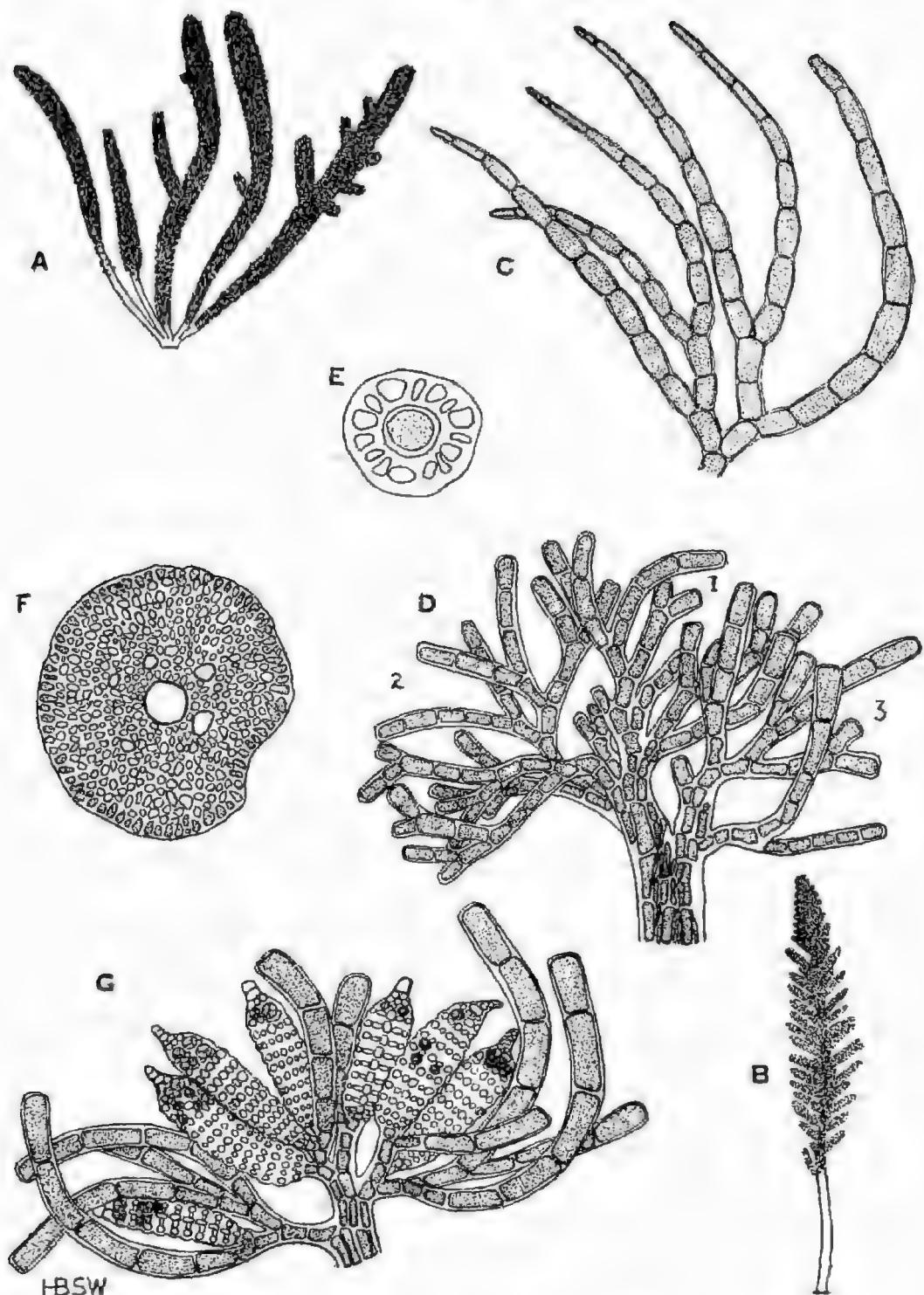


Fig. 1 *Dasyopsis clavigera* n. sp.

A, form of specimen from Vivonne Bay; B, form of small specimen from Pennington Bay; C, tuft of hairs from near apex; D, the growing point, showing sympodial growth; E, cross section of stem just below growing point. F, cross section of stem lower down; G, pseudolateral tuft bearing stichidia. A $\times 1\frac{1}{2}$, B $\times \frac{1}{2}$.

become polysiphonous, while according to Falkenberg (p. 169) the basal segment may also become polysiphonous in *Dasya*.

In this species the base of each pseudolateral is clearly polysiphonous (fig. 1, D, G), and divided by successive dichotomies into a number of monosiphonous filaments, all curved upwards and in towards the stem above. All the filaments lie in essentially the same curved plane.

After being displaced from the growing point each pseudolateral develops into a small dense tuft. Further development, however, into lateral branches up to 2 cm. long, may occur, such as in the branched forms from Vivonne and Pennington Bays; i.e., the pseudolaterals retain the power of further growth, the extent to which this occurs being determined by the conditions under which the plant grows.

The form of the filaments is illustrated in fig. 1 C, D, G. At or close to the apex of the stem or branch the filaments taper uniformly in the upper half. As they become larger, and further from the growing point, the upper tapering part invariably becomes broken off, leaving the filaments terminating at the largest cell, the end of which is squarely cut off. Apparently the rough conditions under which the alga grows allow only the strongest basal part of the filament to remain. No trace of the breakage is left, however. Further from the apex the pseudolateral tufts become stubbier, until the stem is finally denuded, although scars in the positions of the old tufts often remain.

Filament dimensions: near growing points, 38-60 μ thick, 47-115 μ thick when fully developed. Cells at base of filaments $1\frac{1}{2}$ -2 times as long as broad, 2-5 times in widest region, 6-8 times towards the ends. Cells in all parts with a distinct firm gelatinous sheath, wider towards the base. Pseudolateral tufts 1-2 mm. long, giving the fronds a thickness of 2-4 mm.

Attachment to the rock substratum is by means of an adhesive disc. At Pennington Bay the plants are often epiphytic on *Cystophora subfarcinata* (Mert.) J. Ag., and may be heavily epiphytised themselves with *Jania* sp., *Ceramium nobile* J. Ag., *Polysiphonia dasyoides* Zan. and other algae.

The filaments of the pseudolateral tufts comprise the main photosynthetic organs of the alga. Each cell contains numerous rose-red laminate chromatophores, usually irregularly polygonal in outline, though in occasional cells spindle-shaped. They are confined to the peripheral cytoplasm of the cells, the colourless spaces left between them giving the whole cell a reticulate appearance in face view. The outer layer of cells of the stem usually contains similar chromatophores.

DEVELOPMENT OF STICHIDIA AND TETRASPORANGIA

Plants bearing tetrasporangia and cystocarps have been collected during both May and January, so it is likely that fruiting material may be found at any time of the year.

A stichidium originates as one branch of a dichotomy of the pseudolateral filaments, very close to the growing point. An initial row of cells each cuts off, from below upwards, six pericentral cells (fig. 2 B). Each of these pericentra then divides transversely to the length of the stichidium to form an upper cell which develops into the tetrasporangium, the lower cell remaining as a basal supporting cell. This basal cell then cuts off two cover cells on the outside (fig. 2 B, C), and all from one layer of pericentra lie in the same plane, slightly below and outside each tetrasporangium (fig. 2 A).

The central row of cells elongates slightly at this stage and as the tetrasporangia mature they become almost completely exposed (fig. 1 G, 2 A, C).

Mature stichidia comprise 10 to 13 series of pericentrals, but usually only four tetrasporangia form in each row of six. At an early stage the young stichidium has a wide base and tapers to the apex (fig. 2 A). Development occurs from the base upwards, and by the time the stichidium is mature most of the tetraspores in the lower part have escaped (fig. 1 G).

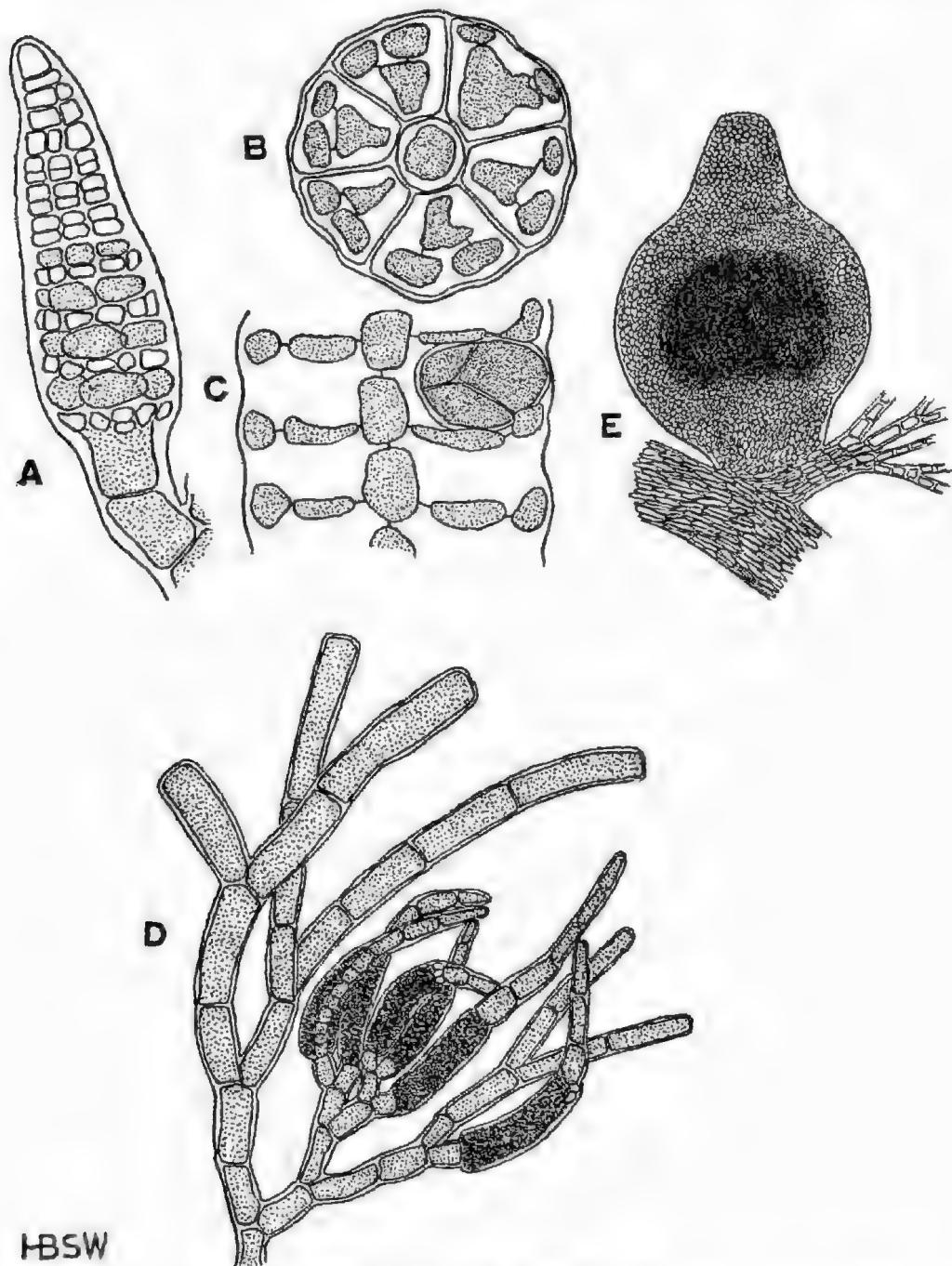


Fig. 2 *Dasyopsis clavigera* n. sp.

A, young stichidium; B and C, transverse and longitudinal section respectively of mature stichidium; D, pseudolateral tuft bearing spermatangia; E, cystocarp.

Mature stichidia are borne profusely on the pseudolaterals, each on a short monosiphonous pedicel of 1-3 cells. Each is oblong cylindrical in shape, narrowing at the top to a uniseriate beak of up to five cells (fig. 1 G). Length 310-450 μ , width 80-110 μ . Tetrasporangia tetrahedrally divided, rose-red in colour, 24-25 μ in diameter.

DEVELOPMENT OF SPERMATANGIA

Spermatangia develop on filaments of the pseudolateral tufts, in a similar position to the stichidia. Often 70 to 80% of the filaments bear spermatangia.

A row of 6 to 10, but usually about 8, almost quadrate cells forms in place of one of the filaments, and beyond this row of cells the filament develops normally though much less extensively, forming a chain of only 3 to 5 small cells (fig. 2 D). Each of these quadrate cells cuts off two rows, one above the other, of 8 pericentral cells; later more may be formed, giving up to 16, and these become the spermatangial mother cells. Each of these gives rise to 1 to 3 (usually 2) spermatangia, resulting in a horizontal row of from 16 to 32 spermatangia. At the apex of the spermatangial mass a group of 2 to 4 larger cells, surrounding the axial cells, is usually left. Development occurs from the base up, but most spermatangia form almost simultaneously. Spermatangial masses 75-120 μ long, 30-50 μ wide, the whole encased in a gelatinous matrix (see fig. 2 D).

This is in general agreement with spermatangial development for *Dasyopsis* (also *Polysiphonia*) as recorded by Fritsch. It will be noticed also that many similarities are shown with development of tetrasporangia as previously discussed.

CYSTOCARP STRUCTURE

Cystocarpic plants of *D. clavigera* were found during both May and January.

Cystocarps occur in the axils of pseudolateral tufts, the pericarp being attached at maturity to both the base of the pseudolateral and the main branch, but more so to the latter (fig. 2 E). Fritsch (711) states that as a general rule only one cystocarp matures on each branch, but in this species up to six were found on one lateral branch. They often occur on otherwise almost denuded branches. Each cystocarp is large, spherical, with a prominent apical beak surrounding the ostiole, the whole just showing through the crowded pseudolaterals when mature. Length when mature 0·8-1·2 mm., width 0·6-0·85 mm. Pericarp of three layers of cells, containing a large mass of dark-red carpospores. Carpospores irregularly ovoid to spherical, 9-18 μ long.

Early stages of cystocarp development have, as yet, not been found.

RELATION TO OTHER SPECIES OF *Dasyopsis*

D. clavigera appears most closely related to *D. cervicornis* (see Falkenberg, 664, De Toni, 1,178), differing in the terete stem compared with the angular stem and winged branch insertion of the latter. Other species also appear to possess distichously arranged pseudolaterals, these also being monosiphonous, whereas in *D. clavigera* they are polysiphonous at the base and spirally arranged.

D. clavigera appears to be the only species of *Dasyopsis* known from the Southern Hemisphere, thus establishing considerable geographic discontinuity within this genus.

TAXONOMIC DESCRIPTION

Frondes cum caulis unus aut plures, erecti teretes, ex uno base, principes caules parce ramosi, plerumque tecti cum brevibus ramulis quoquoversum egredientibus; frons in forma angusti pyramidis, 4-20 cm. altus, ramuli 1-2·5 cm. longi. Caules et ramuli tecti cum brevibus floccis pseudolateralibus ramellis, nudis ad basem. Pseudolaterales polysiphonii ad basem, aliter monosiphonii et

decomposites-dichotome. Cellulae pericentrales nullae, axi cortice rhizoideo immediate cincto, 1-2 mm. latae. Cystocarpia globosa, osteolata, cum rostro in apice, 0·8-1·2 mm. longa, 0·6-0·85 mm. lata, cum copia rubidorum carposporum. Spermatia in ramellis pseudolateralum, 70-120 μ longa, 30-50 μ lata. Stichidia in ramellis pseudolateralum, oblonga, rostrata, 310-450 μ longa, 80-110 μ lata, in pedicello monosiphonio 1-3 cellularum. Color fulvus, juvenis sanguineus. Specimina exsiccatione chartae adherent.

Fronds comprising one to several upright terete stems from a common base, main stems rarely branched, but usually closely set with short laterals, spreading on all sides, giving a narrowly pyramidal outline; frond 4 to 20 cm. high, laterals 1-2·5 cm. long. Stems and branches covered with short tufts of pseudo-lateral filaments, denuded near base. Pseudolaterals polysiphonous at base, otherwise monosiphonous and dichotomously branched. Stem with a single central siphon, pericentrals obscured, 1-2 mm. thick. Cystocarps globose, osteolate, with a prominent beak, 0·8-1·2 mm. long by 0·6-0·85 mm. wide, containing a mass of dark red carpospores. Spermatangia borne on filaments of pseudolaterals, masses 70-120 μ long, 30-50 μ wide. Stichidia replacing filaments of pseudolaterals, oblong cylindrical, apiculate, 310-450 μ by 80-110 μ , borne on a monosiphonous pedicel of 1-3 cells. Colour yellowish-brown, rose red at branch tips or in young plants. Adheres to paper.

Loc.—Pennington Bay, Vivonne Bay and West Bay, Kangaroo Island, South Australia. In lower littoral or sub-littoral fringe, on rocks.

Type (No. A 2,845a) and cotype specimens have been deposited in the Algal Herbarium of the Botany School, University of Adelaide. Cotypes have also been sent to the National Herbaria of Melbourne and Sydney.

SUMMARY

A new species of the genus *Dasyopsis*, *D. clavigera*, from the south coast of Kangaroo Island, is described. The range of form in relation to its habitat is discussed, and the development of vegetative organs, stichidia and spermatangia outlined.

It is considered that in finding the range of form and variation of a species an ecological approach is necessary. The geographical discontinuity between this species and others of the genus (from Europe and west coast of the United States) proves this to be a most interesting record.

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**THE SIMPSON DESERT EXPEDITION, 1939 – SCIENTIFIC REPORTS
NO 7, BOTANY – PART ONE: CATALOGUE OF PLANTS**

BY C. M. EARDLEY, HERBARIUM OF THE UNIVERSITY OF ADELAIDE

Summary

This collection compromises approximately 350 species representing 50 families, including Fungi, Pteridophyta (*Masilia* only) and Flowering Plants; Lichens were not collected. The actual Desert crossing was merely a portion of the journey of the Expedition, and 79% of the species listed here were collected outside the Desert proper, in the neighbourhood of Charlotte Waters and Andado Station, on the western side and especially along the track from Birdsville to Marree, on the south-eastern side; here the Diamantina was in flood and much of the country in good heart.

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PLATES XXVIII TO XXX

[Read 9 May 1946]

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INTRODUCTION

This collection comprises approximately 350 species representing 50 families, including Fungi, Pteridophyta (*Marsilia* only) and Flowering Plants; Lichens were not collected. The actual Desert crossing was merely a portion of the journey of the Expedition, and 79% of the species listed here were collected *outside* the Desert proper, in the neighbourhood of Charlotte Waters and Andado Station, on the western side, and especially along the track from Birdsville to Marree, on the south-eastern side; here the Diamantina was in flood and much of the country in good heart.

The 76 species collected from Camp 5 to Camp 19 inclusive, are listed separately and considered to belong to the flora of the sandridge Desert proper, interrupted only by the floodplain of the Hay River.

The plants come from three States—South Australia, Central Australia and Queensland. The regions around the Desert are fairly well known botanically and it was not expected that many new plants would be found; however, there is a new species of *Atriplex*, *A. cordifolia* described by J. M. Black, from Camp 45 on the eastern edge of Lake Eyre North. Mr. Blake and Mrs. Lee discovered among the Gramineae and among the species of *Swainsona* respectively, further examples of forms recognised by them as new. A possibly new variety of *Zygophyllum ammophilum* is also described. Dr. G. H. Cunningham, of New Zealand, and Dr. J. B. Cleland have established one of the fungi (*Schizostoma laceratum*) as new to Australasia.

In his paper "The Simpson Desert and its Borders" (12) (q.v. with its bibliography), Madigan gave an account of the journeys of earlier explorers around the margins of the Desert. It is interesting to survey their botanical activities. Sturt (1845) did not collect on a very large scale, apparently confining himself to plants that looked new or interesting, and Robert Brown, who wrote the botanical appendix to Sturt's narrative, found a large percentage of new plants in the 100 or so collected by Sturt during 1844-46. Hodgkinson (1876) seems to have made only the usual general vegetation notes on his map. Lewis (1874) had a collector and naturalist, F. W. Andrews, with him, but states that

there was so little to collect that he confined himself to "grasses"; he gives no report on these grasses nor any indication of what happened to them. Barclay (1878) apparently did no collecting. Winnecke (1877-81 and 1883) was in touch with the great botanist, von Mueller, and collected carefully, sending his plants to von Mueller for identification. He complains that four sets of collections were destroyed during the 1877-81 journey by the inattention of members of his party during his absence from camp; but appended to the journal (15) of his 1883 expedition is a very interesting list of 85 plants determined by von Mueller. Lindsay (1885-86) had Dittrich with him collecting, and sent packets of plants back to von Mueller, but no further account of these plants occurs in Lindsay's article in the Proc. R. Geogr. Soc. 1899. T. E. Day (1916) did not collect (9). For the collecting done on Madigan's own earlier expeditions, see his "Simpson Desert and its Borders" (12); another paper of his, "The Australian Sandridge Deserts" (11), has some general vegetation notes.

In 1937 G. H. Clarke was with E. A. Colson and collected 77 species between Abminga and Anacoora Bore; 19 of these were not included in the present collection. The difference in the two lists of species of *Acacia* is most instructive (unpublished records of the Waite Institute). In August 1938, C. P. Mountford collected on the south-west fringe of the Desert while with a search party for some putative remains of Leichhardt. His plants were identified at the Adelaide University Herbarium and include only one or two further species (list unpublished), notably *Atalaya hemiglauca*, Whitewood.

Some of the plants collected by the 1939 Simpson Desert Expedition are rare, and the determination of others is in doubt because they belong to difficult genera (e.g., *Frankenia*). Two or three plants could not be identified on account of insufficient material. The families represented by the largest number of species are as follows, the asterisk marking those containing the more important desert plants in this collection.

| | Total No. of spp. | Spp. coll. in Desert proper (C 5-19) | | Total No. of spp. | Spp. coll. in Desert proper (C 5-19) |
|----------------|----------------------|--|----------------|----------------------|--|
| Chenopodiaceae | - 51 | 9* | Euphorbiaceae | - 9 | 2 |
| Gramineae | - 50 | 4 | Solanaceae | - 8 | 4 |
| *Leguminosae | - 40 | 13* | Cruciferae | - 7 | 1 |
| Compositae | - 36 | 4 | Aizoaceae | - 7 | 0 |
| Amarantaceae | - 13 | 4 | Zygophyllaceae | - 7 | 0 |
| *Myoporaceae | - 12 | 5* | Frankeniaceae | - 6 | 0 |
| Cyperaceae | - 12 | 1 | Loranthaceae | - 5 | 1 |
| Malvaceae | - 10 | 3 | *Proteaceae | - 5 | 4* |
| Goodeniaceae | - 9 | 3 | | | |

It is seen that half the total number of species collected is evenly distributed among the first four large families, and the remaining 50 families are represented only by a few species each, with the exceptions quoted above.

The predominance of Chenopodiaceae in number both of individuals and species is a characteristic phenomenon of our drier areas and, to a lesser extent, of those in many other parts of the world. Of the Leguminosae, 14 are species of *Acacia*, and it is these and some species of *Cassia* which, because they are perennial shrubs or small trees, are so important in the Desert proper. Families represented by the larger shrubs or trees are Myoporaceae and Proteaceae. The Eucalypts are of first importance wherever they occur. *Eucalyptus Coolabah* is found here and there, while *E. pyrophora* is present, though rare, and the tallest tree in the Desert. The preponderance of Gramineae, Leguminosae and Compositae is a normal feature of most floras.

The two families so outstandingly characteristic of the Australian flora as a whole, Myrtaceae and Proteaceae, are represented by relatively few species, but they at least have the importance of tree status. It is interesting to see the smaller, chiefly Australian families like Goodeniaceae, Myoporaceae and the endemic genera of the Amaranthaceae well to the fore.

The Gramineae are notable because two shrubby species are ubiquitous in the Desert; indeed, one of them, *Triodia Basedowii* (Porcupine Grass or "Spinifex"), is the overwhelmingly constant and frequent plant of the Desert sands. The other is Cane Grass, *Spinifex paradoxus* (now to be known as *Zygochloa paradoxus*). Their ecology is described by Crocker (8) in another of the present series of reports. The common name "Cane Grass" has, in this paper, been applied also to some other grasses on account of their habit; they are *Glyceria ramigera* (now *Eragrostis australasica*), *Chrysopogon fullar* and *Echinochloa Turneriana*.

The Chenopodiaceae of the Desert proper are practically limited to a few common species, e.g., *Rhugodia spinescens*, *Kochia lanosa* and *Enchyalaena tomentosa*; the same applies to the Compositae.

It seems, then, that after the two shrubby grasses mentioned, the chief trees and shrubs hardy in the Desert belong to the families Leguminosae, Myoporaceae and Proteaceae, together with *Eucalyptus Coolabah* (Desert Box), *Dodonaea viscosa*, a very few Malvaceae, *Senevela depauperata*, a few Chenopodiaceae, and some of the small, shrubby Amaranthaceae, Euphorbiaceae and species of *Solanum*. A tree which occurs more rarely is *Codonocarpus cotinifolius* (Native Poplar). The remaining families tabulated above are represented chiefly by small annual or perennial plants.

The presence of several species of fungi, probably rather localized, is interesting. The conditions must be generally unfavourable for geophytes and even ephemerals, though there is still much to learn about this most important aspect of the Desert flora. As regards the rest of the collection, a few short remarks on species of particular interest will be made.

Ruppia maritima (Hale River)—There is a scarcity of records of the distribution of this cosmopolitan aquatic plant in Australian inland waters, but one has little doubt that it must be widespread in spite of the distances separating suitable habitats; it is also recorded for many waters and springs in the Egyptian desert. The only other aquatic plant was a *Myriophyllum*; *Marsilia* does not fall into quite the same category.

In the Gramineae, the large number of *Eragrostis* species (ten) should be mentioned. No *Schismus barbatus* (Mediterranean Grass) was collected. This is an introduced annual which has rapidly invaded the northern areas of South Australia, and is bound to follow transport routes to Central Australia.

Ptilotus latifolius, first collected by Sturt and evidently not uncommon in this region, is interesting taxonomically.

Fruiting specimens only of the rare *Acacia peuce* were gathered at Andado Station and near Birdsville, on the western and eastern edges of the Desert respectively, the only known localities for this species; the globular flower-heads have not yet been described, but probably will be in the second edition of J. M. Black's "Flora of South Australia" (3). Most writers who have seen this tree mention its "pine-like habit." It is commonly called "Casuarina" at Andado, which is misleading, and "Waddy" (13) at Birdsville. Blake (1938) gives photographs (4) and it is also illustrated here in pl. xxix; F. M. Bailey (1) calls it "Ironwood." Colson (1940) (7) says that the wood is as heavy as iron and nearly as hard; that it was used for the survey-line mile-posts erected by Poeppel on

the Queensland-South Australian border in 1879, and that these posts are still in good condition. Dr. L. K. Ward collected it at Andado in 1925 and 1928 and took photographs. T. E. Day (1916) (9) published a photograph described as "Casuarina" which probably illustrates this species. *Acacia peuce* is very likely on the way to extinction.

The only mulga collected was *A. brachystachya*, Umbrella Mulga.

Triumfetta Winneckeana (Tiliaceae) is a small plant found on the crests of sandridges in the Desert and apparently seldom collected. Winnecke obtained the first specimens in his journey north-east and east of the Desert in 1883 (15).

Plagianthus incanus specimens have now been found far from the type locality and extend our knowledge of the species greatly. Another malvaceous plant, *Sida inclusa*, must be well enough known by now, but its large, spiny fruit completely enclosed by the calyx is still remarkable.

Some of the Goodeniaceae are worth mention. *Calogyne Berardiana* is a small desert plant like a *Goodenia*, except for the curious divided style bearing an indusium on each of the two branches; *Leschenaultia divaricata* is a leafless, wiry bush with podlike capsules.

Much help from various botanists is very gratefully acknowledged, as follows:

Fungi—Identified by Dr. J. B. Cleland of Adelaide.

Gramineac—Identified by Mr. S. T. Blake, Brisbane National Herbarium, the author of many studies on grasses.

The genus *Enneapogon*—Identified by Miss N. T. Burbidge, Waite Institute, who has recently revised it.

Cyperaceac—Identified by Mr. S. T. Blake, a specialist on the family.

Chenopodiaceae—Identified with the help of Mr. R. L. Crocker, the collector, and Mr. R. H. Anderson, Chief Botanist, National Herbarium, N.S.W.

The genus *Swainsona*—Identified by Miss A. Melvaine (Mrs. Lee), National Herbarium, N.S.W.

Mr Blake determined over 60 species, a large share of the work most critically and competently performed.

In addition, Mr. P. F. Morris, of the Victorian National Herbarium, has checked the identity of *Triumfetta Winneckeana* and determined *Euphorbia MacGillivrayi* and a puzzling form of *Bassia quinquecuspis*.

The Western Australian State Herbarium has also been consulted.

Finally, Mr. J. M. Black's Herbarium was continually used and his advice sought. Most of the plants in this list are described in his "Flora of South Australia," Adelaide 1922-29 (also Part I, second edition, 1943) (3), and in his "Additions" published annually in subsequent volumes of the Trans. Roy. Soc. S. Aust.; in other cases, a reference to a description, not necessarily the original one, has been given.

The excellent and important botanical collection itself, with the careful notes of Mr. Crocker, the collector, has been presented to the Herbarium in the Botanical Department of the University of Adelaide by Dr. Madigan.

Now that we have a picture of the flora of this most inhospitable of the Australian deserts, as displayed in the present list and in Crocker's companion paper on the plant ecology (8), the question at once presents itself, "How does this vegetation compare with that of the other great deserts of the world, and does it help us to an accurate conception of the true relative aridity of our own desert?" This theme has, therefore, been developed as a logical conclusion to the present paper, and, it is hoped, will soon be published.

ITINERARY

Dates and Camp Numbers (C.) as used in Collector's Notes

MAY, 1939

- 25
26
27 Charlotte Waters
28 Andado H.S., Mayfield's Swamp
29 " "
30 " "
31 " " Indinda Well

JUNE

- 1 Andado Bore No. 2.
2 Crown Stn., Finke River; Mayfield's Swamp; Charlotte Waters; Andado
3 Abminga Creek, S. Aust.; Indinda Well
4 Near Andado
5 Andado Bore No. 1 C. 1. The Illitera
6 C. 2. Flood plain of Todd River
7 C. 3. Flood plain of Hale River
8 C. 3. Edge of tableland and Hale flood plain
9 C. 4. Hale River channel, Allua Soak Western edge of Desert crossed
10 C. 5. Mulga flat with Porcupine Grass
11 C. 6. Desert proper
12 C. 7
13 C. 8. Rain
14 C. 8. "
15 C. 8. "
16 C. 8. "
17 C. 9
18 C. 10
19 C. 11. Gidgee hollows
20 C. 12
21 C. 13
22 C. 14
23 C. 15
24 C. 16. Flood plain of Hay River
25 C. 17

Queensland Border crossed at C. 17
26 C. 18. Gidgee hollows, Queensland
27 C. 19 " " "
Rabbit Board Fence crossed
28 C. 20. Claypans, "Lake Crocker"
29 C. 20. Mulligan River,⁽¹⁾ Kuddaree W.H., Kaliduwatty Station
30 C. 20

JULY

- 1 C. 20
2 C. 21. Georgina⁽²⁾ flood plain
3 C. 22
4 C. 23. Stony flat
5 C. 24. Red gibber flat
Eastern edge of Desert crossed
6 C. 25. Birdsville Hotel
7
8
9
10 North Birdsville
11 Leave Birdsville
South Australian Border crossed
12 C. 26. Diamantina River
13 C. 27. Eleanor Creek, S.A.
14 C. 28 Andrewilla W.H., Diamantina
15 C. 29 Burt's W.H. Diamantina
16 C. 30. Goyder's Lagoon
17 C. 31. Canegrass Swamp, Goyder's Lagoon
18 C. 32. 7-Mile Creek, Goyder's Lagoon Bore
19 C. 33. Gibber plain
20 Mount Gason
21 C. 34. Mount Gason
22 C. 35
23 C. 36. Warburton River. Hot bores
24 C. 37. " " Cowarie Station, Derwent Creek
25 C. 38
26 C. 39. Cowarie Crossing. Warburton flood plain
27 C. 40. Claypans, Kalamurina Stn.
28 C. 41. Gypseous area
29 C. 42. Junction Warburton River and Macumba River, near L. Eyre
30 C. 43
31 C. 44. Gypseous claypan

AUGUST

- 1 C. 45 Dillon Bush hollows
2 C. 46
3 C. 47
4 C. 48
5 C. 49. Near Lake Eyre North
6 C. 50. Clayton River branch
7
8 Lake Letty. About 15 miles N. Marree
9 Marree

⁽¹⁾ There has been much confusion about the correct limits of the Mulligan and Georgina Rivers, and the two names have been used rather indiscriminately on the plant labels.—R. L. Crocker.

SUMMARY OF PLANTS COLLECTED

| | Total spp. | Desert spp. | | Total spp. | Desert spp. |
|------------------|---------------|----------------|-----|---------------|----------------|
| Fungi | - | - | 8 | 6 | |
| Marsiliaceae | - | - | 2 | | |
| Potamogetonaceae | - | - | 1 | | |
| Gramineae | - | - | 50 | 4 | |
| Cyperaceae | - | - | 12 | 1 | |
| Liliaceae | - | - | 1 | | |
| Amaryllidaceae | - | - | 1 | | |
| Proteaceae | - | - | 5 | 4 | |
| Santalaceae | - | - | 1 | | |
| Loranthaceae | - | - | 5 | 1 | |
| Polygonaceae | - | - | 3 | | |
| Chenopodiaceae | - | - | 51 | 9 | |
| Amarantaceae | - | - | 13 | 4 | |
| Nyctaginaceae | - | - | 1 | | |
| Phytolaccaceae | - | - | 1 | 1 | |
| Aizoaceae | - | - | 7 | | |
| Portulacaceae | - | - | 3 | | |
| Caryophyllaceae | - | - | 1 | | |
| Capparidaceae | - | - | 1 | | |
| Cruciferae | - | - | 7 | 1 | |
| Leguminosae | - | - | 43 | 14 | |
| Geraniaceae | - | - | 1 | | |
| Zygophyllaceae | - | - | 7 | | |
| Meliaceae | - | - | 1 | | |
| Euphorbiaceae | - | - | 9 | 2 | |
| Sapindaceae | - | - | | | |
| Tiliaceae | - | - | | | |
| Malvaceae | - | - | | | |
| Sterculiaceae | - | - | | | |
| Frankeniaceae | - | - | | | |
| Thymelaeaceae | - | - | | | |
| Lythraceae | - | - | | | |
| Myrtaceae | - | - | | | |
| Halorrhagidaceae | - | - | | | |
| Umbelliferae | - | - | | | |
| Gentianaceae | - | - | | | |
| Convolvulaceae | - | - | | | |
| Boraginaceae | - | - | | | |
| Verbenaceae | - | - | | | |
| Labiatae | - | - | | | |
| Solanaceae | - | - | | | |
| Scrophulariaceae | - | - | | | |
| Myoporaceae | - | - | | | |
| Plantaginaceae | - | - | | | |
| Cucurbitaceae | - | - | | | |
| Campanulaceae | - | - | | | |
| Goodeniaceae | - | - | | | |
| Brunoniaceae | - | - | | | |
| Compositae | - | - | | | |
| Totals | - | - | 346 | 76 | |

Of the above 49 families present, the 23 families in heavy type are those with representatives collected in the Desert proper (*i.e.*, between Camps 5-19 inclusive), the number of species being given in the last column opposite the appropriate family.

PLANTS FOUND IN SIMPSON DESERT PROPER

Collected between Camp 5 and Camp 19, inclusive, from 10 June 1939 to 27 June 1939. Plants collected before 10 June 1939 may have occurred in the Desert without being collected again. Camps 15-16 were along the flood-plain of the Hay River.

FUNGI

- Montagnites Candollei*—C. 16-17.
Podaxon pistillaris—Common, C. 7-8.
Tulostoma albicans—C. 16-17.
T. McAlpinianum—Common, C. 7-8.
Disciseda cervina—C. 16-17.
Pisolithus tinctorius—Hay River.

GRAMINEAE

- Setaria Brownii*—C. 18.
Zygochloa paradoxa (= *Spinifex paradoxus*), "Cane Grass"—Common in Desert, C. 5, 6, 7, etc., though not collected there.
Triodia Basedowii "Porcupine Grass" or "Spinifex"—Occurs very frequently in Desert.
Eragrostis eriopoda—2 collns., in Desert only, C. 8 and C. 16.

CYPERACEAE

Fimbristylis dichotoma?—C. 19, very common.

PROTEACEAE

Hakea leucoptera—C. 8, not collected here; identification *fide* R. L. Crocker.
H. intermedia—Up to 2 m. high; C. 7, C. 10.
Grevillea juncifolia—Up to 3 m. high, very common, C. 6-8.
G. stenobotrya—Up to 2 m. high; collected only in Desert; C. 5, 6, 7, 12, 13.
? *G. striata*, Beefwood—Up to 5 m. high, C. 5; leaves only.

LORANTHACEAE

Loranthus sp.—“On *Hakea leucoptera*” (sic) which was not collected in the Desert; C. 8.

CHENOPodiACEAE

Rhagodia spinescens—Common with *Triodia*, C. 10.
Atriplex vesicarium—C. 19, Gidgee—Saltbush association.
Bassia bicornis—C. 19, Goathead.
B. intricata—C. 19.
B. paradoxa—C. 19-20.
B. uniflora—C. 19.
Kochia lanosa—C. 11 and C. 18.
Salsola Kali—C. 5.
Enchytraea tomentosa—C. 8, C. 9, C. 19.

AMARANTACEAE

Trichinium alopecuroides var. *rubriflorum*—Common, C. 14.
T. obovatum var. *grandiflorum*—C. 8, C. 11.
Pilostus latifolius—Very common on all Canegrass sandhills between Andado and C. 10.
Amarantus grandiflorus—C. 11.

PHYTOLACCACEAE

Codonocarpus cotinifolius, “Native Poplar”—C. 16, Hay River.

CRUCIFERAE

Blennodia pterosperma—C. 11.

LEGUMINOSAE

Acacia Cambagei, “Gidgee”—Not collected in Desert, but certainly occurs at C. 11, 18, 19 and probably elsewhere.
A. brachystachya—Not collected in Desert, but occurs at C. 5. “Mulga.”
A. dictyophleba—C. 6, to 2 m. high; C. 11.
A. ligulata—“Sandhill Wattle,” C. 6, to 2 m. high.
A. Murrayana—C. 6.
A. patens—C. 6-C. 8, up to 1 m. high.
A. Wattiana—Prob., no fruits, C. 17, 5 miles east of Hay River.
Cassia pleurocarpa—“Sandhill legume,” C. 10, C. 13.
C. eremophila—Common C. 7, C. 14; flood plain of Hay River.
Crotalaria Cunninghamii—“Parrot Bush” or “Felt Bush.” Common Andado, C. 8.
C. dissitiflora—C. 8, C. 15.

Psoralea eriantha—C. 14.

Swainsona rigida—Common after C. 17.

S. microphylla ssp. *affinis*—C. 6, 7, 13.

EUPHORBIACEAE

Adriana Hookeri—Common C. 5 - C. 8, but often dead.

Euphorbia Wheeleri—Very common Andado; C. 11.

SAPINDACEAE

Dodonaea viscosa—Edge of Desert, C. 12, C. 13 and C. 18.

TILIACEAE

Triumfetta Winnekeana—C. 6 - 8.

MALVACEAE

Sida corrugata—C. 6 and 7 common, C. 8, C. 19 Gidgee hollow.

S. virgata—Common up to C. 13.

Hibiscus Krichauffianus—“Common across S.D.”

MYRTACEAE

Eucalyptus pyrophora—“Bloodwood.” Rare, C. 17-18, 9 m. high.

E. Coolabah—C. 6 - 7, 5 m. high; C. 12 - 13; Hay River, 7-9 m. high.

Thryptomene Maisonneuvei—C. 18.

HALORRHAGIDACEAE

Halorrhagis Gossei—C. 9 - 10.

CONVOLVULACEAE

Ipomoea Muelleri—Hay River flood plain, C. 15.

VERBENACEAE

Newcastlia cephalantha—C. 17.

Dicrastylis Doranii v. *eriantha*—C. 16 - 17.

SOLANACEAE

Solanum ellipticum—C. 5 and Hay River.

S. esuriale—C. 16.

S. coactiliferum—C. 14.

S. chenopodium—C. 19, Gidgee hollow.

SCROPHULARIACEAE

Morgania glabra—C. 15.

MYOPORACEAE

Eremophila Latrobei—C. 5, C. 18.

E. longifolia—C. 7, C. 8.

E. Willsii—Very common, C. 6 - 7.

E. Strehlowii—Very common, C. 12 - 13.

E. strongylophylla—C. 5.

GOODENIACEAE

Goodenia cycloptera—C. 6.

Calogyné Berardiana—C. 5.

Scaevola depauperata—C. 5, C. 8, C. 18; only in Desert.

COMPOSITAE

Calotis erinacea—Andado to C. 7.

Helipterum moschatum—C. 8.

Helichrysum ambiguum v. *paucisetum*—C. 13.

H. roseum v. *Davenportii*—C. 8.

Total, 76 species in 23 families.

LIST OF ALL PLANTS COLLECTED

CRYPTOGAMS

FUNGI

For descriptions of the following fungi, see J. B. Cleland (6).

BASIDIOMYCETAE

(1) HYMENOMYCETALES

AGARICACEAE

Coprinus sp.—Spores oblique, sometimes ovate. 7.5 to 9 μ x 5.5 μ . No details of locality.

Montagnites Candollei Fr.—Sand-slope between C. 16 - 17. Spores 15 to 28 μ x 9.5 to 11 μ .

(2) GASTEROMYCETALES

HYMENOGASTRACEAE

Hydnangium glabrellum (Z. and D.) G. H. Cunn.—Spores spherical, 11 to 12.5 μ . No details of locality. Identified by Dr. G. H. Cunningham, of New Zealand (v. his "Gasteromycetes of Australia and New Zealand," Dunedin, N.Z., 1944).

TULOSTOMATACEAE

Podaxon pistillaris (L.) Fr.—Common between C. 7 and 8. Stable sand.

Spores 13 to 15 μ x 9 μ . Capillitium scanty, brownish, 5 to 7 μ . 16.6.39.

Tulostoma albicans White—Sand-slope between C. 16 and 17. Spores 5.5 μ .

T. McAlpinianum Lloyd—Stable sand, common between C. 7 - 8. Spores 4.5 μ . 16.6.39.

Schizostoma laceratum Ehrenb. ex Leveille. (*Queletia mundkuri* Ahmad.

Journ. Indian Bot. Soc., 20, 135, 1941.) Named for the Punjab, the genus is a new record for Australia. Also found in Africa. Identified by Dr. G. H. Cunningham, of New Zealand.

LYCOPERDACEAE

Disciseda cervina (Berk.) Cunn.—(1) Near C. 3; spores 6.7 μ ; capillitium short, fuscous, 3.7 to 4.5 μ . (2) Sand-slope between C. 16 - 17; spores 5.5 to 7.5 μ ; capillitium short lengths, occasionally branched, brown, 3.5 to 5.5 μ .

SCLERODERMATACEAE

Pisolithus tinctorius (Micheli ex Pers.) Coker et Couch.—(1) Flood plain, Hay River; spores 9 μ . (2) Channel of Hay River; spores 8.5 μ .

PTERIDOPHYTA

MARSILIACEAE

Marsilia hirsuta R. Br.—Watercourse, Charlotte Waters. 27.5.39.

Marsilia Drummondii A. Br., "Nardoo"—Georgina River, C. 21. 2.6.39.

Phanerogams
MONOCOTYLEDONS
POTAMOGETONACEAE

Ruppia maritima L.—Channel of the Hale River. A water plant.

GRAMINEAE

ANDROPOGONEAE

Chrysopogon fallax S. T. Blake, Univ. Queensland Papers, Dept. Biol., 2, No. 3, 9, 1944. "Cane Grass," Seven-mile Creek; tall grass 1-1.5 m. high. 18.7.39.

Dichanthium humilius J. M. Black—(1) Finke River, Crown Past. Co. 2.6.39.
(2) Common on flood plain of Hale River, C. 3.

Eulalia fulva (R. Br.) O. Kuntze—Watercourse, Charlotte Waters.

Iseilema membranaceum (Lindl.) Domin—(1) Finke River, Crown Past. Co.
(2) Inter-ridge watercourse near Andado H.S.

I. vaginiflorum Domin—(1) Charlotte Waters; in watercourse and associated with *Eragrostis* sp. 27.5.39. (2) Common on tableland and small watercourse thereon between C. 30 and C. 33.

ZOYSIEAE

Tragus australianus S. T. Blake, Univ. Queensland Dept. Biol. Papers 1, No. 18, 1941—Off small watercourse, C. 34. Formerly referred to as *T. racemosus* (L.) All. 21.7.39.

PANICEAE

Brachiaria praetervisa (Domin) C. E. Hubbard (*Urochloa praetervisa* (Domin) Hughes)—(1) Finke River flood plain, Crown Station. 2.6.39. (2) Flood plain of Hale River, C. 3. 7.6.39.

Digitaria ammophilà (F. Muell.) Hughes—C. 34. 21.7.39.

Ichnanthus australiensis (Domin) Hughes—Sandridge 8 miles north-east Andado Bore. 5.6.39.

Panicum decompositum R. Br.—(1) Watercourse, Charlotte Waters. 27.5.39.
(2) Abminga Creek. 3.6.39. (3) Flood plain of Hale River, C. 3. 7.6.39.
(4) Common in canegrass swamp; Goyder's Lagoon. 17.7.39. (5) Edge of claypan, gypseous hollows, C. 41. 28.7.39.

P. Whitei J. M. Black—(1) Inter-ridge watercourse, Andado Station. 30.5.39.
(2) Common about Diamantina River. C. 29. 15.7.39.

Echinochloa Turneriana Domin, in Biblioth. Bot., 20, Heft 85, 307, (1915), cited as an alternative name for *Panicum Turnerianum* Domin l.c. "Cane Grass"; tall grass about 1 m. high along Diamantina channels and Goyder's Lagoon, C. 29. 16.7.39.

Eriochloa australiensis Stapf ex Thellung in Vierteljahr. Natürforsch. Gesellsch., Zürich, 64, 697 (1919).—Swamp between Charlotte Waters and Andado.

E. pseudo-acrotricha (Stapf ex Thellung) C. E. Hubbard ex S. T. Blake, Trans. Roy. Soc. S. Aust., 67, 43 (1943)—(1) Watercourse between Andado and Charlotte Waters. 28.5.39. (2) Finke River, Crown Pastoral Co. 2.6.39.
(3) Very common about Goyder's Lagoon. 16.7.39. (4) Common along Warburton River. 23.7.39.

E. longiflora S. T. Blake, Univ. Queensland Papers, Dept. Biol., 1; No. 18, 1941—(1) Sandy watercourse, Charlotte Waters. 27.5.39. (2) Burt's Waterhole, C. 29. 15.7.39.

Plagiosetum refractum (F. Muell.) Benth.—(1) Very common with *Spinifex* (Cane Grass) on rather unstable dune, east of Andado Station. 29.5.39. (2) "Drooping Oat Grass." Sandhills near Mulligan River. 28.6.39.

Selaria Brownii Herm., in Rosen, Beitr. Biol. Pflanzen, 10, 61, (1910)—Rare, sand-slope, C. 18, Qld. 26.6.39.

S. Dielsii Herm., l.c., 52, (1910)—Box flood plain of Finke River between Charlotte Waters and Mayfield Swamp. 2.6.39.

Zygochloa paradox (R. Br.) S. T. Blake. (*Spinifex paradoxus* (R. Br.) Benth.). N.B.—"Spinifex" is regularly used as a popular name and applied to *Triodia* spp. q.v., a long-standing and unfortunate confusion. (1) Sandhills near Mayfield Waterhole; "Cane Grass"; male plant. 28.5.39. (2) "Cane Grass" 1-1½ m. high; sandy flat, near C. 3; female plant. 8.6.39. Recently published as a new genus, Univ. of Queensland Papers, Dept. Biol., 1, No. 19, 1941.

AGROSTIDEAE

Aristida anthoxanthoides (Domin) Henr.—Inter-ridge watercourse, Andado Station. 30.5.39.

A. Browniana Henr. (*A. Muelleri* Henr.)—(1) Sandhill near Andado Station homestead. 29.5.39. (2) Between sandhills, 2 miles north-east C. 1. 6.6.39. (3) Sandy Creek, near C. 3. 8.6.39. (4) Claypan and gidgee country. 28.6.39. (5) Red gibber flat. 5.7.39.

A. arenaria Gaud.—(1) Between sandhills, 2 miles north Mayfield's Swamp, Andado. 2.6.39. (2) C. 3. 8.6.39. (3) Gibber tableland; C. 33. 19.7.39.

Stipa nitida Summerhayes and Hubbard—Common about gypseous claypans, C. 44 and 45. 1.8.39.

Sporobolus actinocladus F. Muell.—Very common, stony tableland. Goyder's Lagoon Bore. 18.7.39.

Agrostis avenacea Gmel.—J. W. Vickery, Contribns. N.S.W. National Herb., 1, No. 3, 1941. (1) Andrewilla, small swamp. 14.7.39. (2) A very common grass, Goyder's Lagoon, C. 30. 16.7.39.

AVENAEAE

Eriachne nervosa Ewart and Cookson, in Ewart and Davies, Flora of the Northern Territory, 44 (1917)—Abminga Creek channel. 3.6.39.

E. Benthamii Hartley, J. Linn. Soc. Bot., 52, (No. 344), 345. 1942 (*E. ovata* Nees var. *pallida* Benth.)—(1) Charlotte Waters watercourse. 27.5.39. (2) Wetter habitat, red gibber flat; between C. 23 and 24. 5.7.39.

E. aristidea F. Muell.—(1) Sandhill, east Andado Station. 29.5.39. (2) Sandy Creek, C. 2. 6.6.39.

FESTUCAEAE (*Enneapogon* spp. determined by N. T. Burbidge.)

Enneapogon avenaceus (Lindl.) C. E. Hubbard (v. N. T. Burbidge, Proc. Linn. Soc. Lond., 153rd Session (1940-41), pt. i, Aug. 1941, 52.)—(1) Common in claypan hollows west of Mulligan River. 28.6.39. (2) Common in gibber country, Mount Gason. 20.7.39.

E. cylindricus N. T. Burbidge, loc. cit.—Between sandhills near Cowarie Station, C. 37. 25.7.39.

E. polyphyllus (Domin) N. T. Burbidge, loc. cit.—(1) Watercourse, Charlotte Waters. 27.5.39. (2) Inter-ridge watercourse near Andado H.S. 30.5.39. (3) Small watercourse off Finke (Crown Past. Co.). 2.6.39. (4) Flood plain, Hale River, C. 3. 6.6.39. (5) Common on gibber country, Mount Gason. 20.7.39.

Triraphis mollis R. Br.—(1) Sandy watercourse. 27.5.39. (2) Flood plain of Hale, C. 3. 8.6.39.

- Triodia Basedowii* E. Pritzel. "Porcupine Grass" or "Spinifex"; v. note on *Zygochloa* above. (Formerly known as *T. pungens*, v. Black, Flora S.A., First Ed.)—(1) Base of sandhill east of Andado Station. 29.5.39. (2) Between sandridges, about 2 miles north of Mayfield's Swamp, Andado Station. 2.6.39. (3) Between sandhills, 2 miles west of C. 8. 13.6.39. Also widespread in the Desert.
- Diplachne Muellieri* Benth. (*D. fusca* (L.) Beauv. var. *Muellieri*)—(1) Watercourse, Charlotte Waters. 27.5.39. (2) Common along bore drains, Goyder's Lagoon Bore; C. 32. 18.7.39. (3) Seven-mile Creek. 18.7.39 (4) Bore drain, Mount Gason. 20.7.39.
- Cynosurus cristatus* L., Bentham and Hooker, British Flora, 536, 1908 edn. No loc.
- Eragrostis setifolia* Nees—(1) Charlotte Waters. 27.5.39. (2) Channel of Hale River; near C. 3. 8.6.39.
- E. leptocarpa* Benth.—(1) Watercourse, Charlotte Waters. 27.5.39. (2) Andado Station homestead bore. 29.5.39. (3) Stony flat, C. 23. 4.7.39. (4) Watercourse off stony gibber plains, Goyder's Lagoon Bore. 18.7.39.
- E. laniflora* Benth.—Gentle slope of sandrise; C. 1. 6.6.39.
- E. japonica* (Thunb.) Trin.—Charlotte Waters, watercourse. 27.5.39.
- E. eriopoda* Benth.—(1) Between sandridges; C. 8. 13.6.39. (2) Sandy rise; near C. 16, Hay River. 24.6.39.
- E. Dielsii* Pilger—(1) Sandridge. 29.5.39. (2) Common in sandy watercourse; C. 2. 6.6.39. (3) Flood plain of Hale; near C. 3. 8.6.39. (4) Common on sandrise; C. 24. 5.7.39. (5) Very common about Andrewilla Waterhole. 14.7.39. (6) Very common in hollows and base of sandhills; C. 40 and 41. 28.7.39.
- E. confertiflora* J. M. Black—(1) Finke River, Crown Past. Co. 2.6.39 (2) C. 4. 9.6.39.
- E. Basedowii* Jedwabnik, in Bot. Arch., 4, 328 (1923)—(1) Sandy watercourse, Charlotte Waters. 27.5.39. (2) Common about claypans along Rabbit Board Fence; C. 20. 29.6.39. (3) Sandy patch at edge of sandridge on gibber plain. 19.7.39. (4) Watercourse, edge of sandhill; C. 39. 27.7.39.
- E. Basedowii* Jedwabnik forma vel sp. aff.—Sandridge slope, Kaliduwarry Camp. Not common. 29.6.39.
- E. australasica* (Steud.) C. E. Hubbard, Kew Bull., 26 (1941) (= *Glyceria ramigera* F. Muell., and other synonyms).—"Cane Grass." Tall grass about 1-2 m. high, common in some swamps on Goyder's Lagoon; C. 31. 17.7.39
- Tripogon loliiformis* (F. Muell.) C. E. Hubbard, Kew Bull., 448, 1934 (*Diplachne loliiformis* F. Muell.)—(1) Near C. 34. 21.7.39. (2) Gibber plain between C. 32 and 33. 19.7.39.

CHLORIDEAE

- Chloris pectinata* Benth., Fl. Aust., 7—(1) Sandy watercourse, Charlotte Waters. 27.5.39. (2) Common at 7-mile Creek. 18.7.39.
- Ch. virgata* Sw.—Watercourse, Charlotte Waters. 27.5.39.
- Astrebla pectinata* (Lindl.) F. Muell. ex Benth.—"Mitchell Grass." (1) Claypans near Rabbit Board Fence. 28.6.39. (2) Gibber plain; C. 32, etc. 18.7.39. (3) Stony tableland, Mount Gason. 20.7.39.
- Dactyloctenium radulans* (R. Br.) Beauv.—"Button Grass." Sandy watercourse, Charlotte Waters. 27.5.39.
- Leptochloa digitata* (R. Br.) Domin—Large tussock to 1 m. high. Bed of Finke River, Crown Past. Co. 2.6.39.

CYPERACEAE

- Cyperus aristatus* Rottb.—(1) Hale River Channel; C. 4, Allua Soak. 9.6.39.
 (2) Derwent Creek; C. 37. 25.7.39.
- C. bulbosus* Vahl. Enum., pl. ii, 342 (1806).—(1) Charlotte Waters, 27.5.39.
 (2) Hale River Channel; C. 3. 8.6.39. (3) Hale River Channel; C. 4, Allua Soak. 9.6.39. (4) "Yowa." About "Lake Crocker," in small sandy watercourse. 28.6.39.
- C. dactyloides* Benth., forma vel sp. aff.—Too young for satisfactory determination. Common on edge of Abminga Creek (Gidgee and Box). 3.6.39.
- C. sp. aff C. dactyloides* Benth. and *C. alterniflorus* R. Br.—Too young for satisfactory determination. Watercourse, Charlotte Waters. 27.5.39.
- C. difformis* L.—Cowarie, Derwent Creek. 26.7.39.
- C. gymnocephalus* Steud. Synops. Cyper., 12 (1855); = *C. vaginatus* R. Br. var. *densiflorus* Benth., Fl. Aust., 1, 273, (1878)—(1) Kuddaree Waterhole, Georgina River. 29.6.39. (2) Common along bore drain, Mount Gason. 20.7.39. (3) Common along edge of Warburton Channel (also hot bores). 23.7.39.
- C. laevigatus* L.—Goyder's Lagoon, bore drain. 18.7.39.
- C. rigidellus* (Benth.) J. M. Black—(1) Edge of waterhole on Warburton, about 6 miles from C. 38. 27.7.39. (2) Edge of claypan near C. 39 on Warburton flood plain. 27.7.39.
- C. victoriensis* C. B. Clarke, in Kew Bull. Addit., Ser. viii, 12 (1908)—Watercourse, Charlotte Waters. 27.5.39.
- Fimbristylis dichotoma* (L.) Vahl.?—Very common amongst Gidgee about C. 19. 27.6.39.
- Scirpus maritimus* L.—Common at Goyder's Lagoon, bore drain. 18.7.39.
- S. australiensis* (Maiden and Betche) S. T. Blake, Proc. Roy. Soc. Qld., 51, 179, 1940.—Derwent Creek; C. 37. 25.7.39.

LILIACEAE

- Bulbine semibarbata* (R. Br.) Haw.—Common along Diamantina and Eleanor River flats. 13.7.39.

AMARYLLIDACEAE

- Crinum pedunculatum* R. Br.—"Murray Lily." ? Flood plain of Mulligan River, Qld.

This determination is in doubt, the perianth segments are narrower than those of most South Australian specimens; Black (3) 2nd ed., now considers the South Australian species to be *C. flaccidum* Herbert.

DICOTYLEDONS

PROTEACEAE

- Hakea intermedia* Ew. et Davies—(1) Plain west of Andado Station. 29.5.39.
 (2) Rarely exceeding 2 m. high, between sandridges; C. 7. 12.6.39.
 (3) C. 10. 18.6.39.
- H. leucoptera* R. Br., probably, no flowers—Needlebush near C. 2. Also in sandhills between C. 1 and 2. Probably also in Desert, C. 8. 6.6.39.
- Grevillea juncifolia* Hook.—(1) Andado Station. (2) Flower tangerine. Tree rarely exceeding 3 m. high. Very common between sandridges from C. 6-C. 8. 13.6.39.
- G. stenobotrya* F. Muell.—(1) Sandhill near C. 5. 11.6.39. (2) Common between sandridges, C. 6 and 7; shrub 1½-2 m. high. 12.6.39. (3) Sand-slope *Grevillea*. Rare to C. 12, more common between C. 12 and 13. Flower, pale yellow.

? *G. striata* R. Br., leaves only—(1) Sandhill; C. 5. 11.6.39. (2) "Beefwood" tree to 5 m. high; creek near Mount Gason; C. 34. 21.7.39.

SANTALACEAE

Santalum lanceolatum R. Br.—"Sweet Tree." Creek near C. 3. Good camel fodder; slightly drooping habit. 8.6.39.

As some of the leaves on this specimen are almost 3 cm. broad, it has been considered to belong to the type rather than the variety which follows. The majority of the leaves are no more than 1 cm. broad.
var. angustifolium Benth.—"Sweet Bush" or "Wild Plum." Gibber plain near C. 33. Fruit black when ripe. 19.7.39.

LORANTHACEAE

Loranthus Exocarpi Behr.—Andado Bore No. 1. Mistletoe on *Acacia peuce*. 4.6.39.

L. Maidenii Blakely—Mistletoe on Mulga; C. 3. 8.6.39.

L. Murrayai F. Muell. et Tate—Mistletoe on Mulga; Co. 3. 8.6.39.

L. gibberulus Tate—No flowers present; berries only. The specimen is probably a glabrous form of this tomentose-leaved species. No locality given. Blakely has described this form with glabrous leaves as var *Tatei* (Proc. Linn. Soc. N.S.W., 47, 395. 1922).

L. sp.—Mistletoe on *Hakea leucoptera*, C. 8. 17.6.39.

This specimen approaches *L. Quandang* Lindl. and *L. Maidenii* Blakely, but the leaves are glabrous. The specimen is incomplete and does not show the type of inflorescence.

POLYGONACEAE

Rumex crystallinus Lange—Eleanor Creek, Andrewilla Waterhole. 14.7.39.

Polygonum plebejum R. Br.—Diamantina River; C. 28 and 29.

Muehlenbeckia Cunninghamii (Meisn.) F. Muell. "Lignum."—(1) Creek, Charlotte Waters. 27.5.39. (2) Inter-ridge watercourse near Andado H.S. 30.5.39. (3) In Coolabah flood plain of Hale River. 7.6.39. (4) Goyder's Lagoon. 17.7.39. (5) Sandhills between Warburton River and Cowarie Station. 24.7.39.

CHENOPodiaceae

Rhagodia parabolica R. Br. "Oldman Saltbush."—Tall shrub 1½-2 m. high. Andrewilla Waterhole; C. 28. 14.7.39.

Rh. spinescens R. Br.—(1) Abminga Creek. 3.6.39. (2) Watercourse off table-land; C. 3. 8.6.39. (3) Common with *Triodia* between ridges; C. 10. 18.6.39. (4) C. 34, near Mount Gason. 21.7.39.

Chenopodium auricomum Lindl.—(1) Near bore, Andado Station. 29.5.39. (2) Goyder's Lagoon. 16.7.39.

Ch. cristatum F. Muell.—Finke flood plain (Crown Station), very common. 2.6.39.

Ch. Blackianum Aellen (*Dysphania littoralis* R. Br.), Trans. Roy. Soc. S. Aust., 58, 172, 1934—Inter-ridge watercourse, 1 mile north Andado H.S. 30.5.39.

Ch. myriocephalum (Benth.) Aellen (*Dysphania myriocephala* Benth.), loc. cit. —Edge of claypan; C. 39. 27.7.39.

Ch. simulans F. Muell. et Tate (*Dysphania simulans* F. Muell. et Tate), loc. cit.—Fairly common about "Lake Crocket," Qld. 28.6.39.

Atriplex angulatum Benth.—(1) Mount Gason. 20.7.39. (2) Flood plain of Warburton. 20.7.39.

A. cordifolia J. M. Black in Trans. Roy. Soc. S. Aust., 69, (2), 309, 1945—
Sandhills and hollows east of Lake Eyre North, C. 45, with crucifers and
Buckbush (*Salsola Kali*?); not a dense plant. 1.8.39.

Mr. Black has described the above new species from this specimen; it
is near *A. Muelleri* in the fruit, but the leaves are smaller, sessile and
cordate. An erect, glabrous annual, 40-60 cm. high, stems and branches
rigid, whitish; leaves ovate-lanceolate, sinuate-dentate, somewhat thick,
ashy-grey, with minute papillae, sessile-cordate at base, 7-15 mm. long,
6-8 mm. wide; flowers clustered in the axils, upper clusters androgynous,
lower ones female (owing to an error, the lower clusters are described as
male in the original Latin diagnosis); fruiting bracteoles almost as in
A. Muelleri, but scarcely denticulate, sub-triangular, 3 mm. long and broad,
lightly three-nerved.

A. elachophyllum F. Muell.—Charlotte Waters, slaty rise. 27.5.39.

A. halimoides Lindl.—(1) Gibber plain; C. 34. 21.7.39. (2) Warburton flood
plain flats. 23.7.39.

A. leptocarpum F. Muell.—Near Warburton at Cowarie Crossing. 26.7.39.

A. limbatum Benth.—(1) Very common in Needlebush sand hollow; C. 24.
5.7.39. (2) Sandy hollow between two sandridges west of Cowarie; C. 37.
25.7.30. (3) Goyder's Lagoon (?). Approaches var. *sexifidum* J. M.
Black.

A. nummularium Lindl. "Giant Saltbush."—(1) Probably this sp.; swamp near
Mayfield. 28.5.39. (2) Lignum-Box association, Georgina River, Queens-
land. 29.6.39. (3) Shrub 1½ m. high; Georgina Box flood plain. 2.7.39.
(4) Shrub 1 m. high; common on plain about Goyder's Lagoon Station
and South, 18.7.39. (5) Flood plain, Warburton; about 2 m. high; "Old
Man Salt-bush," common. 23.7.39.

A. Quinii F. Muell.—Stony tableland, Abminga, S. Aust. 3.6.39.

A. spongiosum F. Muell.—(1) Watercourse, Charlotte Waters. 27.5.39. (2)
Abminga Creek. 3.6.39. (3) Tableland and watercourse, Andado.
2.6.39. (4) Georgina; C. 21. 2.7.39. (5) Sandhill, Andrewilla. 14.7.39.
(6) Stony gibber tableland between Goyder's Lagoon and the old Station
homestead; C. 31. 17.7.39. (7) Grey flats of Warburton. 23.7.39. (8)
Warburton River flood plain. 23.7.39. (9) Lake Letty. 8.8.39.

The usual wide range of form and size of fruits and leaves was en-
countered in this collection of specimens of *A. spongiosum*.

A. velutinellum F. Muell.—Sandhills, Burt's Hole. 15.7.39.

A. vesicarium Heward—(1) Gibber tableland, Abminga. 2.6.39. (2) Table-
land about 5 miles south of C. 2. 6.6.39. (3) Gidgee-saltbush association,
about C. 19. 27.6.39. (4) Gibber tableland; C. 34. 21.7.39. (5) Gibber
tableland; C. 34. 21.7.39. (6) About gypseous claypans between C. 44
and 45. 1.8.39.

Bessia bicornis (Lindl.) F. Muell.—(1) Sandrise near Indinda Well, Andado.
31.5.39. (2) "Goathead"; Gidgee-*Atriplex* hollow. 27.6.39.

B. brachyptera (F. Muell.) R. H. Anderson—Lake Letty. 8.8.39.

B. convexula R. H. Anderson—Between ridges east of C. 22. 4.7.39.

B. divaricata (R. Br.) F. Muell.—(1) Tableland west of Andado Station Home-
stead. 31.5.39. (2) Stony flats between C. 23 and 24. 5.7.39.

B. eriacantha (F. Muell.) R. H. Anderson—Bore No. 2, Andado, stony Cre-
taceous tableland. Probably this sp., but perianth immature. 1.6.39.

B. intricata R. H. Anderson—(1) Gidgee hollow, C. 19. 27.6.39. (2) Common
about claypans, C. 20. 28.6.39. (3) Andrewilla, small watercourse, C. 28.
14.7.39. (4) Stony tableland, Mount Gason. 21.7.39. (5) Lake Letty.
8.8.39.

- B. lanicuspis* F. Muell.—(1) Charlotte Waters, 27.5.39. (2) No. 2 bore, Andado, 1.6.39. (3) Abminga, 3.6.39. (4) Stony rise, North Birdsville, 10.7.39. (5) Common on gibber tableland; C. 34. 21.7.39.
- B. paradoxa* (R. Br.) F. Muell.—Gidgee-*Atriplex* hollow; C. 19-20. 28.6.39.
- B. quinquecuspis* F. Muell.—(1) Probably this sp.. Stony rise 4 miles north Birdsville, 10.7.39. (2) Flood plain and watercourse of Diamantina River, Andrewilla Waterhole, 15.7.39. (3) Small sandrise east of Andado Station. A form with the perianth tube almost at right-angles to plane of attachment and to stem. 30.5.39.
- B. patenticuspis* R. H. Anderson—Lake Letty, 8.8.39.
- B. Tatei* F. Muell.—Stony rise, C. 34; rare, 21.7.39.
- B. uniflora* (R. Br.) F. Muell.—(1) Common about C. 19 in gidgee hollow, 27.6.39. (2) Very common in sand hollows; C. 24. 5.7.39. (3) About Diamantina, Burt's Waterhole; C. 29. 15.7.39.
- var. *incongruens* J. M. Black—(1) Abminga Creek, 3.6.39. (2) Watercourse at Charlotte Waters. 27.5.39.
- Babbagia acroptera* F. Muell. et Tate—(1) Claypan, samphire gypseous hollows near C. 20. 28.6.39. (2) Edge of sandhills, C. 38. 26.7.39.
- B. dipterocarpa* F. Muell.—Andado Creek, 1.6.39.
- Kochia aphylla* R. Br.—Rare on flats between ridges; near C. 23. 4.7.39.
- K. coronata* J. M. Black—Sandy watercourse, Charlotte Waters, 27.5.39.
- K. Georgei* Diels—Abminga, 3.6.39.
- K. lanosa* Lindl.—(1) Gidgee hollows near C. 11. 19.6.39. (2) Gidgee hollows near C. 18. 26.6.39.
- K. pentagona* R. H. Anderson—Common on gibber plain between Goyder's Lagoon and C. 33. 19.7.39.
- K. planifolia* F. Muell.—C. 34. 21.7.39.
- K. pyramidata* Benth.—C. 34. 21.7.39.
- K. tomentosa* (Moq.) F. Muell.—(1) C. 3; probably this sp. 8.6.39. (2) C. 34. 21.7.39.
- var. *appressa* (Benth.) J. M. Black—(1) Gypseous hollows. 28.7.39. (2) Low edge of Warburton; C. 42. 29.7.39. (3) Edge of gypseous salt claypan between C. 44 and 45. 1.8.39.
- Salsola Kali* L., "Buckbush"—(1) Sandhill near Andado Station, 29.5.39. (2) Near No. 2 Andado Bore, 1.6.39. (3) C. 2. 6.6.39. (4) Near C. 5, with Canegrass, etc, 11.6.39.
- var. *strobilifera* Benth.—(1) Watercourse near Andado H.S. 30.5.39. (2) Abminga, 3.6.39.
- Enchytraea tomentosa* R. Br.—(1) Abminga Creek, 3.6.39. (2) C. 8. 13.6.39. (3) Inter-ridge; C. 9. 17.6.39. (4) C. 19. 27.6.39.
- Threlkeldia inchoata* J. M. Black—Abminga Siding, watercourse, 3.6.39.
- Th. proceriflora* F. Muell.—(1) 5 miles north-east of Charlotte Waters, 28.5.39. (2) Lake Letty, 8.8.39.
- ? *Pachycornia tenuis* (Benth.) J. M. Black—(1) Near C. 2; no fruits present. 6.6.39. (2) 3 miles west of Andado; no fruits present. 31.5.39. (3) "Lake Crocker." 28.6.39. Some spp. of Samphire with insufficient material. — (4) "Lake Crocker." 28.6.39. (5) C. 43. 31.7.39.

AMARANTACEAE

- Trichinium alopecuroideum* Lindl.—(1) Sandhill west of Andado Station, 29.5.39. (2) Flat between sandridges east of Andado Homestead, 30.5.39. (3) Very common between sandhills; C. 1 and on. 6.6.39.
- var. *rubriflorum* J. M. Black—(1) Very common in a sandy watercourse; C. 2. 6.6.39. (2) Common; C. 14. 23.6.39.

- T. exaltatum* (Nees.) Benth.—(1) Stony slopes by Finke River. 30.5.39. (2) Edge of watercourse, Finke River, Crown Pastoral Co. 2.6.39. (3) Sandy watercourse; C. 2. 6.6.39.
- T. obovatum* Gaudich.—Flat east of C. 22. 4.7.39.
var. *grandiflorum* Benth.—(1) Andado Station. 28.5.39. (2) Tableland gutters. 13.6.39. (3) Towards crest of ridge. 19.6.39.
- T. corymbosum* Gaudich.—Abminga Siding. 3.6.39.
- T. helipteroides* F. Muell. var. *minor* J. M. Black—(1) Abminga. 3.6.39. (2) Tableland east of C. 4. 9.6.39.
- T. macrocephalum* R. Br.—(1) Abminga. 3.6.39. (2) Watercourse east of C. 4. 9.6.39.
- T. semilanatum* Lindl.—Charlotte Waters. 27.5.39.

Ptilotus latifolius R. Br.—(1) Sandridges east of Andado. 30.5.39. (2) Very common on all canegrass sandhills between Andado and C. 10. 18.6.39.

The identity of this species has been checked carefully with specimens in the Tate Herbarium and seems in no doubt whatever. It has, on the rim of the staminal cup, alternating with the filaments, an equal number of membranous, divaricate teeth; specimens in the Tate Herbarium, on examination, proved also to have these membranous teeth. The interest lies in the fact that this was not mentioned by J. M. Black or by Bentham; indeed, Bentham probably did not know the plant very well, it is somewhat rare. Bentham described the genus *Ptilotus* as being *without* intervening teeth between the stamens; in the very closely related genus *Trichinium* he has a small section *Squamigera*, to include the species showing this character, which, however, he does not consider of absolute generic importance.

- P. Murrayi* F. Muell. var. *major* J. M. Black—At Eleanor Creek along edge of sandhill; C. 27-28.
- Amarantus grandiflorus* J. M. Black—(1) Charlotte Waters, creek or watercourse. 27.5.39. (2) First sandhill west of Andado. 29.5.39. (3) Towards crest of sandridge; C. 11. 19.6.39.
- A. Mitchellii* Benth.—Watercourse between Charlotte Waters and Andado Station. 28.5.39.
- Alternanthera angustifolia* R. Br.—Sandy watercourse, Charlotte Waters. 27.5.39.
- A. nodiflora* R. Br.—(1) Indinda Well, Andado Station. 31.5.39. (2) Andrewillia Waterhole. 14.7.39.

NYCTAGINACEAE

- Boerhaavia diffusa* L.—(1) Inter-ridge watercourse near Andado H.S. 30.5.39. (2) On Box Flat, overflow of Finke River, near Charlotte Waters. 2.6.39. (3) Very common in flood plain of Hale River; C. 3. 7.6.39.

PHYTOLACCACEAE

- Codonocarpus cotinifolius* (Desf.) F. Muell.—Hay River, sandy bank at edge of flood plain. 24.6.39.

AIZOACEAE

- Carpobrotus aequilaterus* (Haw.) N. E. Br. (*Mesembrianthemum aequilaterale*, Haw.)—East side of Lake Eyre; low, undulating, sandy country.
- Tetragonia expansa* Murr.—Cowarie, Derwent Creek; C. 37; "Wild Spinach." 25.7.39.
- Aisoon quadrifidum* F. Muell. (*Gunniopsis quadrifida* (F. Muell.) Pax)—Gypseous hollow; C. 41. 28.7.39.

- Trianthema decandra* L.—(1) Watercourse, Charlotte Waters. 27.5.39. (2) On sandhill about Burt's Hole. 15.7.39.
T. crystallina Vahl—Charlotte Waters. 27.5.39. var. *clavata*, J. M. Black; C. 33. 19.7.39.
T. pilosa, F. Muell.—(1) Sandhill near Andado. 28.5.39. (2) Sandy watercourse near C. 2. 6.6.39.
Glinus lotoides Loefl.—(1) Small Box Swamp, near Andado H.S. 30.5.39. (2) C. 28 or 29.

PORTULACACEAE

- Calandrinia ptychosperma* F. Muell.—(1) Andado. 1.6.39. (2) Common, 7-mile Creek. 18.7.39.

- Portulaca intraterranea* J. M. Black—"Munyeroo"; C. 2. 6.6.39.

Great mats of "Munyeroo" were seen around the claypans at C. 11. This common name is applied to various succulent Portulacaceae; good camel fodder (13).

- P. olcracea* L. probably—Watercourse, Charlotte Waters. 27.5.39.

CARYOPHYLLACEAE

- Polycarpha corymbosa* (L.) Lamk.—Sandy watercourse, Charlotte Waters. 27.5.39.

CAPPARIDACEAE

- Palauisia viscosa* (L.) DC. Andado Station. 31.5.39.

CRUCIFERAE

- Blennodia eremigena* (F. Muell.) Benth.—(1) Flood flats near Cowarie Station. 24.7.39. (2) Edge of small claypan, flowers white. 27.7.39.

- B. blennodioides* (F. Muell.) Druce (*B. lasiocarpa* F. Muell.), Trans. Roy. Soc. S. Aust., 62, (1), 101, 1938—(1) 7-mile Creek. 18.7.39. (2) C. 38. 26.7.39.

- B. pterosperma* J. M. Black—(1) Sandy watercourse, Charlotte Waters. 27.5.39. (2) C. 11. 19.6.39. (3) Very common on sandhills about the Diamantina from Birdsville to Andrewilla Waterhole. A "Wild Stock." 14.7.39. (4) C. 38. 25.7.39.

- B. filifolia* (F. Muell.) Benth.—(1) C. 33, 21.7.39. (2) C. 42. Junction of Macumba and Warburton River. 29.7.39.

- Menkea sphaerocarpa* F. Muell.—7-mile Creek. Flower white. 18.7.39.

- Lepidium rotundum* DC.—(1) Watercourse, Charlotte Waters. 27.5.39. (2) Abminga. 3.6.39. (3) Edge of sandhills along Eleanor River; C. 27-28. 12.7.39. (4) Goyder's Lagoon. 16.7.39.

- Stenopetalum nutans* F. Muell.—Very common on flats east of C. 22. 4.7.39

LEGUMINOSAE

MIMOSOIDEAE

- Acacia brachystachya* Benth. "Umbrella Mulga"—(1) "Mulga." Sandy watercourse near C.2. Tree to 4 m. high.; pods absent. 6.6.39. (2) "Mulga." Very spreading habit. 7.6.39.

- A. Cambagei* R. T. Baker. "Gidgee"—(1) Abminga. (2) Edge of tableland and Hale flood plain. Tree to 5 m. high. 8.6.39.

- A. colletioides* A. Cunn.—(1) Sandhills near C. 40 and 41. 28.7.39. (2) Sandhills about Lake Eyre; C. 48. 4.8.39.

The legumes with these specimens are abnormally large for the species, up to 18 mm. broad and 12 cm. long and curled; they are not attached to the twigs bearing the phyllodes.

A. dictyophleba F. Muell.—(1) Shrub 1 m. high. Sandhills north-east of Andado Bore No. 1. 5.6.39. (2) Sandridge in Desert proper; C. 6. Tree to 2 m. high. 11.6.39. (3) Towards crest of ridge, C. 11. 19.6.39.

The phyllodes of these specimens are larger than usual, up to 7 cm. long and 1.5 cm. broad.

A. estrophiolata F. Muell. "Ironwood"—Flood plain of Hale; C. 3. 7.6.39.

A. Kempeana F. Muell. (in the absence of fruits)—Creek near C. 2. 6.6.39.

A. ligulata A. Cunn.—(1) "Sandhill Wattle," between Andado H.S. and Finke River, 2.6.39. (2) Between C. 1 and C. 2. 6.6.39. (3) Near crest of sandridge (west side); C. 6. Tree to 2 m. high. 11.6.39.

A. ligulata A. Cunn. or *A. salicina* Lindl.—(1) Near bore at Andado Homestead. 29.5.39. (2) Sandy creek near C. 3. To 2 m. high. 8.6.39.

These two specimens are without pods and difficult to name exactly.

A. Murrayana F. Muell.—(1) Andado Station. 29.5.39. (2) C. 6. 11.6.39.

A. patens F. Muell.—Common between C. 6 and C. 8. Seldom more than 1 m. high.

A. peuce F. Muell., Fragm. iii, "The Sheoaks," J. M. Black. (1) Andado Station. (2) North of Birdsville.

These are the two classic localities for this rare species. Fruits, but no flowers; the latter have never been described. *Loranthus* q.v. (Mistletoe), on tree. J. M. Black quotes phyllodes to 25 cm. long, these specimens have them 30 and 40 cm. long; v. introductory remarks. Madigan (1945, 122) states that there are only 50 or so trees remaining at each of the two localities.

A. salicina Lindl.—(1) Flood plain of Finke, near Charlotte Waters. Small, drooping tree, 2 m.-3 m. high. 2.6.39. (2) Finke overflow between Charlotte Waters and Mayfield Swamp. Sometimes slightly drooping. 2.6.39. (3) Common along Warburton River; also collected at Kuddaree Waterhole on the Mulligan. 23.7.39.

? *A. stenophylla* A. Cunn.—Kaliduwarry, Kuddaree Waterhole, Georgina River. Tree about 3 m. high. Identification uncertain in absence of pods. 29.6.39.

A. tetragonophylla F. Muell. "Dead Finish"—Swamp between Charlotte Waters and Andado Station. The phyllodes are unusually long—up to 6 cm. 2.5.39.

A. Wattiana F. Muell. (probably this species in the absence of fruits)—5 miles east of Hay River; C. 17. 24.6.39.

? *A. aff. teretifoliae* Benth. (no flowers or fruits)—C. 34. Tree 3 m. high, on stony rise. 21.7.39.

Neptunia monosperma F. Muell.—In small watercourse, Charlotte Waters. 2.5.39.

CAESALPINIOIDEAE

Cassia pleurocarpa F. Muell. "Sandhill legume."—(1) Very common on sandhills at Andado Station; C. 1. 6.6.39. (2) C. 10. 18.6.39. (3) C. 13. 21.6.39.

C. desolata F. Muell.—(1) West of Andado. 31.5.39. (2) Creek near C. 2. 6.6.39. (3) Stony flats near C. 23. 4.7.39. (4) Near Lake Eyre North; C. 49. 5.8.39.

C. Sturtii R. Br.—Abnitinga Creek. 3.6.39.

C. Sturtii R. Br. var. *involucrata* J. M. Black—Common on gibber plains; C. 33. 19.7.39.

Some of the specimens of *C. desolata* and *C. Sturtii* are very difficult to separate.

C. eremophila A. Cunn.—(1) Andado Homestead. 29.5.39. (2) Common between sandridges; C. 7. 12.6.39. (3) C. 14. 22.6.39. (4) Flood plain of Hay River. (In this specimen leaflets are unusually long—up to 8 cm.) 24.6.39. (5) Stony watercourse, Birdsville. 9.7.39. (6) In creeks; C. 34. 21.7.39. (7) C. 49, near Lake Eyre North (also has leaflets to 7 cm. long). 5.8.39. (8) Near Lake Eyre North; C. 49 (leaflets up to 6 cm. long). 6.8.39.

Specimens 3, 5 and 6 have unusually broad leaflets, up to 5 mm. wide.

C. artemisioides Gaertn.—Abminga.

Bauhinia Carronii F. Muell. "Queensland Bean," "Bean Tree."—Not in flower, pods and leafy shoots only. Occurs along Eyre Creek, Kaliduarry Station; C. 20. 29.6.39.

PAPILIONATAE

Crotalaria Cunninghamii R. Br. "Bird Flower."—(1) Slope of sandridge east of Andado Station. 29.5.39. (2) "Parrot Bush" or "Felt Bush." Common on sandhills from Andado Station to C. 8. 13.6.39. (3) Andrewilla, sandridges. 14.7.39.

C. Mitchellii Benth.—Box flat near Georgina River; C. 21. 2.7.39.

C. dissitiflora Benth. A species with a wide range of forms.—(1) Sandhill saddle, Andado Station. (2) Poisonous pod. Sandhills, Andado Bore. 1.6.39. (3) Common on sandridges; C. 8. 13.6.39. (4) C. 15. 23.6.39. (5) "Broombush." Much greyer in appearance than further west. Sandhills about Georgina; C. 21. 2.7.39. (6) Sandy part, 7-mile Creek. 18.7.39.

Pritzel (Ferde, Report. xv, 356, 1918) has distinguished the species *C. Strehlowii* Pritzel, which differs from *C. dissitiflora* Benth. mainly in being glabrous and in having leaves of only one leaflet. In the above range of specimens, however, there occur glabrous, slightly pubescent and densely grey-pubescent forms. Also, some of the glabrous forms have three leaflets; in all cases the terminal leaflet is larger than the other two. Although some of the above specimens conform to the description of *C. Strehlowii*, we prefer to follow J. M. Black and include them all under *C. dissitiflora*.

C. Novae-Hollandiae DC.—Sandhill, Andado Station. 28.5.39.

Trigonella suavissima Lindl.—(1) Georgina River about Kuddaree Waterhole; C. 20. 29.6.39. (2) Goyder's Lagoon; C. 30. 16.7.39. (3) Lake Letty, "Claver." 8.8.39.

Lotus australis Andr. var. *parviflorus* Benth.—(1) Inter-ridge watercourse near Andado H.S. 30.5.39. (2) Flood plain of the Hale; C. 3. 8.6.39. (3) Common about claypans; C. 20. 28.6.39. (4) Watercourse, Goyder's Lagoon Bore. 18.7.39. (5) Creek; C. 34. 21.7.39. (6) Flats and near claypans. 27.7.39.

Psoralea eriantha Benth.—(1) Sandhills about C. 14. 23.6.39. (2) Common on sandridges about Mulligan River; C. 20. 2.7.39. This specimen has unusually large leaflets, up to 5 cm. long. (3) Sandhills along Diamantina, Burt's Waterhole; C. 29. 15.7.39.

P. cinerea Lindl.—(1) Mayfield Swamp. 28.5.39. (2) Kuddaree Waterhole; C. 20. 29.6.39.

P. patens Lindl.—(1) Finke River Crossing near Andado. Common about swamps. Leaflets very large, up to 7 cm. "Verbine." 2.6.39. (2) Georgina flood plain; C. 21. 2.7.39. (3) Andrewilla Waterhole. 14.7.39. (4) C. 33. 19.7.39.

Tephrosia purpurea Pers.—No locality or date.

Sesbania aculeata Poir.—Kuddaree Waterhole, Georgina River; C. 20. 29.6.39.

The species of *Swainsona* were identified by Mrs. Lee as follows:

- S. rigida* (Benth.) J. M. Black—(1) Common on sandridges after C. 17. 27.6.39. (2) Common on sandhills about Kalamurina Station; C. 40. 27.7.39.
- S. oligophylla* F. Muell., ex Benth.—(1) Watercourse, 1 mile north Andado H.S. 30.5.39. (2) Sandy watercourse, Charlotte Waters.
- S. microphylla* A. Gray ssp. *tomentosa* A. Lee, MS.—(1) Near Warburton River; C. 37. 24.7.39. (2) Near Kalamurina Station; C. 40. 27.7.39.
- S. microphylla* A. Gray ssp. *affinis* A. Lee MS (*S. affinis* Maiden and Cheel ined.)—(1) Between C. 6 and C. 7. 12.6.39. (2) Near C. 15. 23.6.39.
- S. oroboides* F. Muell. ex. Benth. ssp. *oroboides* A. Lee, MS.—Charlotte Waters. 27.5.39.
- S. stipularis* F. Muell. var. *purpurea* A Lee, MS.—C. 41. 28.7.39.
- S. phacoides* Benth. ssp. *phacoides* A. Lee, MS.—Near C. 2. 6.6.39.
- Glycine sericea* (F. Muell.) Benth.—Sandrise, C. 24, and elsewhere east of Mulligan River. 5.7.39.
- Vigna lanceolata* Benth.—Large creeping herb, common along banks of Finke River, Crown Station. 2.6.39.

GERANIACEAE

- Erodium cygnorum* Nees—(1) Watercourse, Crown Pastoral Co. 2.6.39. (2) Warburton River, Cowarie Station; C. 37. 24.7.39. (3) Lake Letty. 8.8.39.

ZYGOPHYLLACEAE

- Nitraria Schoberi* L. "Nitre Bush."—"Dillon Bush." Gypseous hollows; C. 41. 28.7.39.
- Zygophyllum fruticosum* DC.—Stony rises about Mount Gason. 20.7.39.
- Z. compressum* J. M. Black—(1) Common about "Lake Crocker"; C. 20. 28.6.39. (2) Clayton Branch, North Lake Eyre; C. 50. 6.8.39.
- Z. Howittii* F. Muell.—(1) Finke River. 2.6.39. (2) Sandridge near Andado. 4.6.39. (3) C. 2. 6.6.39. (4) "Lake Crocker"; C. 20. 28.6.39.
- Z. humillimum* M. Koch—Sandhills about Warburton River; C. 37. 24.7.39.
- Z. sp. (aff. *ammophilum*)*—(1) Andado Creek, 10 miles north of homestead. 1.6.39. (2) Edge of watercourse and tableland, Finke River (Crown Pastoral Co.). 2.6.39.

These specimens have affinities with both *Z. ammophilum* F. Muell. and *Z. compressum* J. M. Black. The flowers are four-partite and the filaments eight in number; the fruits are four-angled and very like those of *Z. ammophilum*, they have nearly truncate summits and sharp corners on the angles when immature, these usually round off. The petals (yellow) and sepals are both 3 mm. long, that is, equal as in *Z. ammophilum*. The filaments are like those of *Z. compressum* with the lower part broadened into a membranous wing on either side, ending abruptly in an acute tooth; in *Z. ammophilum*, on the other hand, the filaments gradually broaden towards the base with no teeth. All three types have similar erect, ciliate glands around the ovary. The leaflets of these specimens are ovate-oblong or cuneate and broader than those of *Z. ammophilum*, not appressed to each other, and often notched at the summit, characters not seen in *Z. compressum*. Leaflets are up to 12 mm. long. The petiole is rather broad and flat. As far as could be ascertained, there are one or two seeds in each cell of the ovary.

Mr. J. M. Black has in his collection a fragment of a plant with similar leaves and only one fruit, collected by Captain S. A. White at Dalhousie

Springs in August 1913. The two specimens under discussion were collected in the same region. For the present, they might be considered a broad-leaved variety of *Z. ammophilum*.

Tribulus hystrix R. Br.—(1) Sandhills near Mayfield Swamp, Andado. 28.5.39. (2) Inter-ridge watercourse, Andado. 30.5.39.

MELIACEAE

Owenia acidula F. Muell.—Sandslope near C. 24. "Emu Apple." 5.7.39.

EUPHORBIACEAE

Phyllanthus laciniarius F. Muell.—Kalamurina Station. 27.7.39.

P. sp. Female only—Near C. 38. 26.7.39.

P. Fuermoehrii F. Muell., probably this species.—Andado Station. Female flowers only. 29.5.39.

Ricinus communis L. "Castor-oil Plant."—Andado Station Homestead bore 29.5.39.

Adriana Hookeri (F. Muell.), Muell. Arg. Male and female—Common between C. 5 and 8, but frequently dead. 13.6.39.

Euphorbia Wheeleri Baill.—Very common on all sandridges between Andado and C. 11. 19.6.39.

E. Drummondii Boiss.—(1) Sand plain east of Andado Station. 30.5.39. (2) Abminga watercourse. 3.6.39.

E. eremophila A. Cunn.—(1) Andado Station. 31.5.39. (2) C. 40. (3) C. 41. Probably this sp. in the absence of seed.

E. Macgillivrayi Boiss., Benth. Fl. Aust., 6, 50. "Probably identical and synonymous with *E. hypericifolia*, a cosmopolitan weed" (F. Morris)—Finke River, Crown Pastoral Co. 2.6.39.

SAPINDACEAE

Dodonaea viscosa L.—(1) Occurs rarely on sand slopes all the way across the Desert to C. 12. More common C. 12-13. 21.6.39. (2) C. 18. 26.6.39.

D. attenuata A. Cunn.—C. 50, Clayton River. 6.8.39.

D. microzyga F. Muell.—(1) Stony rise; C. 34. 21.7.39. (2) Near Lake Eyre North; C. 49. 6.8.39.

Atalaya hemiglaucha F. Muell. "Whitewood."—Not collected, but stated by Crocker to have been seen in the Desert sandridge country.

TIKIACEAE

Trifoliate Winneckeana F. Muell., in Append. to Mr. Winnecke's Expl. Diary. 1883. Also F. M. Bailey, Queensland Flora, 1, 156.—(1) Creeping herb common on crest of sandridges about C. 7 and on. 12.6.39. (2) "Bidgee-widgee" (in error on account of the burrs, probably). Very common on top of sandridges; C. 6-8. Flower yellow. 13.6.39.

MALVACEAE

Lavatera plebeja Sims—(1) Finke River, Crown Station. 2.6.39. (2) Lignum Claypan, Mulligan River; C. 20. 29.6.39. (3) Andrewilla Waterhole; C. 28. 14.7.39.

Malvastrum spicatum (L.) A. Gray—Abminga. 3.6.39.

Plagianthus glomeratus (Hook.) Benth.—(1) C. 42. Female flowers only. 30.7.39. (2) C. 48. About arm of Lake Eyre. 4.8.39.

There are two separate branches, bearing respectively male and female flowers.

P. incanus J. M. Black—C. 48. About arm of Lake Eyre. 4.8.39.

Male and female flowers occur on distinct branches at least, probably on distinct plants.

This species was described from material with male flowers only, collected in the Gawler Ranges, Eyre Peninsula. From the present collection, the description in Black's Flora of South Australia may be extended as follows:—"Smallest leaves about 2 mm. long; largest ones 15 mm. long and 11 mm. broad, tapering into a petiole and 3-5-toothed at the summit. Female flowers about the same size as the male ones, corolla only slightly longer than calyx, style branches three with some small abortive anthers around their base." These specimens differ more in appearance from *P. microphyllus* F. Muell. than the plant originally described by Mr. Black, on account of the generally larger leaves. Mr. Black describes the flowers of *P. glomeratus* and another species as bisexual; our experience is that androecium and gynoecium never both fully develop in the same flower, a point made also by Bentham.

Sida corrugata Lindl.—(1) Slope of sandridge east of Andado—an efficient stabilizer. 29.5.39. (2) Very common in all sandhills to C. 3. Inter-ridge watercourse 1 mile north of Andado. 30.5.39. (3) Watercourse, table-land Abminga. 3.6.39. (4) Sandy watercourse near C. 3. 8.6.39. (5) Low and spreading, fairly common on Canegrass sandridges. C. 6 and 7. 12.6.39. (6) Low and spreading, about boundary of stable and unstable portion of ridge; C. 8. 13.6.39. (7) Small, spreading shrub. Gidgee hollow; C. 19. 27.6.39. (8) Spreading, prostrate plant at edge of sandhills and hollows; C. 37. 25.7.39.

S. virgata Hook.—(1) Sandy slope east of Andado. 29.5.39. (2) C. 3. Very common in sandy watercourses and lower parts of sandridges. 8.6.39. (3) Common on sandridges and slopes up to C. 13. 21.6.39

S. intricata F. Muell.—(1) On stony rise, Mount Gason Station. (Probably this sp.) 20.7.39. (2) About 30 cm. high, between C. 46 and 47. 2.8.39.

S. inclusa Benth.—(1) Sandrise 1 mile north-west Indinda Well. Andado Station. 3.5.39. (2) Sandy flat between C. 1 and 2. 6.6.39.

Several species of the genus *Sida* are extremely common in the drier areas of S. Aust., and, no doubt, in contiguous regions of the other States. The majority of these specimens fall into the three species, *S. corrugata*, *S. intricata* and *S. virgata*. *S. corrugata* seems to be the most polymorphic of the three and has in the past been divided into several varieties; in view of the intergrading of the characters used by their authors to separate them, the utility of doing this is questionable, as Bentham himself wrote.

S. intricata, in our experience, preserves its individuality as a small-leaved bush of upright habit.

In his Flora of South Australia, J. M. Black considers *S. pedunculata* A. Cunn. to be a variety of *S. corrugata*, but later (Trans. Roy. Soc. S. Aust., 59, 258, 1935) changes his opinion and raises it to specific rank; the occurrence of the flowers in small or large axillary racemes, quoted as a diagnostic character of this form, is very common in *S. corrugata* and is often associated with smaller leaves and fruits than those described for *S. pedunculata* A. Cunn. As a rule these racemes have very many small linear bracts, giving them a characteristic appearance.

In this Simpson Desert collection, some of the specimens are probably what is described as *S. pedunculata* A. Cunn., but the others are closer to the type; they have all been grouped simply as *S. corrugata* Lindl.

Abutilon otocarpum F. Muell.—(1) Inter-ridge watercourse at Andado Station. 30.5.39. (2) Lower sandhill. Andado Station. 29.5.39.

Hibiscus Krichauffianus F. Muell.—(1) C. 1, sandhills. 6.6.39. (2) At base of sandhills; C. 37. 25.7.39. Also common across Simpson Desert.

STERCULIACEAE

Melhania incana Heyne—(1) Sandy watercourse off tableland; No. 2 Camp. 6.6.39. (2) Common between ridges east of C. 22. 4.7.39. (3) C. 34. 21.7.39.

FRANKENIACEAE

The only genus in this family with which we are concerned is *Frankenia*. It is an extremely difficult one on account of the high degree of general resemblance among the species, making it necessary to resort to microscopic characters for classification.

The only really comprehensive survey of the Australian species was published by V. S. Summerhayes in the Journ. Linn. Soc., 48, 337-388, 1930, q.v. J. M. Black has studied the South Australian members in particular and has described several new species (*v.* especially Trans. Roy. Soc. S. Aust., 56, 43, 1932), and it is hoped that he will soon be in a position to look at this collection of ten gatherings.

The genus is characteristic of the Mediterranean, and desert zones of Australia and other parts of the world. None, however, were found in the Desert proper.

Only the practised expert can hope to come to sound conclusions about the identification of the species of *Frankenia*, and in the meantime tentative suggestions alone will be made for the naming of these specimens.

- A. Near *F. gracilis* Summerh. or *F. Sturtii* Summerh.—(1) C. 33. 19.7.39.
(2) Edge gypseous salt claypan; C. 45. 1.8.39.
- B. Probably *F. hamata* Summerh.—Small shrub, Abminga. 3.6.39.
- C. Near *F. orthotricha* J. M. Black.—C. 43; edge flood, gypseous claypan. 31.7.39.
- D. Near *F. gracilis* Summerh.—Claypan area near Rabbit Board Fence and "Lake Crocker"; C. 29. 28.6.39.
- E. Near *F. gracilis* Summerh. But unlike *F. gracilis*, these plants have terete leaflets up to 16 mm. long. They also have white flowers in contrast to all the other specimens collected, which had pink flowers.—(1) Common at edge of compact white sandhills near Warburton River; C. 37. 24.7.39.
(2) Banks of lower Warburton and gypseous sand-hollows; C. 42. 29.7.39.
(3) Edge of gypseous claypan between C. 44 and 45.
- F. Near *F. foliosa* J. M. Black and *F. muscosa* J. M. Black—Small dense shrub 10-15 cm. high. "Lake Crocker"; C. 20. 28.6.39.
- G. Near *F. subteres* Summerh. and *F. foliosa* J. M. Black—Edge gypseous claypan; C. 45.

THYMELAEACEAE

Pimelea trichostachya Lindl.—(1) Diamantina; C. 28 and 29. (2) Sandy watercourse, near C. 34. 21.7.39.

LVTTIACEAE

Lythrum Hyssopifolia L.—C. 29; Diamantina. 15.7.39.

Ammannia multiflora Roxb.—(1) Edge of channel of Abminga Creek. 3.6.39.
(2) C. 28 or 29; Diamantina. 14.7.39.

MYRTACEAE

Melaleuca glomerata F. Muell.—Paperbark teatree, Finke Channel, Crown Pastoral Co. 2.6.39. Rather rare here.

Eucalyptus pyrophora Benth.—(1) "Bloodwood." Tree with rough, brown bark, 9 m. - 12 m. high; C. 3. 8.6.39. (2) "Bloodwood." Rare, hollow between C. 17 and 18; rough bark, tree 9 m. high. 26.6.39.

E. Coolabah Blakely and Jacobs. W. F. Blakely, Key to the Eucalypts, 245. Sydney, 1934. (These specimens would formerly have been included in *E. microtheca* F. Muell.)—(1) "Desert Box." Swamp, Andado Station. 28.5.39. (2) Creek, flood plain or swamp between C. 6 and 7. Tree to 5 m. high. 12.6.39. (3) Between sandhills from C. 12-13. Entirely smooth-barked. 21.6.39. (4) Tree 7-9 m. high. Flood plain of Hay River. A little rough bark at base of grey-white trunk and branches; C. 16. (v. Madigan, 1945, pl. viii, fig. 1.) 24.6.39. (5) "Box." Georgina River (Queensland). Tree to 6 m. high. Stem rough-barked, branches smooth; C. 20. (Madigan, 1945, pl. viii, fig. 2.) 29.6.39. (6) Tree to 12 m. high. Box habit. Eleanor Creek, S. Aust.; C. 27. 13.7.39. (7) Tree, 6 m. - 9 m. high. Box habit. About junction of the Warburton and Macumba Rivers near Lake Eyre; C. 42. 29.7.39.

Thryptomene Maisonneuvei F. Muell.—(1) Between Andado Bore No. 1 and the Illitera, amongst canegrass sandhills. 5.6.39. (2) C. 18; between sandridges. 26.6.39.

HALORRHAGIDACEAE

Halorrhagis Gossei F. Muell.—Between C. 9 and C. 10. 18.6.39.

H. heterophylla Brongn.—(1) Very common on flood plain of Hale River; C. 3. 7.6.39. (2) Warburton River. 23.7.39.

Myriophyllum verrucosum Lindl.—Hale River Channel; an aquatic and swamp plant. 9.6.39.

UMBELLIFERAE

Didiscus glaucifolius F. Muell.—(1) Near C. 2, in sandy watercourse at edge of sandhills. 6.6.39. (2) Watercourse near C. 34. 21.7.39.

GENTIANACEAE

Erythraea Centaurium Pers.—Andrewilla Waterhole. 14.7.39.

CONVOLVULACEAE

Convolvulus erubescens Sims. "Australian Bindweed."—(1) Inter-ridge watercourse near Andado Station homestead. 30.5.39. (2) Common in flood plain of Hale River; C. 3. 7.6.39. (3) Common on sandhills about Diamantina, Burt's Hole. 15.7.39. (4) Flood flats near Cowarie Station. 24.7.39.

Ipomoea Muelleri Benth.—(1) Sandy watercourse; C. 3. 8.6.39. (2) Common on Hay River flood plain; C. 15. 23.6.39.

BORAGINACEAE

Heliotropium tenuifolium R. Br. var. *parviflorum* J. M. Black, Proc. Roy. Soc. S. Aust., 57, 1933—Near Indinda Well. 31.5.39.

Trichodesma zeylanicum (Burm.) R. Br.—(1) 10 miles north of Andado. 1.6.39. (2) 8 miles north-east of Bore No. 1, Andado. 5.6.39.

VERBENACEAE

Newcastlia cephalantha F. Muell.—C. 17. 25.6.39.

N. spodiotricha F. Muell.—No locality.

Dicrastylis Doranii F. Muell. var. *eriantha* F. Muell.—Between C. 16 and 17. 25.6.39.

LAMIACEAE

Teucrium racemosum R. Br.—(1) Andado Station. 28.5.39. (2) Waterplain of Georgina near Kaliduwarry Station; C. 20. 29.6.39.

Mentha australis R. Br. "Blackfellows' Tea Plant."—(1) Diamantina; C. 28 or 29. (2) Andrewilla Waterhole. 14.7.39.

SOLANACEAE

Solanum ellipticum R. Br.—(1) Very common on tableland watercourse, Abminga. 3.6.39. (2) Mulga flat; C. 5. 11.6.39. (3) Hay River. 24.6.39. (4) Gibber plain. 19.7.39.

S. esuriens Lindl.—(1) Charlotte Waters. 27.5.39. (2) C. 16. 24.6.39.

S. coactiliferum J. M. Black—C. 14. 22.6.39.

S. chenopodinum F. Muell.—Gidgee hollow; C. 19. 27.6.39.

Datura Leichhardtii F. Muell.—Finke River Bed (Crown Pastoral Co.).

? *Nicotiana Goodspeedii* Wheeler (Trans. Roy Soc. S. Aust., 60, 169, 1936)—C. 34. Identification doubtful in absence of lower leaves. 21.7.39.

N. ingulba J. M. Black, loc. cit.—Charlotte Waters. 27.5.39.

N. velutina Wheeler, loc. cit.—(1) Near Andado. 2.6.39. (2) Claypan country near Rabbit Board Fence; C. 20. 28.6.39.

SCROPHULARIACEAE

? *Mimulus* sp. Fragments only—Very common in Canegrass Swamp, Goyder's Lagoon. 17.7.39.

Morgania glabra R. Br.—(1) Common on flood plain of Hay River; C. 15. 23.6.39. (2) Near Mount Gason Bore. 20.7.39 (3) C. 42, Macumba-Warburton. 30.7.39.

MYOPORACEAE

Myoporum montanum R. Br.—Shrub to 2 m. high, Mount Gason Head Station, 20.7.39.

Eremophila Latrobei F. Muell.—(1) C. 2; near tableland. 6.6.39. (2) C. 5. (3) Sandridge; C. 5. 9.6.39. (4) Common in hollows east of Hay River; C. 18. 26.6.39. The corolla lobes are distinctly acute in many of these specimens.

E. longifolia (R. Br.) F. Muell.—(1) Banks of Finke River, Crown Pastoral Co. 2.6.39. (2) Sandy creek off tableland near C. 3. 8.6.39. (3) C. 7. Common, but irregularly so. 12.6.39. (4) C. 8. 13.6.39.

E. Willsii F. Muell.—(1) On stabilized sandrise east of Andado. 30.5.39. (2) Very common between C. 6 and 7. 12.6.39.

The branches in these specimens are glabrous instead of glandular-hairy. (Also noted by von Mueller in the botanical appendix to Winnecke's journal of his 1883 expedition in this region.)

E. Freelingii F. Muell.—Very common on tableland country. Collected near Finke River (Crown Station). 2.6.39.

E. bignoniiflora (Benth.) F. Muell.—(1) Common about waterholes along Diamantina; C. 28 and 29. 14.7.39. (2) C. 36; Warburton River. 23.7.39.

E. Duttonii F. Muell.—Tableland near Clayton River. 6.8.39.

E. maculata (Ker.) F. Muell.—(1) Charlotte Waters. 27.5.39. (2) C. 24. 5.7.39.

E. MacDonnellii F. Muell.—(1) Base of sandhill east of Andado Station. 30.5.39. (2) Hale flood plain. 7.6.39. (3) C. 47 and 48. 4.8.39.

var. *glabriuscula* J. M. Black—(1) 8 miles north-east of Andado Bore No. 1. 6.6.39. (2) Common in flood plain of Todd River, between C. 2 and 3. 7.6.39.

E. Strehlowii E. Pritzel, Fedde Repert., 15, 356, 1918—Common on sandridges and slopes between C. 12 and C. 13. 21.6.39.

E. strongylophylla F. Muell., Fragm. Phyt. Aust., 10,—(1) Small watercourse; C. 2. 6.6.39. (2) Common in sandy mulga country near C. 5. 9.6.39.

PLANTAGINACEAE

Plantago varia R. Br.—(1) Watercourse near Andado H.S. 30.5.39. (2) Sandhill along Eleanor Creek; C. 28. 14.7.39.

CUCURBITACEAE

Melothria maderaspatana (L.) Cogn.—Common in flood plains of Hale and Todd, and occasionally between sandridges; C. 3. 7.6.39.

Cucumis Melo L. var. *agrestis* Naud.—“Ulcardo Melon,” Finke River. 2.6.39.

CAMpanulaceae

Wahlenbergia Sieberi A., DC., Proc. Roy. Soc. S. Aust., 58, 182, 1934—Watercourse near Warburton; C. 38. 25.7.39.

W. quadrifida (R. Br.) A., DC., loc. cit.—7-mile Creek. 18.7.39.

GOODENIACEAE

Goodenia lunata J. M. Black—Andado Creek. 1.6.39.

G. subintegra F. Muell.—(1) In Canegrass Swamp, Goyder's Lagoon. 17.7.39. (2) Common at 7-mile Creek. 18.7.39. (3) In small, sandy watercourse; C. 34. 21.7.39.

G. cycloptera R. Br.—(1) Sand-dune, Andado Station. 29.5.39. (2) Sandhill 8 miles north-east of Andado Bore No. 1. 4.6.39. (3) Very common on sandridges; C. 6. 11.6.39. (4) Common on sandhills near Diamantina and Eleanor, C. 28, Andrewilla. 14.7.39.

Calogyné Berardiana (Gaudich.) F. Muell.—(1) Watercourse, Charlotte Waters. 27.5.39. (2) Among Needlebush on sandy rise in tableland country near C. 2. 6.6.39. (3) C. 5. 9.6.39.

Leschenaultia divaricata F. Muell.—Common in flood plains of Hale, Todd, and also at base of sandridges. (1) Andado Station sandhill, eastern slope. 29.5.39. (2) Sandhill, 10 miles north of Andado Station. 1.6.39.

Scaevola spinescens R. Br.—Rise on stony tableland, C. 34, Mount Gason. 21.7.39.

S. depauperata R. Br.—(1) Sandhill, C. 5, with Porcupine Grass and low Mulga. Glabrous form. 9.6.39. (2) Between sandridges; C. 8. Rough, hairy form. 13.6.39. (3) Sandrises near C. 18. Glabrous form. 26.6.39.

S. collaris F. Muell.—(1) Common on sandy banks about “Lake Crocker”; C. 20. 28.6.39. (2) C. 40, gypseous hollow. 27.7.39.

S. ovalifolia R. Br.—Very common in flood plains of Todd and Hale, and in some of the sandflats between. (1) C. 3. 7.6.39. (2) Slope of sandridge, C. 20, Mulligan River. 29.6.39. (3) Diamantina; C. 28 and 29. (4) Sandy watercourse near C. 34. 21.7.39.

BRUNONIACEAE

Brunonia australis Sm.—Common in sandy mulga country near C. 5. 9.6.39.

COMPOSITAE

Minuria denticulata (DC.) Benth.—(1) Watercourse, Charlotte Waters. 27.5.39. (2) Watercourse, Andado. 30.5.39. (3) Tableland water-

- course, Abminga, S.A. 3.6.39. (4) 7-mile Creek, near Goyder's Lagoon Bore. Common. 18.7.39. (5) Small, bushy plant about 23 cm. high. Claypan, gypseous hollow, C. 41. 28.7.39.
- M. staedifolia* F. Muell.—Small, bushy plant about 30 cm. high. Near gypseous salt claypan between C. 44 and 45. 1.8.39.
- M. leptophylla* DC.—On stony gibber country; C. 34. 21.7.39.
- M. integrerrima* (DC.) Benth.—In creek channel, Abminga. 3.6.39.
- Calotis crinacea* Steetz—Fairly common along sandridges from Andado to C. 7. 12.6.39.
- C. lotiuscula* F. Muell. et Tate—In Dillon Bush hollow near C. 45. 1.8.39.
- C. hispidula* F. Muell.—About the dumps, Indinda Well, Andado Station. 3.6.39.
- Senecio lautus* Sol.—(1) Kuddaree Waterhole, Georgina River, Kaliduwarry; C. 20. 29.6.39. (2) Andrewilla; C. 28. 14.7.39. (3) Goyder's Lagoon. 16.7.39.
- S. Cunninghamii* DC.—Shrub about 1 m. high along Warburton River. 23.7.39.
- S. Gregorii* F. Muell.—(1) Charlotte Waters. Sandy watercourse. (2) C. 3. 7.6.39. (3) Hale Channel; C. 4. 9.6.39. (4) Common on sandhill watercourses about Cowarie Station; C. 38. 26.7.39.
- S. magnificus* F. Muell.—Lake Letty Bore. 8.8.39.
- Pterigeron cylindriceps* J. M. Black—Charlotte Waters; watercourse. Creeping herb.
- P. adscendens*, Benth.—(1) Charlotte Waters; watercourse. 27.5.39. (2) Bore at Andado.
- P. latroides* (Turcz.) Benth.—(1) Watercourse, Charlotte Waters. 27.5.39. (2) Andado Creek, 10 miles north of homestead. Spreading herb, mauve flower.
- Epaltes Cunninghamii* (Hook.) Benth.—Rare, small scraggy shrub about 75 cm. high, Andrewilla, banks of waterhole. 14.7.39.
- Sphaeranthus indicus* L.—About waterholes along Diamantina River; C. 26. 12.7.39.
- Helipterum moschatum* (A. Cunn.) Benth.—(1) Sandy tableland between C. 4 and 5. 9.6.39. (2) Between sandridges near C. 8. 13.6.39. (3) Common along sandhill edge, Eleanor Creek; C. 28. 12.7.39. (4) C. 48. 4.8.39.
- H. stipitatum* F. Muell.—(1) Sandy mulga watercourse; C. 5. 9.6.39. (2) Common between C. 4 and 5. 9.6.39.
- H. pterocheatum* (F. Muell.) Benth.—(1) Sandy dissected tableland east of C. 4. 9.6.39. (2) Stony rise; C. 34. 21.7.39.
- H. floribundum* DC.—(1) Sandy watercourse, Charlotte Waters. 27.5.39. (2) Inter-ridge watercourse near Andado H.S. 29.5.39. (3) Common on tableland and creeks near C. 2. 6.6.39. (4) Flood flats between Warburton River and Cowarie Station. Very common. 24.7.39. (5) Off edge of gypseous salt claypan; C. 45. 1.8.39.
- H. strictum* (Lindl.) Benth.—Andrewilla; C. 28. 14.7.39.
- H. Charlesya* F. Muell.—(1) Abminga Creek. 3.6.39. (2) Between C. 4 and 5. 9.6.39.
- Ixiolaena leptolepis* (DC.) Benth.—Goyder's Lagoon. 17.7.39.
- Helichrysum apiculatum* (Labill.) DC.—No locality.
- H. ambiguum* Turez. v. *pauisculum* J. M. Black—Fairly common about C. 13. 22.6.39.
- H. semifertile* F. Muell.—Watercourse near C. 34. 21.7.39.
- H. roseum* (Lindl.) Druce v. *Davenportii* Benth.—Between ridges near C. 8 where more rain has fallen. 13.6.39.
- H. podolepideum* F. Muell.—Common on gibber plain. 19.7.39.

- Rutidosis helichrysoidea* DC.—(1) Inter-ridge watercourse, Andado Station.
 (2) Georgina flood plain; C. 21. 2.7.39.
- Myriocephalus Rudallii* (F. Muell.) Benth.—Box Swamp, Andado Station.
- M. Stuartii* (F. Muell. et Sond.) Benth.—(1) Watercourse at Charlotte Waters.
 27.5.39. (2) Andrewilla Waterhole, 14.7.39.
- Gnephosis cyathopappa* Benth.—Box Swamp, Andado Station. Probably this species, but inflorescences immature.
- G. skirrophora* (Sond. et F. Muell.) Benth.—Common about claypan country.
 C. 20. 28.6.39.
- G. eriocarpa* (F. Muell.) Benth.—Watercourse, Charlotte Waters.
- Eriochlamys Behrii* Sond. et F. Muell.—Claypan, gypseous hollow; C. 41.
 28.7.39.
- Craspedia chrysantha* (Schlechtd.) Benth.—Flood plain of Diamantina River;
 C. 29. 15.7.39.

SUMMARY

A botanical list is given of the plants collected by R. L. Crocker on this Expedition, with his field notes. The material was gathered all along the route, from Charlotte Waters just north of the South Australian Border, across the parallel sandridges of the Simpson Desert to the north-east, and then southwards via Birdsville and the eastern side of Lake Eyre to the railway line at Marree; a journey by camel of 800 miles, in the months of June, July and August 1939. Two hundred miles of this lay across the heart of the Desert, hitherto unexplored except by air; it is the most arid of the Australian deserts.

The collection numbers 350 species in 50 families, including Fungi. Of these species, 76 were gathered in the Desert proper and are listed as such; the few new forms were found outside the Desert only, and include a new species of *Atriplex*, *A. cordifolia* J. M. Black. The great majority of the plants was determined at the Herbarium of the Adelaide University Botanical School, with the notable exceptions of Gramineae, Cyperaceae, *Swainsona* and the Fungi, which could be submitted to specialists.

Short lists are included which summarise the itinerary and the plants collected. For a map of the route of the Expedition, see the leader's narrative (Madigan, 1945) (13).

The character plant of the Desert is the bushy, perennial grass, *Triodia Basedowii* E. Pritzel, "Porcupine Grass" or "Spinifex." A variety of shrubs and small trees also occurs, but it is considered that we have not as yet an adequate account of the ephemeral flora which one supposes to be present on rare occasions after rain, though *Portulaca*, "Munyeroo," is evidently part of it, and perhaps also the cruciferous herbs common on the Birdsville track, where good recent rains had fallen. The shrubs and small trees belong chiefly to the families Leguminosae, Chenopodiaceae, Myoporaceae and Proteaceae, in that order.

Reference has been made to earlier collectors on the margins of the Desert, and plants of particular interest, notably the almost extinct *Acacia peuce* F. Muell., have been discussed in the introduction.

In comparison with the other great deserts of the world, the Simpson Desert is tolerably well supplied with vegetation, though it is by no means the most fertile of them. This comparison has been drawn in some detail and, it is hoped, will soon appear as Part II of the present contribution.

ACKNOWLEDGMENTS

It is a pleasure to thank those specialists and colleagues named in the introduction for their contributions to the present account, some of which have been

long delayed in reaching the stage of publication. Mr. Crocker also, the botanist of the Expedition, has given much advice during the preparation of the paper.

In conclusion, the Adelaide University Herbarium is very grateful to Dr. Madigan for the plant collection, and for entrusting it with the important work of determining the specimens.

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EXPLANATION OF PLATES XXVIII, XXIX and XXX

PLATE XXVIII

- Fig. 1 *Triodia Basedowii* ("Spinifex"), the typical Desert vegetation, with *Acacia* sp. on the skyline; C. 12.
 Fig. 2 *Triodia* sp. ("Spinifex") showing a common ring formation.
 Fig. 3 *Hakea leucoptera* ("Needlebush") shrubs at C. 8.
 Fig. 4 *Crotalaria dissitiflora* (A) and *Grevillea stenobotrys* (B); C. 13.

PLATE XXIX

- Fig. 1 *Zygochloa paradoxo* (*Spinifex paradoxus*), "Sandhill Canegrass". Herbarium specimen.
 Fig. 2 *Acacia peuce*, "Waddy", Birdsville.
 Fig. 3 *Acacia peuce*, a group of trees at Andado Bore No. 1.

PLATE XXX

- Fig. 1 *Psoralea patens*, Finke River crossing near Andado Station.
 Fig. 2 *Calotis erinacea*, a sandhill daisy, C. 13.
 Fig. 3 *Acacia Cambagei* ("Gidgee"), with *Triodia Basedowii* ("Spinifex"), C. 18-19.
 Fig. 4 *Blechnodias pterosperma* (A - flowering), *Salsola Kali* (B), and *Zygochloa paradoxo* (C - "Canegrass"), Andrewilla Waterhole.

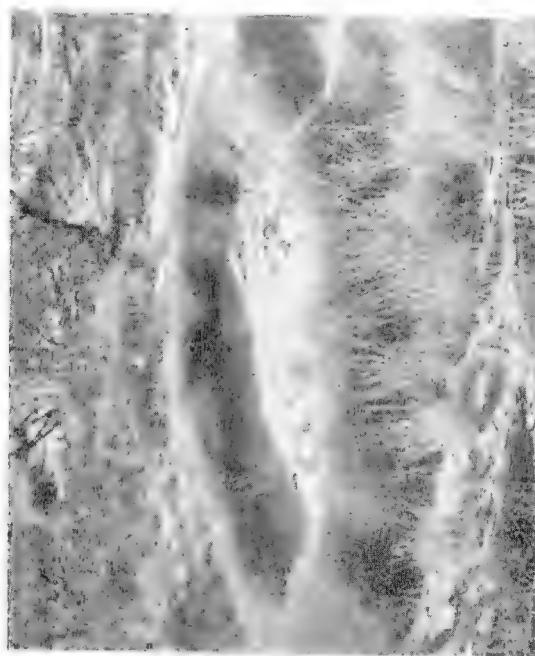
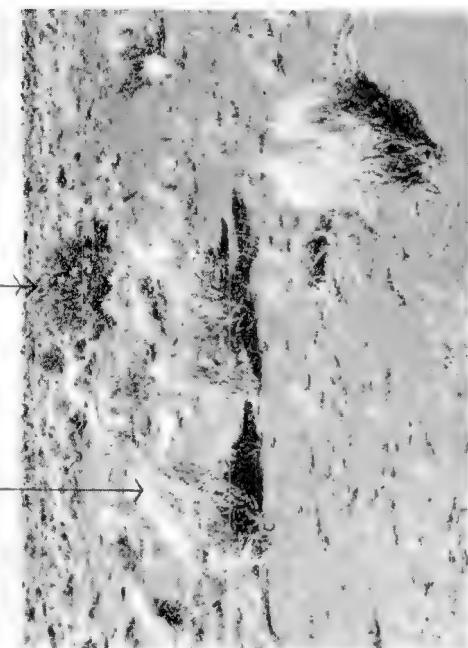


Fig. 1 Photo, C. T. Madigan



Fig. 2 Photo, C. P. McMillan



A
B

Fig. 3 Photo, B. Marshall

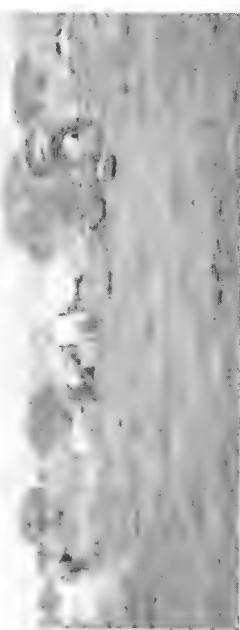


Fig. 4 Photo, D. Marshall



Fig. 1 Photo, K. P. Phillips



Fig. 2 Photo, D. M. Scott



Fig. 3

Photo, E. K. Williams



Fig. 2
Plates D, Messel

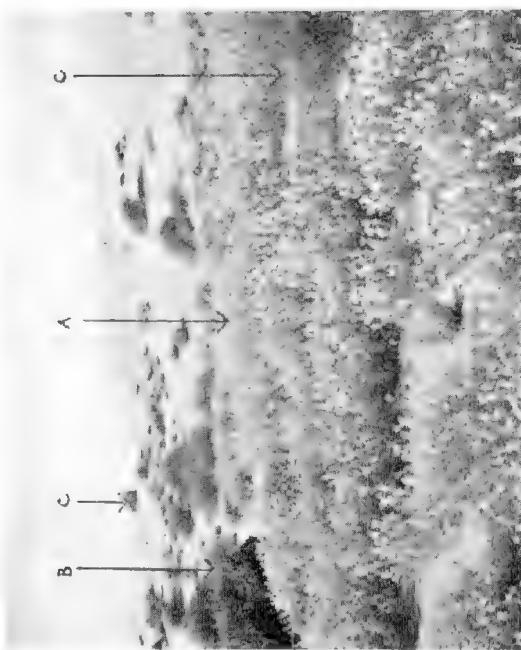


Fig. 3
Plates D, E, F, Messel

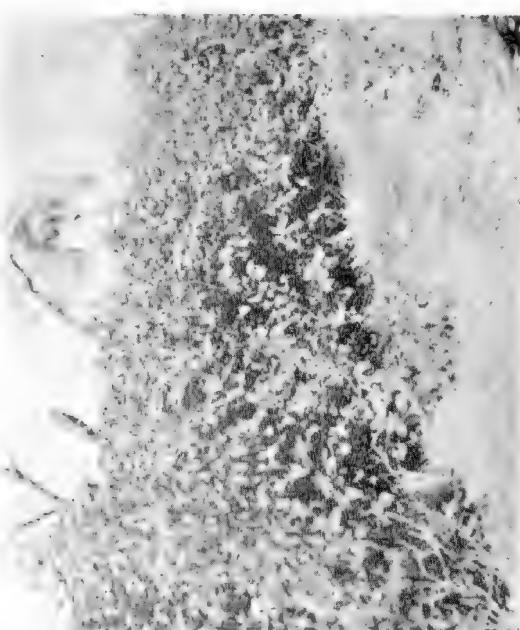


Fig. 4
Plates D, E, F, Messel



Fig. 5
Plates D, E, F, Messel

AN AGE DETERMINATION ON SAMARSKITE FROM MOUNT PAINTER, SOUTH AUSTRALIA

BY A. W. KLEEMAN

Summary

The occurrence of uranium-bearing minerals at Mount Painter was described in a paper by Sir Douglas Mawson (3). In that paper he described as "Fergusonite" a mineral that was analysed by W. S Chapman in 1911 and by the present writer in 1944. Both of these analysis were made on impure material. More recently the writer has obtained from Sir Douglas purer material, on which the present analysis was made.

**AN AGE DETERMINATION ON SAMARSKITE
FROM MOUNT PAINTER, SOUTH AUSTRALIA**

By A. W. KLEEMAN

[Read 9 May 1946]

The occurrence of uranium-bearing minerals at Mount Painter was described in a paper by Sir Douglas Mawson (3). In that paper he described as "Fergusonite" a mineral that was analysed by W. S. Chapman in 1911 and by the present writer in 1944. Both of these analyses were made on impure material. More recently the writer has obtained from Sir Douglas purer material, on which the present analysis was made.

The mineral is associated with monazite, hematite and brown feldspar in a quartz vein and was separated by hand-picking under a binocular microscope. The Samarskite is dark brown in colour, transparent in thin edges and has a resinous lustre. When altered it varies from light brown to yellow, often in the same fragment. There is also a black mineral with a splendid lustre which is probably titaniferous hematite; it was difficult to avoid some grains of this mineral, and some or all of the titania in the analysis may be due to this mineral. There is also the possibility of some feldspar and iron-stained quartz contaminating the powder.

In all about 2 grams of the mineral were obtained for the analysis. This was divided into five portions and different series of constituents were determined on each portion. As the primary object was the determination of lead and uranium, methods were chosen best suited to these two elements. In general the course of analysis follows that recommended by Schoeller (5, 6). The mineral was attacked with pyrosulphate and the melt lixiviated with tartaric acid. The bulk of the lead was found in the residue from this process and was always contaminated by iron sulphates. The remainder of the lead was recovered by treating the filtrate with hydrogen sulphide. In one portion the fusion was leached with dilute hydrochloric acid. This solution contained all of the uranium as well as iron, aluminium, rare earths and some of the lead. The uranium was separated from the rest of the elements precipitated by ammonia by keeping the uranium in solution as a complex with hydroxylamine-hydrochloride after a method of F. Hecht (1). This gave a slightly higher result for uranium than was obtained when uranium was separated after the earth acids and iron had been precipitated. No attempt was made to determine the state of oxidation of the iron or uranium because of the small amount of material. Moreover the mineral was considered to be slightly weathered and probably oxidised.

THE AGE OF THE MINERAL

Three determinations of PbSO_4 gave 0·68%, 0·72%, and 0·80%, with a mean of 0·73%. Four determinations of U_3O_8 gave 10·0%, 10·4%, 10·53% and 10·8%, with a mean of 10·4%. This made the Pb/Ur ratio 0·057, which according to the simple formula $T = \text{Pb}/\text{Ur} \times 7\cdot23 \times 10^9$ years (Keevil, 2) is equivalent to an age of 410 million years. No account is taken for possible contamination by ordinary lead, and in view of this and the difficulties encountered in the analysis, it is suggested that the age be taken as 400 ± 50 million years.

THE FORMULA OF THE MINERAL

The analysis of the mineral is given in Table I, column 1, with an analysis by R. C. Wells of the Samarskite from Glastonbury, Connecticut, in column 2 for comparison. The constituents are listed in order of decreasing ionic radius. The SnO_2 , SiO_2 and Al_2O_3 reported are considered to be impurities. The SnO_2 was insoluble in the original bisulphate fusion, which according to Schoeller (5, 166) is an indication that it is mechanically admixed. Al_2O_3 is possibly derived from the glassware.

TABLE I

| | (1) | (2) | | (1) | (2) |
|--------------------------------|-----|-------|---------------------------------|-------------------------|-------|
| U_2O_6 | - | 10.42 | 7.85 (UO_3) | Fe_2O_3 | - |
| PbO | - | .54 | .34 | Nb_2O_6 | - |
| CaO | - | 2.11 | .33 | Ta_2O_6 | - |
| CeO_3 | - | .38 | .53 (Ce_2O_3) | WO_3 | - |
| La_2O_3 , etc. | - | .18 | 1.55 | TiO_2 | - |
| ThO_2 | - | nill | 3.47 | Al_2O_3 | - |
| Y_2O_3 , etc. | - | 4.93 | 12.47 | SiO_2 | - |
| MnO | - | .43 | 1.75 | H_2O^+ | - |
| SnO_2 | - | 3.36 | | H_2O^- | - |
| FeO | - | 13.16 | 2.11 | Remdr. | - |
| MgO | - | .51 | .02 | | |
| | | | | 100.18 | 99.51 |

The cerium is reported as CeO_3 , as the consideration of ionic radii suggests that the smaller Ce^{IV} ion would more readily fit in the structure.

TABLE II

| | (1) | (2) | (3) | (4) | (5) |
|------------------|-----|------|---------------|------|------|
| Ur & Pb | - | .40 | .29 | .68 | .37 |
| Ca | - | .37 | .05 | .74 | .09 |
| Rare Earths & Th | - | .37 | 1.03 | .85 | 1.61 |
| Mn, Sn, Zr, etc. | - | .06 | .23 | .19 | .22 |
| Fe'' & Mg | - | 1.92 | { .28 1.19 | .66 | 1.55 |
| Fe''' | - | | | | .24 |
| A metals | - | 3.12 | 3.07 | 2.73 | 3.12 |
| Nb | - | 3.75 | 3.08 | 3.79 | 2.17 |
| Ta | - | .12 | .66 | .08 | .52 |
| Ti | - | .02 | .18 | .20 | .09 |
| W | - | | | | .06 |
| B metals | - | 3.89 | 3.92 | 4.26 | 3.87 |
| | | | | | 2.94 |

(1) Mount Painter, South Australia; (2) Glastonbury, Connecticut;
(3) Antanamalaza, Madagascar; (4) Aslaktaket, Norway; (5) Miask, U.S.S.R.

Table II gives the ionic ratios of the elements in the two minerals and in three others quoted in Dana's System (4). The proportions are calculated on the basis of total metals = 7 rather than oxygen = 14, as in several of the analyses the state of oxidation is uncertain. The metals present fall into three groups: Ca, rare earths, Th, Ur and Pb form the first group in which the ionic radii are close to 1.0\AA ; Mn, Sn, Zr, Fe'' and Mg form the second with radii above 0.75 , and the third group contains Nb, Ta, Ti, W and Fe''' all with radius about 0.66 . The Revisors of Dana's System divide the metals into two groups, A and B, placing Nb, Ta, Ti, W, Fe''' in group B. They then divide the minerals into two groups, those in which the ratio A:B = 1:1 and those in which the ratio A:B = 1:2. The former group contains Fergusonite and the latter group Euxenite and Eschynite. They also place Samarskite in the latter group, but in the footnote point out that Machatschki assigns a value of 3:4 to the A:B ratio and that in the Glastonbury mineral the ratio A:B = 2:5 ($\text{A}_2\text{B}_5\text{O}_{14}$). If Fe''' in the Glastonbury mineral is assigned to the A group the ratio is 3.07:3.92. In our

mineral with all the iron in the A group the ratio is 3·12:3·89, but if some of the iron is assumed to be in the ferric state it could approach the 2:5 ratio. However, in view of the slight difference in the ionic radii, the metals of the niobium and the ferrous iron groups should be placed together. This leaves the metals with ionic ratio about 1·0 Å, which may constitute up to one-third of the metals present. Until much more is known of the arrangement of the metallic ions in the structure the only possible classification is a chemical one, and if this is so only Nb, Ta and Ti should be in group B. On the facts presented above it is obvious that any attempt to find a classification in which there is a fixed ratio between the A and B metals is doomed to failure. The proportion of A:B must vary with the average valency of the A metals in order to keep the metal:oxygen ratio at 1:2. Thus if A is divalent $\text{FeO} + \text{Nb}_2\text{O}_5 = \text{FeNb}_2\text{O}_6$; if A is trivalent $\text{Y}_2\text{O}_3 + \text{Nb}_2\text{O}_5 = \text{YNbO}_4$.

In our specimen the average valence of A is just below 3, so that A:B = 3:4. In the Miask Samarskite A:B is 4:3, suggesting an average valence of A above 3. This would be the case if all the ions were reported in the ferric state.

This line of reasoning brings the Samarskite group much closer to Fergusonite and suggests that the only difference between the two groups is the greater amount of rare earths in Fergusonite.

SUMMARY

An analysis is given of Samarskite from the uranium field at Mount Painter. The age determination places the age of the mineralisation in Lower Palaeozoic and infers that the general metamorphism of the area is of the same age. The presence of 10% of uranium in the mineral suggests that it is the primary source of uranium on this field.

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AUSTRALIAN CUMACEA NO. 13⁽¹⁾
THE FAMILY LAMPROPIDAE

BY HERBERT M. HALE, DIRECTOR, SOUTH AUSTRALIAN MUSEUM

Summary

Two species are represented amongst the many Cumacea now available from southern and eastern Australia coasts. Both are referable to *Hemilamprops* and have been taken only between lat. 34°-43° S. and long. 147° -152° E.; the depths range to 120 metres.

AUSTRALIAN CUMACEA. No. 13⁽¹⁾
THE FAMILY LAMPROPIDAE

By HERBERT M. HALE, Director, South Australian Museum

Fig. 1-4

[Read 9 May 1946]

Fam. LAMPROPIDAE

Two species are represented amongst the many Cumacea now available from southern and eastern Australian coasts. Both are referable to *Hemilamprops* and have been taken only between lat. 34°-43° S. and long. 147°-152° E.; the depths range to 120 metres.

Genus HEMILAMPROPS Sars

Hemilamprops Sars 1883, 11 and 55; Stebbing 1913, 55 (ref.).

Hemilamprops is separated from *Lamprops* (Sars, 1863, 239) by male characters only. If *Lamprops carinata* Hart (1930, 34 (12), fig. 4 A-E) is retained in *Lamprops*, then the latter differs from *Hemilamprops* only in that the male lacks pleopods. A few species are referred tentatively to one or other of these genera because the female only is available. A combined key of the females of all species placed in the two genera is therefore given below.

KEY TO FEMALES OF SPECIES OF *Lamprops* AND *Hemilamprops*

- | | | |
|---|--|---|
| 1 | Telson with three spines at distal end. | 2 |
| | Telson with more than three spines at distal end. | 9 |
| 2 | Carapace with at least one ridge on each side, below frontal lobe. | 3 |
| | Carapace with sides smooth. | 7 |
| 3 | Peduncle of uropod subequal in length to telson. | 4 |
| | Peduncle of uropod distinctly longer than telson. | 5 |
| 4 | No distinct antennal notch. Carpus of first pereiopod reaching to level of front of carapace. Peduncle of uropod shorter than endopod. | |
| | <i>H. uniplicata</i> (Sars) | |
| | A distinct antennal notch. First pereiopod shorter, its carpus not nearly attaining level of front of carapace. Peduncle of uropod a little longer than endopod. | |
| | <i>L. (?) beringi</i> Calman | |
| 5 | Carapace with a longitudinal ridge near inferior margin and below a carina running from antero-lateral margin to hinder edge. | |
| | <i>H. gracilis</i> Hart. | |
| | Carapace with no ridge below the carina extending from antero-lateral margin to hinder edge. | 6 |
| 6 | First pereiopod slender, the carpus reaching to level of front of carapace. Peduncle of uropod longer than endopod. | |
| | <i>H. matsoni</i> Hale. | |
| | First pereiopod stout, the carpus not nearly reaching to level of front of carapace. Peduncle of uropod subequal in length to endopod. | |
| | <i>H. lata</i> sp. nov. | |
| 7 | Median dorsal crest of anterior half of carapace not denticulate. | |
| | <i>H. (?) ultimae</i> sp. Zimmer. | |
| | Median dorsal crest of carapace denticulate | 8 |
| 8 | Dactylus of first pereiopod longer than propodus and twice as long as carpus. | |
| | <i>H. cristata</i> Sars | |
| | Dactylus of first pereiopod shorter than propodus and little longer than carpus. | |
| | <i>H. pellucida</i> Zimmer | |

⁽¹⁾ For No. 12 see Rec. S. Aust. Mus., 8, (3), 357-444, fig. 1-60

| | | |
|----|---|----|
| 9 | Telson with five spines at distal end. | 10 |
| | Telson with more than five spines at distal end. | 21 |
| 10 | Peduncle of uropod considerably shorter than telson. | |
| | Peduncle of uropod at least as long as telson. | 11 |
| 11 | Carapace with at least one ridge on each side. | 12 |
| | Carapace without lateral ridges. | 16 |
| 12 | Carapace with not more than two ridges on each side. | 13 |
| | Carapace with three or four ridges on each side. | 14 |
| 13 | Carapace with a single curved ridge on each side below frontal lobe: pseudorostrum short, truncate in front. | |
| | <i>H. (?) californica</i> Zimmer. | |
| | Carapace with two ill-defined curved ridges crossing each branchial region: pseudorostrum longer, tapering to the subacute front. | |
| | <i>L. sarsi</i> Derjavin. | |
| 14 | Uropod with first joint of exopod distinctly shorter than second. | |
| | Uropod with first joint of exopod subequal in length to second. | 15 |
| 15 | First joint of endopod of uropod more than half as long again as combined lengths of second and third joints. | |
| | <i>L. krasheninnikovi</i> Derjavin. | |
| | First joint of endopod of uropod little longer than second and third together. | |
| | <i>I. quadruplicata</i> S. I. Smith (4). | |
| 16 | Peduncle of uropod subequal in length to telson. | 17 |
| | Peduncle of uropod distinctly longer than telson. | 18 |
| 17 | Antero-lateral margin of carapace not dentate. All distal spines of telson truly terminal | |
| | <i>L. fuscata</i> Sars. | |
| | Antero-lateral margin of carapace with five teeth. Two of distal spines of telson situated below the other three. | |
| | <i>I. serrata</i> Hart (5). | |
| 18 | First antenna almost three-fourths as long as carapace. Carpus in posterior pereiopods three times as long as merus. | |
| | <i>I. (?) romana</i> Mimmer (6). | |
| | First antenna not more than half as long as carapace. Carpus in posterior pereiopods at most not much longer than merus. | 19 |
| 19 | Peduncle of uropod longer than endopod. | |
| | Peduncle of uropod shorter than endopod. | 20 |
| 20 | Carapace with denticulate median dorsal crest; eye wanting. Telson not much shorter than peduncle of uropod. | |
| | <i>H. normani</i> Bonnier. | |
| | Carapace without denticulate dorsal crest; eye developed. Telson only half as long as peduncle of uropod. | |
| | <i>L. korroensis</i> Derjavin (7). | |
| 21 | Telson with six spines at distal end. Eye without corneal lenses. | |
| | <i>H. assimilis</i> Sars. | |
| | Telson with eight spines at distal end. Eye with eight corneal lenses. | |
| | <i>H. rosea</i> (Normall) | |

Hemilamprops lata n. sp.

Ovigerous female—Integument thin but calcified and brittle; reticulate pattern somewhat diffuse.

Carapace more than one-fourth of total length of animal, and a little more than pedigerous somites together; it is very broad, half as wide again as deep and as wide as long; on its upper surface a sharp carina runs from the ocular lobe to about middle of length, and terminates at anterior end of a wide median gutter which is margined on each side by a crest-like ridge which extends practically to posterior margin; a short and not very well-defined carina extends from the front of each pseudorostral lobe towards frontal lobe, and from neighbourhood of antennal angle to posterior margin is a rugose ridge resulting from the sudden inflexing of the inferior lateral part of carapace; posterior parts of sides with short, irregular, and not well-defined ridges. Ocular lobe not much wider

(3) See remarks by Calman, 1912, 629. *L. fasciata*, *quadruplicata* and *krasheninnikovi* (Derjavin, 1926, 179, pl. iii, fig. 6, and pl. vi) seem to be very closely related.

(4) *fide* Hart, 1930, p. 14 and fig. 4 F.

(5) Possibly representative of a new genus.

(6) A species from fresh water.

than long and with small corneal lenses. Pseudorostral lobes widely truncate and slightly concave, both as seen from above and from the sides; meeting for a distance equal to only about one-twentieth of total length of carapace. Antero-lateral angle subacutely rounded; no distinct antero-lateral sinus.

First pedigerous somite short, smooth except for some obscure tubercles at anterior margin, and partly concealed by pleural parts of second, which is dorsally longer than any of the others; second somite with a pair of dorsal carinae, on each side of which is a dorso-lateral ridge and a broken lateral carina; third with ridges as in second but with the lateral ones more distinct; in fourth and fifth somites the same ridges are present but are short and those of the sides tend to become almost tooth-like.

First three pleon somites with, on each side, a longitudinal dorso-lateral carina, a lateral ridge and a faint infero-lateral carina; fourth to fifth somites each with a strong, median, longitudinal carina, flanked on both sides by a lateral ridge and an infero-lateral ridge; the last, though feeble, is more distinct than that of third somite; fifth somite little longer than fourth (which is longer than the subequal first three somites) and with sides subparallel and a little sinuate; sixth somite only about half as long as fifth, very slightly dilated at the rear where it is distinctly broader than long; like the two preceding somites it has a median dorsal ridge (but one that is much less pronounced) flanked on each side with a dorso-lateral carina and an obsolete lateral ridge; telson elongate, subtriangular, roundly subtruncate at distal end and more than twice as long as sixth pleon somite; each lateral margin of telson is very finely serrate for part of proximal half and in distal half bears half-a-dozen articulated spines: its apex is furnished with three spines subequal in length.

First antenna with first segment of peduncle subequal in length to second and third together, and second fully twice as long as third; flagellum as long as second and third peduncular segments together, two-jointed (possibly a third minute joint), the second joint more than half as long again as first; accessory lash four-fifths as long as main flagellum, two-jointed, the second segment twice as long as first. Second antenna with second segment short, third shorter than first and a little longer than fourth.

Palp of first maxilla with two filaments.

Basis of third maxilliped only about one-fifth as long as combined lengths of remaining joints, with external distal angle not at all forwardly produced and furnished with two very long plumose setae; ischium very short; merus with a forwardly produced but not greatly dilated outer lobe; carpus longer than either merus or propodus, which are subequal in length and each longer than dactylus.

First pereopod stout and rather short, the carpus not reaching nearly to level of anterior margin of carapace; basis not much more than two-thirds of length of rest of limb: carpus longer than ischium and merus together and about equal in length to propodus; dactylus subequal in length to merus, and with longest terminal seta (like distal setae of propodus) as long as propodus.

Second pereopod five-sixths as long as first leg; basis subequal in length to rest of limb and with exopod rather small; ischium relatively large, armed with a strong distal spine as well as slender setae; merus half as long as carpus and with a stout inner distal spine; carpus longer than propodus and dactylus together and with a row of inner spines, one near proximal end being longer than the others; dactylus twice as long as propodus, with distal setae short.

Third and fourth pereopods with two-jointed exopods; basis in third pair nearly twice as long as rest of limb, that of fourth half as long again as remaining joints together, that of fifth a little shorter than the rest of limb; in all three

posterior limbs the merus, carpus, propodus and dactylus successively decrease a little in length while the two longest distal carpal setae together with the propodal seta reach well beyond the tip of dactylus.

Peduncle of uropod so strongly keeled above that it is subtriangular in section and with a score of spines on inner margin; it is one-fourth as long again as telson; endopod barely shorter than peduncle, with first segment not very much longer than second and third joints combined and second distinctly shorter than third; spines of inner margins of joints of endopod respectively sixteen, five and six, and stout terminal spine only half as long as distal joint; exopod equal in length to first and second endopodal segments combined.

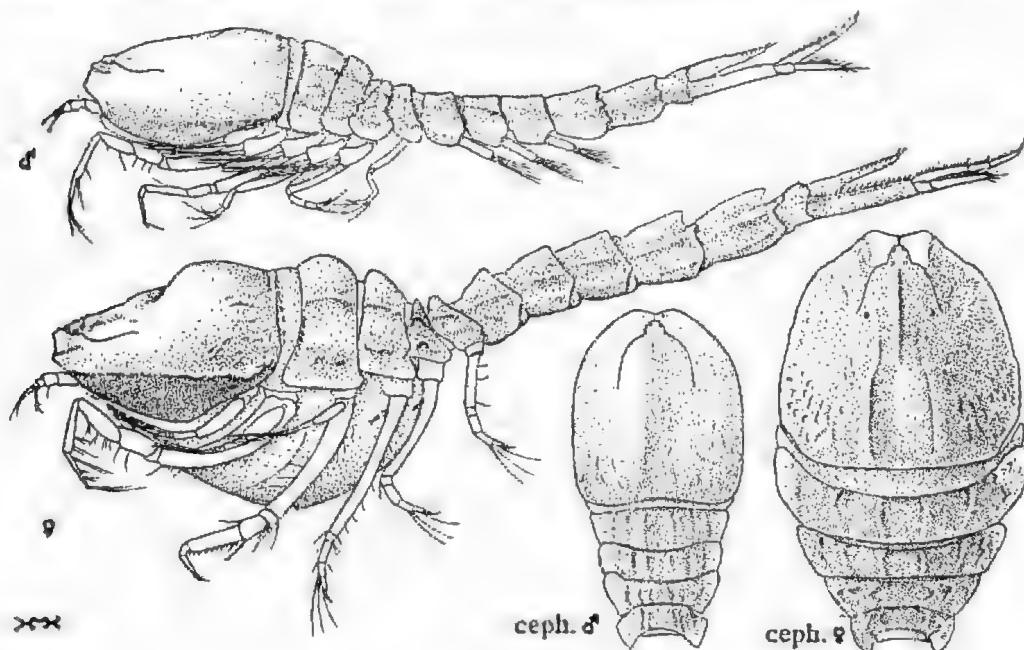


Fig. 1

Hemilamprops lata, type female and allotype male; lateral views and (ceph.) cephalothorax from above (x 23).

Colour, creamy-white. Length, 6·4 mm.; embryo with pleon curved over back, 0·42 mm.

Adult male—Integument brittle, less calcified than in female, but with sculpture similar though less pronounced; the crests on the branchial regions of the carapace in particular are noticeably less elevated, so that as seen from the side the dorsal outline is far less irregular.

Carapace a little longer in relation to total length of animal than in adult female and less broadened posteriorly; seen from above it is suboval in shape; nearly half as wide again as deep, longer than wide and almost twice as long as broad. Antero-lateral margin as in female, but antero-lateral angle rather more obtuse.

Telson relatively a little longer than in female, but with similar armature; the median of the three terminal spines is shorter than the other two.

First antennae with first peduncular segment longer than in female and with both flagella three-jointed, the distal joint in both longer than either of the remaining two. Second antenna with flagellum reaching quite to end of fifth pleon somite.

Mandible with ten and eleven spines in the row.
 Third maxilliped as in female except that basis and exopod are wider.
 First peraeopod relatively a little longer than in female, the basis being five-sixths of combined lengths of remaining joints, and propodus a trifle longer than carpus.

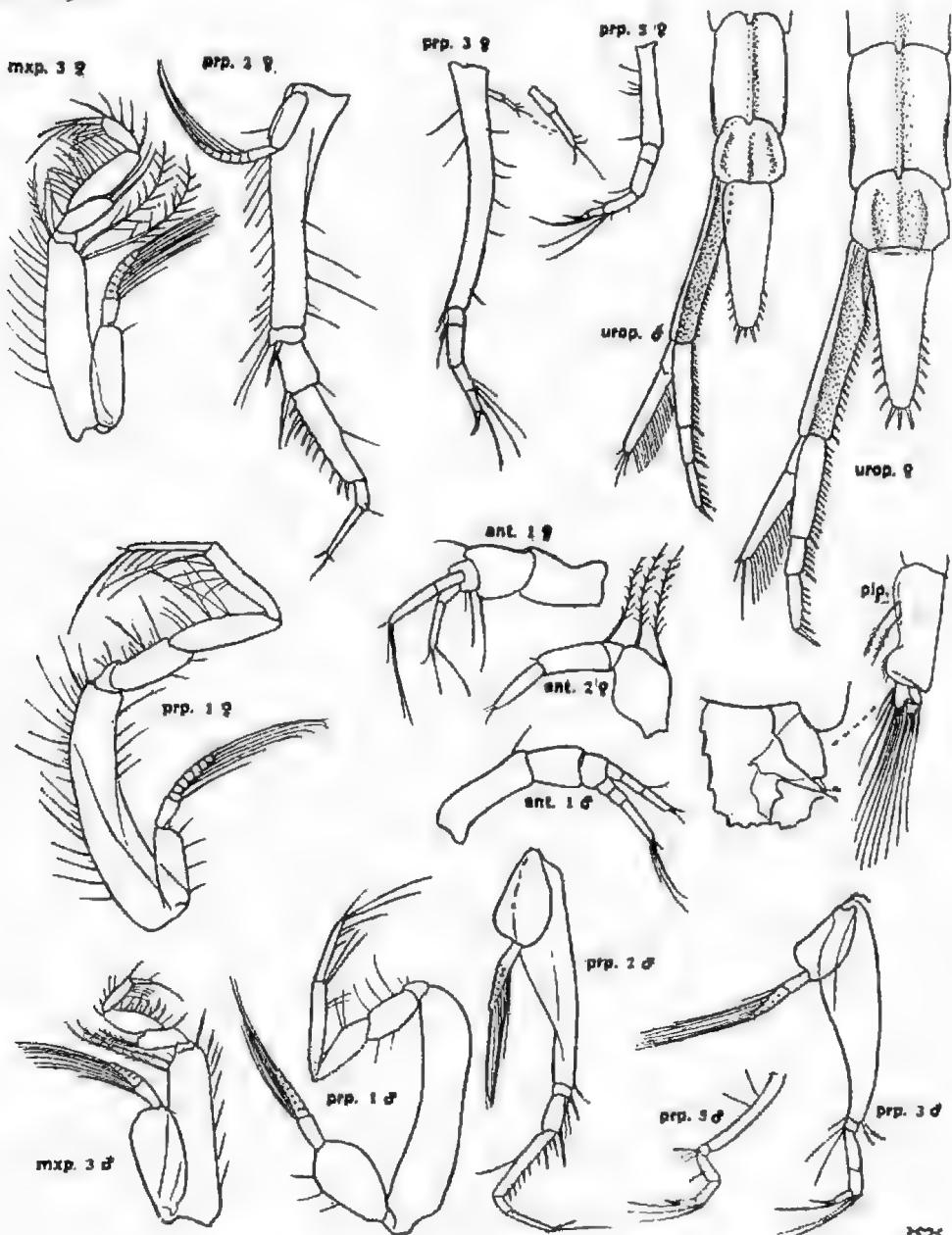


Fig. 2

Hemilamprops lata, type female and allotype male; ant., antennae (x 56); mxp., third maxilliped (x 30); prp., first to third and fifth peraeopods (x 30); plp., pleopod (x 56; rami, x 250); urop., uropod with fifth and sixth pleon somites, and telson (x 30).

Basis of second peraeopod one-sixth longer than rest of limb; armature and proportions of joints otherwise much as described.

Third pereopod not specially modified, differing only from that of female in the wider basis and large exopod, which has the peduncle, as in first and second pairs, very broad.

The three pairs of pleopods are similar to those figured for other species of the genus (fig. 2, plp.).

Peduncle of uropod less than one-fifth longer than telson and barely longer than endopod, the first joint of which is armed with a greater number of spines than in the female.

Length, 5 mm.

Loc.—New South Wales: off Sydney, from stomach of Morwong or Jackass Fish—*Dactylopagrus macropterus* (A. C. Simpson, July 1939); off Coffs Harbour, 50 metres (K. Sheard, A. Trawl, June 1941); 11 miles off Eden, 120 metres (type female, K. Sheard, A. Trawl, Jan. 1943); off Wata Mooli, 70 metres (allotype male, K. Sheard, Trawl Station 4, July 1943); 5 miles east of Port Hacking, 100 metres, on mud (K. Sheard, Trawl Station 7, July 1943); off Jibbon, 45-50 metres, on coarse sand (K. Sheard, Trawl Station 10, Aug. 1943); off Ulladulla, 75 metres and 80 metres, on coarse sand (K. Sheard, A. Trawl, June and Aug. 1944). Tasmania: off Babel Island, lat. $39^{\circ} 55'$ S., long. $148^{\circ} 31'$ E. ("Warreeneen" Station 29, Jan. 1939). Types in South Australian Museum, Reg. No. 2,802 and 2,804.

The type is the largest female available; other ovigerous examples are only 4·0 mm. and 5·5 mm. in length and the uropod has fewer spines, there being sometimes only about ten on first joint of endopod and fifteen on peduncle, which also may be a little shorter in relation to the telson. Almost always the median of the three terminal spines of the telson is distinctly shorter than the others, as in the male figured (fig. 2, urop. 3). In small immature specimens (3 mm. or so in length) the carapace has the sides, as seen from above, converging slightly towards the rear, and it is less widened than in the adult, but is still broader than in the related Antarctic *mawsoni* Hale. The last-named bears a close general resemblance to *lata* but is separated by its relatively gigantic size (the immature female, 20·5 mm.), the shape of the pseudorostral lobes which are not widely subtruncate in front, the character of both first and second antennae, the less robust pereopods, the different proportions of the uropods, etc. It should be noted that the cleaning and mounting of the posterior appendages of the single available young female of *mawsoni* shows that very small exopods are present on the third and fourth pereopods (see Hale, 1937, 46).

Hemilamprops diversa n. sp.

Ovigerous female—Integument semi-membranous with small reticulate patterning (especially distinct on carapace), but almost polished; smooth except for the sculpture of carapace as described.

Carapace short and robust, less than one-fifth of total length of animal, three-fourths as long as pedigerous somites together, very little wider than deep and not much longer than broad; seen from above the sides are curved and converge towards the widely subtruncate front; on the back a sharply defined, median carina runs from the ocular lobe to about three-fourths of length of carapace; in posterior fourth the dorsum is depressed between the slightly swollen branchial regions, the indentation emphasised on each side by a feeble crest, which fades into a faint antero-lateral fold continuing forward outside (or below) the frontal lobe; the dorsum is hollowed on each side between the median carina and the frontal-lobe sutures. Antero-lateral margin almost straight, very slightly concave, and scarcely any indication of antennal angle. There is no distinct pseudo-

tostrum, the lobes only just meeting in front of ocular lobe, which is rounded, with small lenses. Frontal lobe large, extending to about half length of carapace.

First pedigerous somite short, its pleural parts partly overlapped by those of second which, like the third, is longer than any of the other somites; none is much expanded laterally.

Pleon distinctly longer than cephalothorax; first and second somites subequal in length, then successively increasing in length to fifth which is two-thirds as long again as sixth and tapers to the rear; sixth little dilated posteriorly, where it is distinctly wider than long; telson narrowly subtriangular, rounded at distal end and twice as long as sixth somite; each of its lateral margins bears three slender,

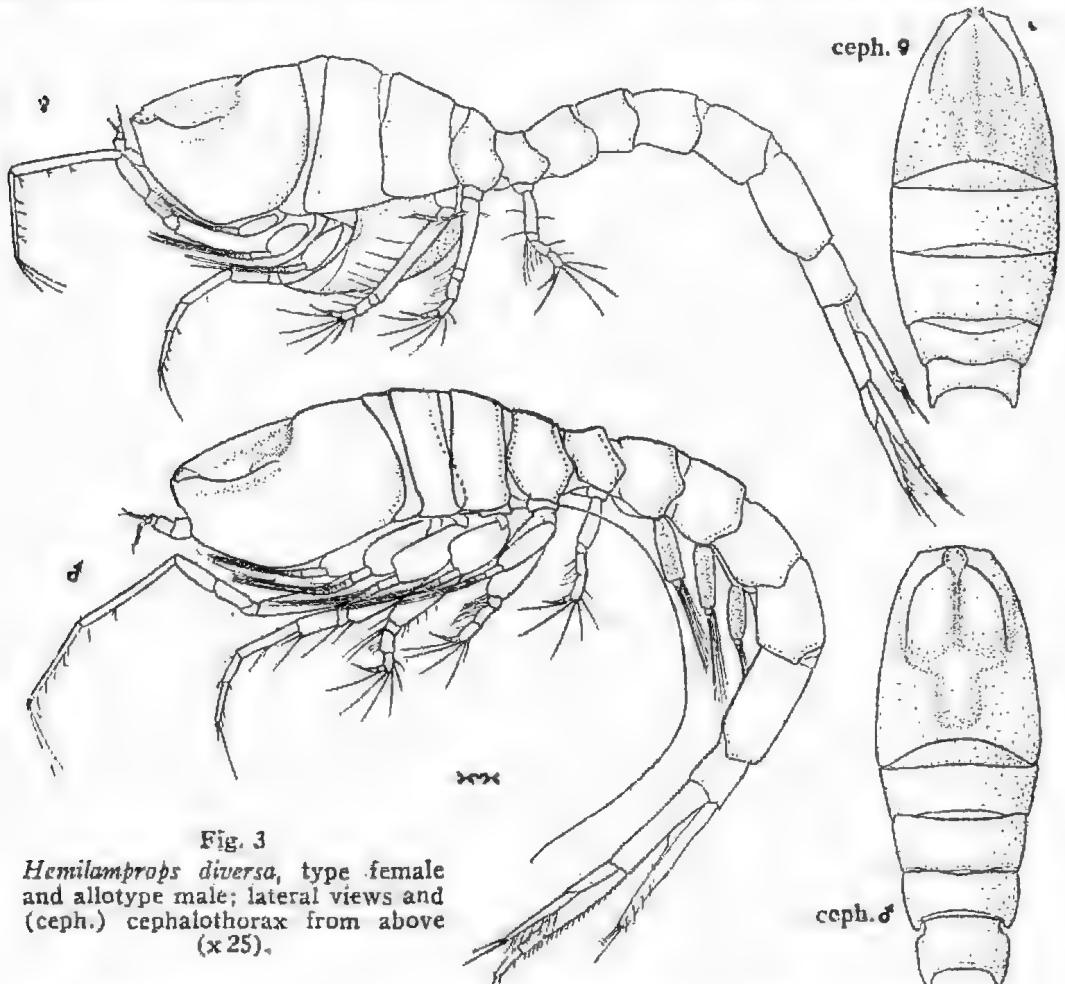


Fig. 3

Hemilamprops diversa, type female and allotype male; lateral views and (ceph.) cephalothorax from above (x 25).

finely serrate, spines; its distal end has three similar spines subequal in length, and above these a pair of much longer subapical slender spines.

First antenna with first joint of peduncle longer than second and third segments together; second twice as long as third; flagellum three-jointed, as long as second and third peduncular segments together and with second joint much the longest; accessory lash two-jointed, two-thirds as long as main flagellum. Second antenna as usual in female of genus; second segment about half as long as third, which is a little shorter than fourth.

Mandibles with ten and eleven spines in the row.

Basis of third maxilliped half as long again as remaining joints together and with outer distal angle rounded but not at all forwardly produced; merus slightly dilated, nearly three times as long as ischium, and two-thirds as long as carpus which is little longer than propodus.

First pereopod with carpus reaching to level of front of carapace and with propodus and dactylus long and slender; basis half as long as remaining joints together, carpus not much longer than merus; propodus one-fifth as long as dactylus and longer than ischium, merus and carpus together.

Second pereopod two-thirds as long as first; basis little longer than distinct ischium, merus and carpus together; carpus half as long again as merus and almost twice as long as propodus which is about two-thirds as long as dactylus.

Third and fourth pereopods with two-jointed exopods; basis of third half as long again as remaining joints together, that of fourth about as long as rest of limb, of fifth much shorter than this; merus, carpus and slender dactylus of posterior limbs subequal in length and propodus much shorter; three distal carpal setae, like propodal seta, reaching well beyond tip of dactylus.

Peduncle of uropod less than four-fifths as long as telson, armed with half-a-dozen slender spines on distal half of inner margin; endopod nearly half as long again as peduncle and one-fifth as long again as exopod, with its first segment one-fourth as long again as combined lengths of second and third, which are subequal in length; spines of inner margins of joints respectively twelve, four and three, and terminal spine as long as distal joint.

Length, 4·5 mm.; ova approximately 0·28 mm. in diameter.

Adult male.—Carapace with sculpture much as in female except that the median dorsal carina of anterior half is grooved medianly, producing the effect of a pair of ridges when seen from above; viewed thus the carapace is narrower at the rear, where it is not much wider than deep and about two-thirds as broad as long; it is equal in length to the pedigerous somites together and is more than one-fifth of total length of animal.

First pedigerous somite shorter than the others, which do not differ much in length and are not expanded laterally.

Pleon a little longer in relation to cephalothorax than in female but somites one to six of the same proportions; telson two and one-half times as long as sixth somite, each of its lateral margins with four spines, its rounded distal end with three spines but differing from those of female in that the median one is nearly twice as long as the others; there are similarly two subapical spines, seated on the dorsal surface, which are longer than any of the other telsonic spines (see fig. 4, tels. 8).

First antenna relatively very slightly larger than in female but with flagella more subequal in length, each composed of three distinct segments, the distal of which is the longest. Second antenna with flagellum reaching well beyond end of sixth pleon somite.

First pereopod with carpus reaching a little beyond level of anterior margin of carapace; basis two-thirds as long as remainder of limb; carpus quite as long as merus and ischium together; propodus and dactylus each longer in relation to combined lengths of ischium, merus and carpus than in female.

Second pereopod more than two-thirds as long as first; basis longer than the next four segments of limb.

Third pereopod with no specialized appendages but like fourth with basis relatively wider and longer than in female and with the usual wide exopods; setae of all posterior pereopods as in female.

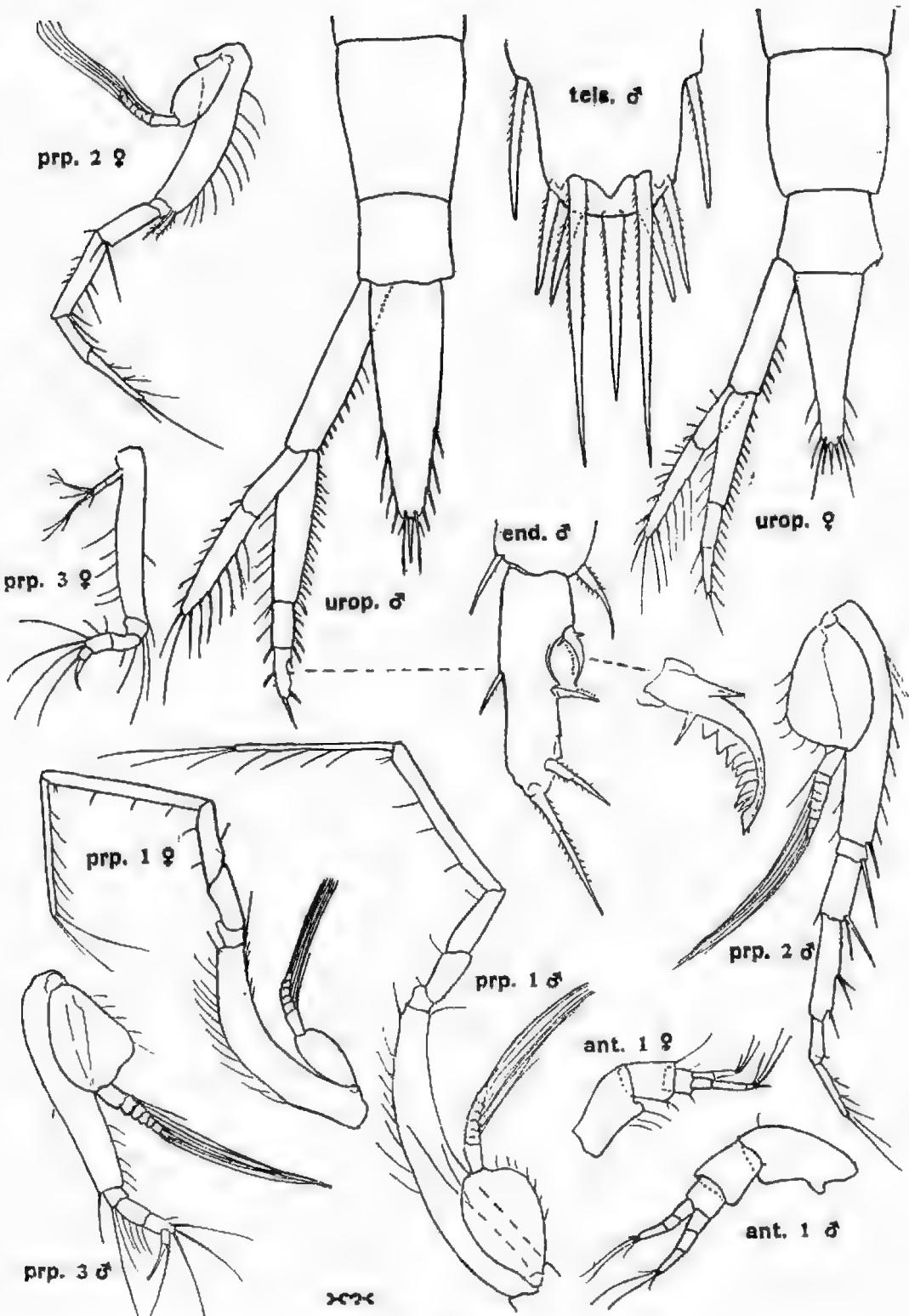


Fig. 4

Hemilamprops diversa, type female and allotype male; ant., first antenna ($\times 85$); prp., first to third peraeopods ($\times 45$); urop., uropod with fifth and sixth pleon somites and telson ($\times 45$); end., last segment of endopodite of uropod ($\times 180$; spine, $\times 550$); tels., distal end of telson from above ($\times 180$).

Peduncle of uropod longer in relation to fifth pleon somite than in female but still less than four-fifths as long as telson; in distal half it is armed with seven short, stout serrate spines, preceded by a couple of more slender spines; endopod only one-third as long again as peduncle and one-fourth as long again as exopod, the inner margin of its first segment with two dozen spines (alternatively long and short) and its second joint with five inner spines; third segment of endopod specialized, there being at second-fourth of length of inner margin a recess, at both proximal and distal ends of which is an articulated spine more modified than the others margining the ramus; the proximal spine is curved backwards and inwards, has on the inner (or posterior) margin a thin lamellate and serrate plate (fig. 4, end. A); the spine at posterior end of the recess, and also a short subapical and longer apical spine of the joint are divided in proximal half by a suture.

Length, 5 mm.

Loc.—New South Wales: off Broughton Island (K. Sheard, submarine light, 11.30 p.m. to midnight, Dec. 1938); off Sydney, from stomach of Morwong or Jackass Fish—*Dactylopagrus macropterus* (A. C. Simpson, July 1939); off Coffs Harbour, 50 metres (K. Sheard, A. Trawl, June 1941); 11 miles off Eden, 120 metres (K. Sheard, A. Trawl, Mar. 1943); off Wata Mooli, 70 metres (K. Sheard, A. Trawl, July 1943); off Jibbon, 70 metres (K. Sheard, A. Trawl, July 1943); 4 miles off Eden, 70 metres, in silt (type loc., K. Sheard, Oct. 1943); 5 miles off Eden, 60 metres, on mud (K. Sheard, submarine light, Dec. 1943); 14 miles east of Cronulla, 150 metres, on mud (K. Sheard, Jan. 1944); off Ulladulla, 75 metres and 60 metres on coarse sand (K. Sheard, A. Trawl, June and Aug. 1944). Tasmania: south end of Marion Bay (W. S. Fairbridge, Euphausiid bottom net, Dec. 1944). Types in South Australian Museum, Reg. No. C. 2,809-2,810.

The size is a little variable (adult male, Tasmania, 5.5 mm.), as is also the armature of the lateral margins of telson and inner edge of first joint of endopod of uropod; the spines of the distal end of telson (three truly terminal and a longer subapical pair) are constant. An ovigerous female 5 mm. in length has five spines on each lateral margin of telson and fourteen inner spines on first joint of endopod of uropod. A male has fourteen short and fourteen longer spines on inner margin of endopod of uropod, but the spines of second and third joints of this ramus are as in type and paratype adult males. The peduncle of the uropod may be very slightly longer in relation to the endopod of that appendage than in the types.

The specialized third segment of the endopod of the uropod of the adult male seems to be distinctive for the species.

Of the forms referred to *Hemilamprops* and *Lamprops*, *Hemilamprops* (?) *californica* Zimmer (1936, 429, fig. 36) and perhaps also *Lamprops serrata* Hart (1930, 36 (14), fig. 4, F-G) agree with *diversa* in having a pair of telsonic spines which are neither truly terminal nor lateral. In Zimmer's paper these spines are figured and described as being situate "Below, and somewhat external to the two lateral spines" of the terminal three, whereas in *diversa* they emanate from above the three terminal spines. Hart's fig. 4, F shows for *Lamprops serrata* a pair of spines seated, apparently, beneath the three terminal spines.

Amongst the differences separating *diversa* from the Californian species the different sculpture of the carapace and the proportions of the uropod may be mentioned: in Zimmer's species the peduncle of the last-named is as long as the endopod, and is fully as long as the telson.

SUMMARY

The first two representatives of the family Lampropidae to be noted from Australian waters are described. Both occur, apparently fairly commonly, off the eastern coasts of Australia and Tasmania, between lat. 34°-43° S. The forms are *Hemilamprops lata* and *H. diversa* spp. nov.

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**CONTRIBUTIONS TO OUR KNOWLEDGE OF THE AUSTRALIAN
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BY A. JEFFERIS TURNER

Summary

Disorderly.

I substitute this name for *C. acritodes* Turn., which is preoccupied.

CONTRIBUTIONS TO OUR KNOWLEDGE OF THE AUSTRALIAN
TORTRICIDAE (LEPIDOPTERA) PART II

By A. JEFFERIS TURNER

[Communicated by H. Womersley, 13 June 1946]

Capua arrythmodes nom. nov.

ἀρριθμωδης, disorderly.

I substitute this name for *C. acritodes* Turn., which is preoccupied.

Subfam. EUCOSMINAE

Hermenias rivulifera n. sp.

riviliferus, carrying a rivulet.

♂, 19 mm. Head and thorax pale grey. Palpi $3\frac{1}{2}$; grey. Antennae grey; ciliations in male minute. Abdomen grey. Legs fuscous with whitish rings; posterior pair whitish. Forewings narrow, costa scarcely arched, apex rounded, termen extremely oblique; in male with a broad costal fold reaching beyond two-thirds; whitish with numerous longitudinal fuscous lines; these combine to form an undulating median line to apex, basally three-forked, forks subcostal, median, and one to fold; costal edge fuscous; cilia white with fuscous bars, below mid-termen pale grey. Hindwings grey; cilia whitish.

Queensland: Maryland, near Stanthorpe, in April (W. B. Barnard); one specimen.

Hermenias callimita n. sp.

καλλιματος, prettily threaded.

♂, ♀, 10-12 mm. Head, thorax, and abdomen fuscous. Palpi $2\frac{1}{2}$, whitish. Antennae fuscous; ciliations in male minute. Legs fuscous with whitish rings; posterior pair mostly whitish. Forewings narrow, costa scarcely arched, apex rounded-rectangular, termen straight, scarcely oblique; in male without costal fold; white partly suffused with grey; markings dark fuscous; costal half of basal area clear white to one-third, there interrupted and continued as a sub-costal streak to apex, interrupted again at two-thirds and before apex; many fuscous dots in basal area; many oblique dark fuscous streaks from apical two-thirds of costa; a curved line from two-thirds of costa to termen beneath apex; a spot above two-fifths dorsum; several fine longitudinal streaks in disc; a white apical dot; a dark fuscous terminal line; cilia white, on apex blackish, on tornus grey. Hindwings and cilia grey.

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

Bathrotoma spodostola n. sp.

σπόδουστολος, grey-cloaked.

♂, 18 mm. Head and thorax whitish-grey. Palpi $2\frac{1}{2}$; grey. Antennae grey; ciliations in male minute. (Abdomen missing.) Legs fuscous with whitish rings; posterior pair whitish. Forewings narrow, costa gently arched to middle, thence straight, apex rectangular, termen slightly rounded, slightly oblique; in male with a broad costal fold nearly reaching middle; whitish mostly suffused with grey; markings fuscous; very numerous costal strigulae; a small sub-basal median spot; a series of strigulae on dorsum; an elongate median spot broader anteriorly, tapering to a point posteriorly; a wedge-shaped spot above tornus;

another wedge-shaped spot beneath apex, connected by a strigula with costa; a line from apex to midtermen; cilia white with an apical spot and a bar beneath it, from middle to tornus grey. Hindwings grey; cilia whitish.

The unusual shape of the forewings is like that of *B. melanographa* Turn.

Western Australia: Margaret River in November; one specimen.

Bathrotoma aethalostola n. sp.

αιθαλοστολος, black-cloaked.

♀, 15 mm. Head and thorax grey. Palpi 2½; grey. Antennae fuscous. Abdomen pale grey. Legs fuscous with whitish rings; posterior pair whitish. Forewings narrow, costa slightly arched, apex subrectangular, termen straight, not oblique; grey; markings dark fuscous; a series of minute costal strigulae; an irregular dorsal blotch from base to two-fifths; a post-median blotch not reaching dorsum, posteriorly indented and margined with white, anteriorly touching dorsal blotch; a slender line from costa near apex to midtermen and almost to tornus; grey with a few dark fuscous bars beneath apex. Hindwings grey; cilia whitish.

Western Australia: Taminin in October; one specimen.

Spilonota brachytycha n. sp.

βραχυπτύχης, with short fold.

♂, 14 mm. Head, thorax and abdomen grey. Palpi 2½; whitish. Antenne grey. Forewings with costa slightly arched, apex pointed, termen almost straight, oblique; male with a broad costal fold reaching one-third; whitish mostly suffused with grey; a series of oblique fuscous costal strigulae in apical half; a circular whitish tornal area, posteriorly edged with silvery-white, containing three short blackish longitudinal lines; a narrow oblique apical dot; cilia grey. Hindwings pale grey; cilia whitish.

Western Australia: Perth (Mount Dale) in January (W. B. Barnard); one specimen.

Spilonota euploca n. sp.

εψπλακος, well woven.

♂, 20 mm. Head fuscous. (Palpi missing.) Antennae fuscous; ciliations in male minute. Thorax fuscous with a grey central spot. Abdomen fuscous; tuft grey. Legs fuscous with whitish rings; posterior pair mostly fuscous. Forewings with costa gently arched, apex rectangular, termen slightly rounded, slightly oblique; fuscous with dark fuscous and grey-whitish markings; four grey-whitish spots on dorsum, each with a central fuscous stria; a dark fuscous pretornal spot; dark fuscous strigulae on basal half of costa; similar markings edged with grey-whitish on apical half; brownish spots in mid-disc at two-fifths and one-half; an erect row of short dark fuscous streaks from tornus half-way across wing; a dark fuscous submarginal line from costa to near tornus; cilia grey with fuscous bars. Hindwings grey; cilia whitish.

Queensland: Brisbane in March; one specimen.

Spilonota sphenophora n. sp.

σφηνοφάρης, bearing a wedge.

♂, 12 mm. Head and thorax grey. Palpi 3; grey, lower edge whitish. Antennae grey. Abdomen pale grey. Legs fuscous; posterior pair whitish. Forewings with costa gently arched, apex rectangular, termen straight, slightly oblique; whitish with patchy grey suffusion and fuscous markings; a series of

triangular costal dots with intermediate minute dots; some grey dots in disc; a wedge-shaped spot based on dorsum from two-thirds to tornus, its apex acute and reaching one-third across disc; a grey spot before termen containing a short longitudinal blackish line; cilia grey with some fuscous bars. Hindwings and cilia pale grey.

New South Wales: Brunswick Heads in January (W. E. Barnard); one specimen.

Spilonota ebenostigma n. sp.

μεταβολος, with black dots.

♂, 12-13 mm. Head, thorax and abdomen fuscous. Palpi 3; fuscous, terminal joint white. Antennae fuscous; ciliations in male minute. Legs grey with white rings; posterior pair white. Forewings narrow, costa straight, apex pointed, termen straight, oblique; in male with a narrow costal fold reaching one-third; whitish partly suffused with grey; markings fuscous; numerous costal dots edged with whitish; basal part of dorsum strigulated; an irregular spot on one-third dorsum reaching more than half across wing; a triangular spot on dorsum before tornus; four black dots in a line from tornus, first three approximated, fourth above middle; cilia grey-whitish. Hindwings and cilia grey.

Victoria: Mount Buffalo in June, January; three specimens.

Spilonota dyselia n. sp.

μεταβολος un-illuminated.

♂, ♀, 14-16 mm. Head, thorax and abdomen fuscous. Palpi 2; fuscous. Antennae fuscous; ciliations in male minute. Legs fuscous; posterior pair grey. Forewings with costa slightly arched, apex rounded, termen obliquely rounded; in male with a broad costal fold nearly reaching middle; fuscous slightly sprinkled with ochreous-whitish; some obscurely darker oblique costal strigulae; a fine dark fuscous terminal line; cilia fuscous. Hindwings dark grey; cilia grey.

North Queensland: Cairns in August and March; Atherton in September; Townsville in June. Queensland: Brisbane in May. Ten specimens.

Spilonota metabola n. sp.

μεταβολος, variable.

♂, ♀, 14-16 mm. Head and thorax whitish-grey. Palpi 4; whitish-grey. Antennae and abdomen grey. Legs whitish; anterior pair in male fuscous with whitish rings. Forewings narrow, costa slightly arched, apex pointed, termen straight, oblique; grey-whitish; markings dark fuscous; a short basal line on dorsum; two or three fine oblique costal strigulae, that from one-third longer; a streak along fold; a median longitudinal streak from one-fourth, connected with a broader streak to apex; cilia whitish. Male without costal fold; markings except apical streak not developed; some fuscous suffusion on fold and above middle of disc. Hindwings and cilia grey.

Western Australia: Denmark in March (W.B. Barnard); two specimens.

I have made the female in the Queensland Museum the type.

Spilonota liphaema n. sp.

λειφαιμος, pallid.

♂, ♀, 12-20 mm. Head, thorax and abdomen whitish-grey. Palpi 3; whitish-grey. Antennae grey. Legs pale grey with whitish rings; posterior pair whitish. Forewings narrow, costa slightly arched, apex pointed, termen sinuate, oblique; male with a broad costal fold extending to middle; whitish sprinkled

with grey; markings pale fuscous; numerous slender oblique costal strigulae, longer towards apex; an apical dot; tornal area whitish-grey, edged posteriorly by a silvery terminal line, containing three minute longitudinal blackish streaks; cilia grey, apices partly whitish. Hindwings whitish-grey; cilia whitish.

Queensland: Toowoomba in August, September and November (W. B. Barnard); five specimens. Type in Queensland Museum.

Spilonota zophotypa n. sp.

Εὐφοτύπος, with dark markings.

♂, 18 mm. Head, thorax and abdomen fuscous. Palpi $3\frac{1}{2}$, grey, second joint with fuscous oblique bar before middle. Antennae grey; ciliations in male minute. Legs fuscous with whitish rings; posterior pair whitish. Forewings with costa almost straight, apex obtuse, termen straight, oblique; in male with a broad costal fold reaching to middle; whitish-grey heavily marked with fuscous; basal area to two-fifths occupied by fuscous extending two-thirds across wing and containing dark fuscous dots and costal strigulae, its dorsal margin very irregular; a narrow fascia from costa beyond middle to tornus, interrupted above dorsum; four costal dots beyond this, with minute strigulae between them; a rather long oblique streak from apex; a series of terminal dots; cilia grey with dark fuscous bars and sprinkling. Hindwings and cilia dark grey.

Western Australia: Denmark in March (W. B. Barnard); one specimen.

Spilonota ochronephes n. sp.

Αχρονέφης, pale clouded.

♂, ♀, 11-14 mm. Head, thorax and abdomen grey-whitish. Palpi $3\frac{1}{4}$; grey. Antennae grey; ciliations in male one-half. Legs whitish. Forewings narrow, costa slightly arched, apex pointed, termen very obliquely rounded; in male with a narrow costal fold reaching to one-third; whitish with slight grey suffusion; markings pale fuscous; numerous minute costal strigulae, better shown in female; some dots in disc, more numerous in female; a longitudinal streak from middle of wing to apex; fine dark fuscous terminal line; cilia whitish, on apex dark fuscous. Hindwings and cilia whitish-grey.

Queensland: Brisbane in August; Stradbroke Island in January; Tweed Heads in September; Toowoomba in October; Stanthorpe in September, October, December, January and February. New South Wales: Brunswick Heads in December. Ten specimens.

Spilonota notosphenia n. sp.

Ιωτοσφήνος, with dorsal wedge.

♂, 10 mm. Head, thorax and abdomen whitish-grey. Palpi $3\frac{1}{2}$; grey, terminal joint white. Antennae grey; ciliations in male minute. Legs white; anterior pair grey. Forewings narrow, costa scarcely arched, apex acute, termen sinuate, oblique; in male with a costal fold reaching two-fifths; white with some grey suffusion and fuscous markings; a series of costal dots and others in basal area; an oblique mark from above two-fifths dorsum to middle of wing; an outwardly oblique wedge-shaped dorsal spot before tornus; a slender line from three-fourths costa to termen beneath apex; cilia whitish-grey. Hindwings and cilia grey.

Queensland: Macpherson Range in November; one specimen.

Spilonota euryptycha n. sp.

Εύρυπτυχος, with broad fold.

♂, 11-14 mm. Head, thorax and abdomen grey. Palpi $3\frac{1}{2}$; white, some-

times with an oblique fuscous line on second segment. Antennae grey. Abdomen grey. Legs whitish; anterior pair grey. Forewings with costa slightly arched, apex pointed, termen sinuate, oblique; male with a broad costal fold extending to two-fifths; grey; a broad white costal stripe from base to apex; numerous oblique fuscous lines from costa; a fuscous terminal line; cilia grey. Hindwings grey; cilia whitish.

New South Wales: Brunswick Heads in December (W. B. Barnard); nine specimens.

Spilonota diplostigma n. sp.

διπλοστύμας, twice branched.

♀, 10 mm. Head, thorax and abdomen grey. Palpi $3\frac{1}{2}$; grey, towards apex white. Antennae grey. Legs grey; posterior pair whitish. Forewings narrow, costa straight, apex acute, termen sinuate, oblique; white suffused with grey except a longitudinal median streak; basal area sprinkled and costa strigulated with fuscous; a broad oblique dark fuscous mark in disc at one-third; a rhombiform dark fuscous spot on dorsum before tornus; a slender line from three-fourths costa to tornus; a terminal line; cilia pale grey. Hindwings and cilia pale grey.

Queensland: Brisbane in August; two specimens.

Spilonota ammostigma n. sp.

ἀμμοστύμας, branched with sand.

♂, 13-14 mm. Head and thorax whitish-grey. Palpi 3; grey, inner surface whitish. Antennae grey; ciliations in male minute. Abdomen grey. Legs whitish; anterior pair grey. Forewings narrow, somewhat dilated, costa slightly arched, apex acute, termen strongly sinuate, oblique; costal fold in male vestigial; whitish with slight grey suffusion towards dorsum; markings dark ochreous-brown; a slender or moderately broad streak from base ending in a pretornal spot; in female some strigulae on costa near apex, an apical spot, and a short terminal line; in male these are obsolete; two or three minute blackish dots above tornus; cilia grey, on apex blackish. Hindwings grey; cilia grey, towards apex whitish.

Queensland: Stanthorpe in October; two specimens.

Spilonota clastomochla n. sp.

κλαστομόχλας, with broken bar.

♂, ♀, 13-15 mm. Head, thorax and abdomen fuscous. Palpi $2\frac{1}{2}$; white, outer surface suffused with fuscous. Antennae fuscous; ciliations in male minute. Legs fuscous with whitish rings; posterior pair whitish. Forewings with costa slightly arched, apex pointed, termen sinuate, slightly oblique; in male with a narrow costal fold reaching to one-fourth; whitish-grey; a dark fuscous median blotch, giving off a line to termen beneath apex; a broad whitish-grey costal streak, which becomes white at apex; this is crossed by oblique fuscous lines; a dark fuscous spot above tornus; a fuscous terminal line not reaching tornus; cilia grey, on apex dark fuscous. Hindwings and cilia grey.

Western Australia: Albany and Nornalup in November; four specimens.

Spilonota mediocunea n. sp.

mediocuneus; with a median wedge.

16 mm. Head and thorax grey-whitish. Palpi $2\frac{1}{2}$; grey. Antennae grey. Abdomen grey; tuft whitish. Legs grey; posterior pair whitish. Forewings narrow. Costa slightly arched, apex acute, termen straight, oblique; grey-whitish;

markings fuscous; a median elongate wedge from base to middle of wings, linear at base, gradually becoming broader on fold, ending in a sharp point; some costal strigulae, more numerous towards apex; a terminal grey suffusion, traversed by two parallel erect lines from before and beyond tornus; a blackish apical dot; cilia whitish, on apex blackish. Hindwings and cilia pale grey.

Spilonota atmophanes n. sp.

ἀτμοφανῆς, smoky.

♂, ♀, 13-14 mm. Head, thorax and abdomen fuscous. Palpi 3; fuscous. Antennae fuscous. Legs fuscous with whitish rings; posterior pair whitish. Forewings narrow, costa almost straight, apex rounded, termen obliquely rounded; male with a broad costal fold extending to middle; grey with fuscous markings; a series of minute costal dots; a curved line from four-fifths costa to an apical dot; a curved line crossing this from costa before apex to mid-termen continued to tornus; a spot on base of dorsum; very irregular spots in disc at two-fifths and three-fifths, the latter larger; some white dots in and beyond middle; cilia grey with some fuscous bars. Hindwings and cilia pale grey.

Queensland: Toowoomba in October; Bunya Mountains in April (W. B. Barnard); two specimens.

Spilonota euthytoma n. sp.

εὐθύτομος, straight cut.

♀, 15 mm. Head, thorax and abdomen dark fuscous. Palpi 3½; white, a median dot on upper edge of second dot, and lower edge of terminal joint, fuscous. Antennae fuscous. Legs fuscous; terminal joint grey-whitish. Forewings with costa slightly arched, apex pointed, termen sinuate, slightly oblique; on costal side of a straight line from base to apex whitish-grey, traversed by oblique fuscous costal streaks; on dorsal side of line mostly suffused with fuscous; tornal area grey; an erect curved transverse white line from before tornus, preceded by a fuscous dot; a straight transverse erect white line beyond tornus; cilia grey; on apex fuscous.

Tasmania: Strahan in February; one specimen.

Spilonota mesosticha n. sp.

μεσοστίχος, with median streak.

♀, 16 mm. Head grey. Thorax whitish; side tufts fuscous. Palpi 4; fuscous, inner surface of second joint whitish. (Abdomen missing.) Legs whitish; anterior pair fuscous. Forewings narrow, costa slightly arched, apex pointed, termen straight, oblique; whitish with slight fuscous sprinkling; a broad fuscous streak from base to middle, along fold; a short oblique streak from apex; cilia whitish. Hindwings and cilia grey.

Spilonota leucopyga n. sp.

λευκοπυγός, white-rumped.

♂, 12 mm. Head fuscous. Palpi 2½; fuscous, lower edge whitish. Antennae grey; ciliations in male minute. Thorax whitish mixed with fuscous. Abdomen fuscous; tuft white. Legs whitish; anterior pair fuscous. Forewings narrow, costa slightly arched, apex pointed, termen straight, oblique; in male with a narrow costal fold reaching to one-fourth; fuscous with white markings; broadly white from base of costa to mid-disc at one-third, enclosing a fuscous subdorsal spot near base; a series of costal strigulae separated by fuscous; two oblique streaks from two-thirds dorsum and tornus uniting to form an inverted

V; an erect series of minute black streaks before termen across middle of disc, the lower three approximated; a black apical dot; a white terminal line; cilia grey, on apex black. Hindwings dark grey; cilia whitish.

New South Wales: Kosciusko (3,000 ft.) in January; one specimen.

Spilonota niphosticha n.sp.

νιφοστίχος, white-lined.

♂, 12 mm. Head grey. (Palpi missing.) Antennae grey; ciliations in male minute. Abdomen fuscous. Legs whitish; anterior pair fuscous with whitish rings. Forewings narrow, costa almost straight, apex obtusely pointed, termen sinuate, oblique; in male with a moderately broad costal fold reaching one-fourth; pale fuscous; costal fold white; a white subcostal streak from base to three-fourths, interrupted at one-fourth; some costal strigulae in apical fourth; two black dots above and before tornus, followed by a curved transverse white line, this by two minute black dots, and this again by a white line; transverse white line; a fuscous apical dot; cilia whitish, on apex fuscous. Hindwings grey; cilia pale grey.

Western Australia: Perth in August; one specimen received from Mr. W. H. Matthews.

Spilonota lucifera n.sp.

luciferus, shining.

♀, 12 mm. Head grey-whitish. Palpi $3\frac{1}{2}$; white, outer surface of second joint grey towards apex. Antennae fuscous. Thorax and abdomen dark fuscous. Legs, anterior pair fuscous; middle pair whitish with fuscous rings (posterior pair missing). Forewings narrow, costa slightly arched, apex pointed, termen straight, oblique; dark fuscous; markings white with brilliant silvery lustre; a series of short costal streaks with slender fuscous centres, first basal and spotlike, second and third reaching half across disc, fourth short, fifth prolonged as a solid silver bar to tornus, fifth very short, sixth, seventh and eighth rather longer; a short submarginal line before middle of termen; cilia grey, bases whitish. Hindwings and cilia grey.

Tasmania: Cradle Mountain (3,000 ft.) in February; one specimen.

Spilonota baeodes n.sp.

βαϊωδης, tiny.

♂, 9 mm. Head, thorax and abdomen grey. Palpi $2\frac{1}{2}$; grey. Antennae grey; ciliations in male minute. Legs grey; posterior pair whitish. Forewings narrow, costa straight, apex acute, termen sinuate, oblique; in male without costal fold; whitish-grey with numerous minute pale fuscous dots and strigulae; an irregular pretornal spot; an apical dot and terminal line; cilia whitish-grey. Hindwings and cilia pale grey.

Queensland: Brisbane in August; one specimen.

Spilonota subpallida n.sp.

subpallidus, somewhat pale.

♂, 14 mm. Head, thorax and abdomen grey. Palpi 3; grey-whitish. Antennae grey; ciliations in male minute. Legs grey. Forewings with costa straight to two-thirds, thence arched, apex obtuse, termen obliquely rounded, in male with costal fold extending to beyond middle; pale grey with some fuscous sprinkling; three or four fine oblique costal streaks towards apex; a white suffusion before termen containing three fine blackish longitudinal lines; cilia grey. Hindwings and cilia pale fuscous.

Queensland: Stradbroke Island in September; one specimen.

Spilonota phaeochyta n. sp.

$\phi\alpha\omega\chi\nu\tau\sigma$, darkly suffused.

\female , 20 mm. Head and thorax fuscous. Palpi 6; fuscous. Antennae grey. Abdomen grey-whitish, towards apex grey. Legs fuscous. Forewings with costa slightly arched, apex round-pointed, termen rounded, slightly oblique; whitish sprinkled with fuscous; basal area and a dorsal streak from base to tornus whitish; four minute whitish dots on apical half of costa; a series of dark fuscous terminal dots; cilia fuscous with narrow whitish bars. Hindwings and cilia grey-whitish.

Western Australia: Yanchep in September; one specimen.

Spilonota pellopis n. sp.

$\pi\alpha\lambda\lambda\omega\pi\tau\sigma$, grey.

\male , 14-16 mm. Head and thorax pale ochreous-grey. Palpi $2\frac{1}{2}$; grey, apex of second joint pale fuscous. Antennae grey; ciliations in male minute. Abdomen grey. Legs whitish; anterior pair grey with whitish rings. Forewings with costa slightly arched, apex rectangular, termen slightly rounded, slightly oblique; in male with a broad costal fold reaching middle; whitish mostly densely suffused with grey; numerous pale fuscous streaks from costa, short on basal half, longer and oblique on apical half, and there separated by whitish; three or four very fine short longitudinal blackish subterminal streaks; cilia grey. Hindwings and cilia pale grey.

New South Wales: Brunswick Heads in January (W. B. Barnard); two specimens. Type in Queensland Museum.

Spilonota tornosema n. sp.

$\tau\omega\rho\omega\sigma\eta\mu\sigma$, with tornal marking.

\female , 15 mm. Head, thorax and abdomen grey. Palpi 3; grey, lower edge white. Antennae grey. Legs grey with whitish rings; posterior pair whitish. Forewings narrow, costa slightly arched, apex rounded, termen obliquely rounded; grey with patchy brownish suffusion; a series of fuscous dots on basal half of costa; on apical half oblique strigulae, brownish with fuscous bases; a suffused subdorsal fuscous spot at two-fifths; an oblique apical fuscous dot; a small brownish tornal spot traversed by a slender blackish longitudinal line; beyond this an erect series of three blackish lines, edged posteriorly by a silvery line on termen; cilia grey. Hindwings grey; cilia whitish with a grey sub-basal line.

Western Australia: Perth (Mount Dale) in June (W. B. Barnard); one specimen.

Spilonota stenophylla n. sp.

$\sigma\tau\epsilon\omega\phi\pi\lambda\lambda\sigma$, narrow-winged.

\male , 13-14 mm. Head and thorax pale grey. Palpi 3; white mixed with pale grey. Antennae fuscous. Abdomen grey; apices of segments dark fuscous. Legs fuscous; posterior pair grey. Forewings very narrow, costa almost straight, apex pointed, termen sinuate, oblique; male with a narrow costal fold reaching to one-third; grey with fuscous markings; a white interrupted streak from base of costa to apex; a series of costal strigulae, those near apex separated by white; a series of dorsal dots from base to two-thirds; a series of dots on lower edge of white streak from base to one-third; a dark fuscous streak traversing white streak at two-fifths, then bent along its lower edge to termen beneath apex; tornal area grey containing a short blackish longitudinal line; cilia grey. Hindwings and cilia pale grey.

Western Australia: Albany and Denmark in March (W. B. Barnard); two specimens. Type in Queensland Museum.

Spilonota poliophylla n. sp.

πολιοφύλλος, grey-winged.

♂, 11 mm. Head, thorax and abdomen grey. Palpi $3\frac{1}{2}$; white, at apex grey. Antennae fuscous. Legs fuscous with white rings; posterior pair whitish. Forewings narrow, costa nearly straight, termen sinuate, oblique; male with a broad costal fold reaching two-fifths; grey with whitish suffusion along costa; a series of fine fuscous costal strigulae; a slender dark fuscous median streak from base to apex, expanded by fuscous irroration beyond middle, and then interrupted; two white apical costal strigulae; tornal area grey with two short blackish longitudinal streaks; cilia grey, on apex fuscous. Hindwings pale grey; darker at apex; cilia pale grey, on apex darker.

Western Australia: Denmark in March (W. R. Barnard); one specimen.

Gen. *Hylotropha* nov.

ὑλοτρόφος, forest-bred.

Palpi porrect; second joint with projecting hairs above and beneath; terminal joint short. Thorax smooth. Forewings with 7, 8, 9 stalked, 7 to termen. Hindwings with 3 and 4 stalked, 5 approximated, 6 and 7 stalked. A development of *Acroclita*.

Hylotropha leptotypa n. sp.

λεπτοτυπος, lightly marked.

♀, 16 mm. Head and thorax grey. Palpi $2\frac{1}{2}$; grey, internal surface white. Antennae fuscous. Abdomen fuscous. Legs whitish; anterior pair fuscous. Forewings with costa gently arched, apex pointed, termen sinuate, not oblique; whitish suffused and strigulated with pale grey faintly greenish-tinged; markings fuscous; basal patch indicated by several transverse lines; a narrow inwardly oblique fascia from costa about middle to two-fifths dorsum, not fully developed; several fine longitudinal lines in disc; a broken subterminal fascia; a dark fuscous apical dot; cilia grey, on apex dark fuscous. Hindwings and cilia grey.

New South Wales: Mittagong in January; one specimen.

ACROCITA SEDITIOSANA Meyr.

Proc. Linn. Soc. N.S.W., 1881, 684.

Spilonota deloschema Turn., Proc. Linn. Soc. N.S.W., 1914, 554.

Batrotoma cataplasta Turn., Proc. Linn. Soc. N.S.W., 1915, 192.

Eucosma phaeoscia Turn., Trans. Roy. Soc. S. Aust., 1916, 534.

North Queensland: Atherton. Queensland: Nambour, Brisbane, Macpherson Range, Bunya Mountains. New South Wales: Ebor, Sydney, Bulli.

ACROCITA NEOTHELA Turn.

Trans. Roy. Soc. S. Aust., 1916, 524.

Queensland: Bundaberg, Brisbane, Esk, Toowoomba. One example has been bred from a larva feeding on *Lantana*.

Acroclita hemiochra n. sp.

ἐμμένχης, half pale.

♂, ♀, 9-12 mm. Head, thorax and abdomen fuscous. Palpi $2\frac{1}{2}$; whitish, terminal joint usually fuscous. Antennae fuscous; in male simple. Legs fuscous with whitish rings; posterior pair whitish. Forewings with costa scarcely arched, apex pointed, termen sinuate, oblique; grey-brownish; a rather broad suffused white streak from midbase to apex; numerous dots in basal area

and on costa dark fuscous; a large spot on three-fifths dorsum followed by a tawny blotch extending on termen from apex to tornus, fuscous-brown; a dark fuscous terminal line preceded by a narrow pink suffusion; cilia grey-brownish, bases white, in female more or less mixed with pink. Hindwings and cilia grey.

Western Australia: Denmark in March (W. B. Barnard); four specimens. Type in Queensland Museum.

Acroclita erythrotypa n. sp.

ερυθροτυπος, marked with red.

♀, 14 mm. Head and thorax pale ochreous-grey. Palpi $2\frac{1}{2}$; whitish. Antennae grey. Abdomen pale fuscous. Legs whitish; anterior pair grey. Forewings with costa gently arched, apex pointed, termen sinuate, not oblique; pale ochreous-grey mixed with red; a broad white costal streak from base to middle, giving off at one-third a white streak to tornus; an apical dot and a terminal line fuscous; cilia white. Hindwings grey; cilia white, towards tornus grey.

Western Australia: Albany in February (W. B. Barnard); one specimen.

Acroclita rubrisignis n. sp.

rubrisignis, with red markings.

♀, 14 mm. Head, thorax and abdomen grey. Palpi $3\frac{1}{2}$; whitish. Antennae grey. Legs, anterior pair grey; middle pair reddish on dorsum; posterior pair whitish. Forewings with costa slightly arched, apex pointed, termen sinuate, not oblique; whitish; markings reddish and grey; a grey dorsal suffusion broadening to half across disc at one-third, narrowing to tornus; an oblique reddish mark from midcosta towards but not reaching tornus; a series of minute costal dots and strigulae; a broad grey terminal fascia; a short upwardly oblique line from midtermen; a reddish apical dot and terminal line not reaching tornus; cilia white, bases grey, on apex reddish. Hindwings grey; cilia whitish.

Western Australia: Busselton in October; one specimen.

Acroclita polybalia n. sp.

πολυβαλιος, with many dots.

♀, 13 mm. Head grey. Palpi 2; grey. Antennae grey with dark fuscous annulations. Thorax pale fuscous. (Abdomen missing.) Forewings narrow, costa slightly arched, apex rounded, termen obliquely rounded; whitish sprinkled with grey; markings brownish dotted with dark fuscous; a moderate basal patch with rounded posterior edge; a rather narrow median fascia from two-fifths costa to three-fourths dorsum; a triangular mark on four-fifths costa; an incomplete terminal line; cilia whitish with fuscous sub-basal line. Hindwings and cilia whitish.

Western Australia: Denmark in April (W. B. Barnard); one specimen.

Acroclita ochrophara n. sp.

ωχροφαρος, pale cloaked.

♂, ♀, 10-12 mm. Head and thorax whitish-ochreous-grey. Palpi $2\frac{1}{2}$; white, sometimes tinged with pale ochreous-grey. Antennae grey; in male simple. Abdomen fuscous; tuft grey. Legs whitish. Forewings with costa gently arched, apex pointed, termen sinuate, not oblique; male without costal fold; ochreous-whitish; markings reddish; a series of minute costal dots, sometimes pale fuscous; a spot or some suffusion on fold at one-fourth; an oblique

streak from midcosta; strigulae beyond this silvery-edged; an apical spot; a slender fuscous terminal line; cilia whitish. Hindwings pale grey; cilia whitish.

Western Australia: Albany and Busselton in February (W. B. Barnard); seven specimens. Type in Queensland Museum.

Acroclita acromochla n. sp.

ἀκρομοχλας, with an apical bar.

♀, 12-14 mm. Head and thorax pale ochreous-grey; Palpi 2½; whitish, terminal joint dark fuscous. Antennae fuscous. Abdomen grey. Legs fuscous with whitish rings; posterior pair except tarsi whitish. Forewings narrow; costa gently arched, apex obtuse, termen strongly sinuate, slightly oblique; basal area whitish-ochreous; a series of dark fuscous costal dots; a fuscous dorsal suffusion from near base to two-thirds; a curved ochreous-brown bar from midcosta to apex; a slender dark fuscous terminal line preceded by a broader ochreous-brown line; cilia white, towards apex dark fuscous.

Western Australia: Waroona in January; Perth in February (W. B. Barnard); two specimens. Type in Queensland Museum.

Acroclita nimbata n. sp.

nimbatus, clouded.

♂, 13 mm. Head, thorax and abdomen pale ochreous-grey. Palpi 2; whitish. Antennae pale grey; in male simple. Legs whitish. Forewings with costa gently arched, apex pointed, termen sinuate, not oblique; male with a narrow costal fold reaching two-fifths; whitish mostly suffused with grey and with some fuscous sprinklings; a series of fuscous costal dots; a whitish area on costa from two-thirds almost to apex, with a curved outline reaching one-third across disc, defined by a fine fuscous margin; subterminal area grey with fuscous dots and longitudinal strigulae; a fuscous apical dot; cilia whitish. Hindwings pale grey; apex and terminal edge whitish; cilia whitish.

Queensland: Toowoomba in January (W. B. Barnard); one specimen.

Acroclita commatica n. sp.

κομματικος, impressed.

18 mm. Head and thorax whitish-grey. Palpi 2½; white, apex and a median dot on second joint dark fuscous. Antennae grey. Abdomen fuscous. Legs whitish; anterior pair grey. Forewings with costa gently arched; apex pointed, termen obliquely rounded; white mostly suffused with grey; markings fuscous; a series of short oblique lines from costa with intermediate dots; some grey suffusion on fold; a longitudinal interrupted blackish streak above middle from three-fifths to four-fifths; a blackish streak running to termen beneath apex; a very fine line from three-fifths costa strongly curved outwards so as to run through interruption in discal streak, and then sinuate to mid-dorsum; a terminal line; cilia whitish. Hindwings and cilia grey.

Western Australia: Collie in November; one specimen.

Acroclita atacta n. sp.

ἀτακτος, confused.

♂, ♀, 14-16 mm. Head and thorax fuscous-brown. Palpi 2; fuscous-brown. Antennae fuscous. Abdomen fuscous; tuft whitish. Legs fuscous with ochreous rings; posterior pair ochreous-whitish. Forewings with costa arched to middle, thence straight, apex obtuse, termen slightly rounded, oblique; male with a broad costal fold reaching one-third; shining white suffused with

grey; markings brown and fuscous; basal patch indicated; a fuscous spot on two-thirds costa, followed by an inwardly oblique grey-whitish suffusion across disc; terminal area with four transverse brown lines partly edged with dark fuscous and anastomosing, separated by confused grey-whitish lines; cilia fuscous. Hindwings and cilia grey.

Queensland: Toowoomba in September and November (W. B. Barnard); four specimens. Type in Queensland Museum.

Acroclita albifusa n. sp.

albifusus, suffused with whitish.

♂, 13 mm. Head, thorax and abdomen fuscous. Palpi 2; grey. Antennae grey-whitish; ciliations in male one-half. Forewings with costa gently arched, apex rounded, termen obliquely rounded; male with a broad costal fold reaching one-third; ochreous-whitish with fuscous markings; basal patch well defined towards costa, deficient towards dorsum; a series of dark fuscous costal dots and strigulae; a large roundish dorsal spot before tornus, its apex touching a spot on two-thirds costa; a grey terminal fascia edged with dark fuscous; cilia ochreous-whitish with fuscous bars. Hindwings grey; cilia whitish, towards tornus grey.

Queensland: Toowoomba in September (W. B. Barnard); one specimen.

Ancylis eupena n. sp.

eupena, finely woven.

♀, 11 mm. Head and thorax fuscous. Palpi 1½; ochreous-whitish. Antennae grey. (Abdomen missing.) Forewings narrow, costa slightly arched, apex acute, falcate, termen sinuate, oblique; whitish posteriorly with some ochreous suffusion; basal half with numerous transverse fuscous lines more or less interrupted into dots; posterior half with five broad oblique wedge-shaped blackish lines separated by white lines; an erect blackish line with slight transverse projections from tornus two-thirds across wing, preceded by ochreous and followed by grey suffusion; a white terminal line from apex meeting apex of last costal white line; cilia on apex blackish, beneath apex ochreous, traversed by an erect blackish line, below middle fuscous. Hindwings and cilia dark grey.

Queensland: Mount Tambourine in September; one specimen.

Ancylis panolia n. sp.

panolia, happy.

♂, 14 mm. Head brown. Palpi 2½; brown. Antennae grey; in male simple. Thorax whitish-grey with dark fuscous dots. Abdomen pale grey; tuft whitish. Forewings with costa straight almost to apex, apex pointed, moderately falcate, termen sinuate, not oblique; male with a narrow costal fold reaching to near middle; whitish slightly sprinkled with grey; markings fuscous; numerous costal strigulae; four dorsal spots, near base, at one-fourth, at one-third, and before tornus; a slender curved line from three-fourths costa to tornus; an apical spot and terminal line; cilia fuscous, bases blackish, on tornus whitish. Hindwings pale grey; cilia whitish.

Queensland: Macpherson Range (Springbrook) in October (W. B. Barnard); one specimen.

Procoronis capnophanes n. sp.

capnophanes, dusky.

♂, 15 mm. Head and thorax fuscous. Palpi 3½; fuscous. Antennae fuscous; ciliations in male minute. Abdomen grey, towards base pale brownish. Legs whitish-ochreous; anterior and middle pairs with fuscous rings on tibiae

and tarsi. Forewings with costa arched to middle, thence straight, apex pointed, termen slightly rounded, slightly oblique; male without costal fold; white with extensive fuscous suffusion and strigulae; a large fuscous basal patch, its outer edge from one-fourth costa to two-fifths dorsum, angled above middle; numerous fuscous costal strigulae; median area paler; many fine transverse fuscous lines in apical third of disc, those near termen with whitish between them; cilia fuscous. Hindwings and cilia dark grey.

Queensland: Toowoomba in May (W. B. Barnard); one specimen.

Eucosma periptycha n. sp.

περιπτυχος, fenced around.

♀, 12 mm. Head and thorax fuscous. Palpi $2\frac{1}{2}$; fuscous; lower edge whitish. Antennae fuscous. (Abdomen missing.) Forewings narrow, costa scarcely arched, apex rectangular, termen obliquely rounded; a costal stripe from base almost to apex white; a series of minute triangular dark fuscous costal dots; a white dorsal spot near base, sprinkled with fuscous, continued along dorsum to middle, where it expands triangularly reaching middle of disc; some white suffusion before tornus, edged posteriorly by a curved dark fuscous line; cilia white with dark fuscous bars, apices grey. Hindwings grey; cilia whitish.

Western Australia: Albany in February (W. B. Barnard); one specimen.

Eucosma nitida n. sp.

nitidus, neat.

♀, 14 mm. Head fuscous; face white. Palpi 3; white, second joint with three transverse fuscous bars. Antennae grey. Abdomen grey; tuft white. Legs whitish; anterior pair grey. Forewings with costa slightly arched, termen sinuate, not oblique; white with slight partial grey suffusion; markings dark fuscous, sharply defined; costal edge dark fuscous to two-fifths; a line from costa near base to fold, along which it is continued to one-third, where it joins an oblique streak from two-thirds dorsum half across disc; a large pretornal spot; a series of costal strigulae; a spot on termen above middle; a dark fuscous apical dot; cilia white with a few dark fuscous points, towards tornus grey. Hindwings grey; cilia pale grey.

New South Wales: Mittagong in January; one specimen.

EUCOSMA PACHYNEURA. TURN.

Trans. Roy. Soc. S. Aust., 1916, 525.

This species is variable. Of the three specimens before me only two have the hindwing veins outlined with dark fuscous. In one there is a whitish spot with grey strigulae on the middle of the dorsum of the forewings.

Queensland: Brisbane, Macpherson Range (2,500 ft.), Toowoomba.

Eucosma anisospila n. sp.

ἀνισοσπίλος, unevenly spotted.

♂, ♀, 12-15 mm. Head white. Palpi $1\frac{1}{2}$; fuscous, apices white. Antennae fuscous; ciliations in male minute. Thorax white mixed with fuscous. Abdomen grey. Legs fuscous with white rings; posterior pair white. Forewings narrow, costa gently arched, apex rounded, termen obliquely rounded; male without costal fold; white with dark fuscous spots and dots; several dots near base; an elongate spot from one-third dorsum to near one-third costa, sometimes forming a complete fascia; a second spot on two-thirds dorsum, sometimes connected with a

spot on three-fourths costa; a tornal spot, sometimes connected with that on costa; a variable number of dots on margins and in disc; cilia pale grey. Hindwings grey; cilia whitish with grey sub-basal line.

Western Australia: Kalamunda, near Perth, in December and January (W. B. Barnard); five specimens. Type in Queensland Museum.

Eucosma eridela n. sp.

ἐριδηλος, clearly marked.

♀, 13 mm. Head whitish. Palpi 2; whitish. Antennae fuscous. Thorax fuscous or whitish. Abdomen fuscous. Legs fuscous; posterior pair whitish. Forewings with costa slightly arched, apex rectangular, termen sinuate, oblique; white; markings dark fuscous; a costal series of oblique wedge-shaped streaks with intermediate dots; a slender curved transverse line at one-third enclosing basal patch; joined by a slender line from base along fold; sometimes a similar costal line; a wedge-shaped dorsal spot before tornus, sometimes with a discal spot above it; a whitish tornal area edged with dark fuscous and containing two or three minute longitudinal blackish lines; cilia grey. Hindwings and cilia grey.

North Queensland: Mackay in October; two specimens.

Eucosma charmara n. sp.

χαρμηρος, pleasing.

♂, 18-20 mm. Head and thorax fuscous-brown. Palpi 2½; grey. Antennae fuscous; in male simple. Abdomen grey; tuft grey-whitish. Legs fuscous with ochreous-whitish rings; (posterior pair missing). Forewings with costa gently arched, apex rounded, termen sinuate, slightly oblique; male without costal fold; dark grey tinged with brownish; a dark basal patch, its posterior margin curved from one-fourth costa to two-fifths dorsum, narrowly edged with whitish; costal area dark from one-third to apex, containing five pairs of whitish strigulae from costa; a narrow dark erect wedge-shaped tornal spot, containing some blackish connected dots; dorsal area between this and basal patch grey; tornal area whitish edged anteriorly and posteriorly by erect silvery lines and containing two blackish dots; cilia white with three very slender fuscous lines. Hindwings grey; cilia whitish.

Queensland: Toowoomba in September. New South Wales: Ebor in December; two specimens.

Eucosma striphromita n. sp.

στριφομιτος, closely threaded.

♂. ♀, 13-14 mm. Head and thorax grey. Palpi 2½; white, apex of second joint grey. Abdomen grey; basal segment brownish.. Legs grey with whitish rings; posterior pair whitish. Forewings narrow, costa slightly arched, apex rectangular, termen straight, not oblique; male with a broad costal fold extending beyond middle; whitish partly suffused with grey; markings fuscous-brown; numerous costal strigulae; a median fuscous-brown suffusion from near base to three-fourths; a series of long wavy slender closely packed strigulae; a pale sub-terminal spot; a terminal line; cilia white with three fine blackish bars beneath apex. Hindwings grey; cilia grey, towards apex white.

New South Wales; Brunswick Heads in December (W. B. Barnard); two specimens. Type in Queensland Museum.

Eucosma symploca n. sp.

συμπλοκος, interwoven.

♂, ♀, 10-14 mm. Head grey. Palpi 2; fuscous, inner surface and terminal joint whitish. Antennae fuscous; in male simple. Thorax fuscous mixed with whitish. Abdomen fuscous. Legs whitish; anterior pair fuscous with whitish rings. Forewings strongly arched, apex rectangular, termen straight, not oblique; in male without costal fold; white sprinkled and strigulated with fuscous; markings dark fuscous edged with black; basal patch large, interrupted by a white fascia, outer edge from one-third costa to mid-dorsum, with an acute posterior tooth on fold; median fascia from one-third costa to near tornus, margins very irregular, broadest on costa, often with a slender nearly erect process from outer edge below middle; a curved line from four-fifths costa to midtermen; an apical dot; cilia whitish with fuscous bars. Hindwing grey with a whitish terminal line; cilia grey.

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

Eucosma ebenocosma n. sp.

εβενοκοσμος, decorated with black.

♀, 16 mm. Head black. Palpi $2\frac{1}{2}$; white, second joint with three black dots on outer surface. Antennae black. Thorax white with a black posterior spot. Abdomen grey. Forewings with costa slightly arched, apex obtusely pointed, termen slightly rounded, slightly oblique; white; markings black; two broad oblique streaks from costa, first from one-fourth to below middle at one-third, second from midcosta to mid-disc at two-thirds, the two broadly connected in disc and produced in a triangular expansion extending from apex to midtermen; a dot on base of dorsum; a triangular mark from three-fourths dorsum, its apex touching apical triangle; cilia fuscous, on apex and midtermen black. Hindwings and cilia dark grey.

North Queensland: Kuranda; one specimen received from Mr. F. P. Dodd.

Eucosma phaeoloma n. sp.

φαιωλωμας, dark-fringed.

♂, 12 mm. Head and thorax dark fuscous. Palpi 2; dark fuscous. Antennae dark fuscous. Abdomen brownish. Legs fuscous. Forewings narrow, costa straight, apex obtuse, termen slightly rounded, oblique; male with a broad costal fold reaching two-fifths; grey-whitish sprinkled with fuscous; a broad fuscous costal streak from base to apex, with a series of oblique dark fuscous strigulae in apical half; four minute blackish dots in an erect line from tornus; an apical dark fuscous spot giving off a slender fuscous submarginal line; a pale terminal line; cilia brown, bases dark fuscous. Hindwings with 3 and 4 coincident; grey; cilia grey.

North Queensland: Lake Barrine, Atherton Tableland, in June; one specimen.

Eucosma dolichosticha n. sp.

δολιχοστιχος, with long lines.

♂, 15 mm. Head, antennae and thorax pale grey. Palpi $1\frac{1}{2}$; pale grey. (Abdomen missing.) Forewings with costa gently arched, apex rectangular, termen sinuate, not oblique; male with a narrow costal fold extending to about middle; ochreous-whitish with some fuscous sprinkling, markings dark fuscous;

a broad subcostal suffusion from near base to termen, containing several long dark fuscous lines; numerous oblique costal strigulae; a strongly oblique line from midcosta to middle of disc, with two others slightly beyond and parallel, all ferruginous-edged; two less oblique and converging subapical lines; a white tornal area, edged anteriorly by a fuscous line, and containing three slender longitudinal blackish lines; a terminal line; cilia fuscous, apices whitish. Hindwings grey; cilia whitish.

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

Eucosma psammopasta n. sp.

χαμοταύρος, sprinkled with sand.

♂, 15 mm. Head, thorax and abdomen fuscous-brown. Palpi 2; brownish-whitish. Antennae fuscous; in male simple. Legs whitish-ochreous; anterior pair with dark fuscous rings. Forewings with costa slightly arched, apex rounded, termen slightly rounded, slightly oblique; in male without costal fold; white; markings brownish; a basal patch containing many blackish dots, its outer margin faintly indicated; a moderate median fascia from midcosta to three-fifths dorsum, partly edged with blackish dots and strigulae; a slightly curved fascia from three-fourths costa to tornus, edged anteriorly with blackish dots; a series of blackish costal dots; a fine blackish line close to termen; a fine fuscous line round apex; cilia whitish. Hindwings pale grey; a fine fuscous line round apex; cilia whitish.

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

Eucosma euprepes n. sp.

εὐπεπης, comely.

♂, 12 mm. Head and thorax fuscous. Palpi 2; fuscous. Antennae fuscous; in male simple. Abdomen fuscous; tuft grey. Legs whitish with fuscous rings; posterior pair wholly whitish. Forewings with costa strongly arched, apex rectangular, termen straight, not oblique; fuscous with dark fuscous transverse lines and strigulae; towards dorsum white; a small basal patch, its posterior edge indicated by a transverse line with sharp median angle; a moderate fascia from one-fourth costa to one-third dorsum, edged with dark fuscous, posterior edge angled above dorsum, a fascia from costa before middle to termen before tornus, broad on costa, narrow on dorsum, giving off a short line towards apex, which partly encloses a white spot; a regular series of dark fuscous costal dots with intermediate strigulae; a slender line from three-fourths costa ending in three short branches to termen below middle; a dark fuscous apical dot; cilia grey with whitish apices.

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

Eucosma diaema n. sp.

διαιμός, blood-stained.

♀, 18 mm. Head and thorax pale ochreous-grey. Palpi 3½; pale ochreous-grey. Antennae grey. Abdomen pale fuscous; tuft whitish. Forewings rather broad, costa gently arched, apex rounded, termen slightly rounded, slightly oblique; pale ochreous-grey with slight reddish suffusion on dorsum and beneath midcosta; a triangular reddish apical blotch nearly reaching tornus, preceded by a suffused whitish line; some minute fuscous costal dots; cilia whitish, bases barred with fuscous. Hindwings grey; cilia whitish.

Queensland: one specimen bred from fruit. Unfortunately the record of locality and food plant has been lost.

Eucosma leuconephela n. sp.

λευκονέφελος, clouded with whitish.

♂, 16 mm. Head and thorax fuscous-brown. Palpi $2\frac{1}{2}$; fuscous-brown. Antennae grey; ciliations in male minute. Abdomen fuscous. Legs grey; posterior pair whitish. Forewings with costa gently arched, apex pointed, termen sinuate, not oblique; male without costal fold; fuscous-brown; posterior two-thirds of costal area whitish with many longitudinal fuscous-brown lines; a large basal patch; a costal series of dark fuscous oblong dots; an apical dot; cilia brown. Hindwings grey; cilia whitish, bases grey.

New South Wales: Ebor in December; one specimen.

Eucosma syntaractis n. sp.

συντρακτικός, confused.

♂, ♀, 13-16 mm. Head fuscous; face ochreous-whitish. Palpi $2\frac{1}{2}$; fuscous, upper edge ochreous-whitish. Antennae fuscous; ciliations in male one-fourth. Thorax fuscous. Abdomen ochreous-grey; tuft whitish. Legs dark fuscous; posterior pair whitish. Forewings with costa gently arched, apex pointed, termen obliquely rounded; male without costal fold; whitish more or less suffused with grey; markings fuscous; basal patch not well developed, but posterior edge sometimes distinct; an irregular series of oblique costal strigulae; a median costal spot at two-thirds, sometimes connected with costa and termen beneath apex; a terminal line; cilia grey, bases whitish. Hindwings pale grey; cilia whitish.

New South Wales: Brunswick Heads in December (W. B. Barnard); six specimens. Type in Queensland Museum.

Eucosma tornocosma n. sp.

τορνοκοσμος, with tornal ornament.

♀, 14 mm. Head and thorax brown. Palpi 2; fuscous, inner surface and terminal joint whitish. Antennae fuscous. (Abdomen missing.) Legs fuscous with whitish rings; posterior pair whitish. Forewings narrow, costa nearly straight, apex pointed, termen sinuate, oblique; brown mixed with fuscous; a series of fuscous costal dots; a whitish spot containing fuscous dots on mid-dorsum; a brown tornal triangle traversed by a longitudinal blackish line, edged posteriorly by a silvery terminal line, and above by a curved fuscous line; a fuscous apical dot with a minute white centre; a fuscous terminal line; cilia grey with a fuscous median line. Hindwings and cilia pale grey.

Queensland: Noosa in May; Brisbane; two specimens. Mr. A. R. Dodd has bred one example from *Lantana*.

Eucosma ochrotorna n. sp.

ώχρωτορνος, with pale tornus.

♂, 13 mm. Head and thorax fuscous. Palpi 2; grey-whitish, upper edge fuscous. Antennae fuscous; in male dentate with minute ciliations. Abdomen fuscous; tuft grey-whitish. Legs whitish; anterior pair fuscous. Forewings dilated posteriorly, costa rather strongly arched, apex rectangular, termen almost straight, oblique; male with a broad costal fold extending to beyond middle; whitish with grey strigulae; towards costa grey-suffused; a series of dark fuscous costal strigulae separated by whitish; basal patch indicated by a fuscous spot at one-third, posteriorly bidentate, connected by a slender oblique line with costa; median patch from two-thirds costa, narrow, strongly oblique to middle, there interrupted, completed by an oblong spot on three-fifths dorsum; a dark fuscous sinuate line from three-fourths costa to midermen, preceded by a broad grey

suffusion; tornal area occupied by a large whitish suffusion extending almost to costa; cilia whitish. Hindwings whitish; towards apex grey with fuscous strigulae; a broad grey and fuscous suffusion on dorsum; cilia whitish.

New South Wales: Brunswick Heads in December (W. B. Barnard); one specimen.

Eucosma transfixa n. sp.

transfixus, pierced through.

♀, 16 mm. Head and thorax pale grey. Palpi $2\frac{1}{2}$; grey. Antennae fuscous. Abdomen fuscous; dorsum of first segment white. Legs pale grey; posterior pair whitish. Forewings with costa slightly arched, apex subrectangular, termen straight, slightly oblique; whitish with some grey suffusion; markings fuscous; a longitudinal streak from near base to apex, interrupted at one-third; a series of minute costal dots; a dorsal spot before tornus; an apical dot; cilia whitish. Hindwings and cilia grey.

North Queensland: Kuranda in June; one specimen.

Eucosma gracilistria n. sp.

gracilistrius, with slender lines.

♀, 15 mm. Head and thorax brownish-fuscous. Palpi $2\frac{1}{2}$; brownish-fuscous. Antennae fuscous. Abdomen ochreous-whitish. Legs grey; anterior pair fuscous with whitish rings; posterior pair whitish. Forewings with costa gently arched, apex rectangular, termen sinuate, not oblique; ochreous-whitish with fuscous markings; basal three-fourths of costa with minute strigulae; an oblique line from three-fifths costa, becoming transverse about middle, ending on three-fifths dorsum; several fine longitudinal lines running into this; a series of more or less interrupted fine lines running from median line to termen; three oblique streaks from apical part of costa; an apical dot; a terminal line; cilia ochreous-whitish with a median fuscous line. Hindwings with 2 and 3 connate; grey-whitish; cilia grey-whitish.

North Queensland: Palm Island in May; one specimen.

Eucosma apicinota n. sp.

apicinotus, with apical mark.

♂, 12 mm. Head and thorax whitish. Palpi $2\frac{1}{4}$; grey-whitish. Antennae grey with dark fuscous annulations; in male simple. Abdomen whitish-grey. Legs grey; posterior pair mostly whitish. Forewings narrow, costa slightly arched, apex obtuse, termen sinuate, oblique; male without costal fold; pale grey; markings dark fuscous; a broad whitish costal streak beyond middle; some whitish suffusion in dorsal area; a series of minute costal dots; a whitish suffusion before tornus, containing two minute longitudinal blackish streaks; an apical spot, cilia grey, on apex dark fuscous. Hindwings with 2 and 3 long-stalked or coincident; whitish; cilia whitish.

North Queensland: Mackay in August; one specimen.

Eucosma polymita n. sp.

πολυκτος, with many threads.

♂, ♀, 12-15 mm. Head and thorax white. Palpi $2\frac{1}{2}$; white, in male with apex of second joint fuscous. Antennae grey, in male with minute ciliations. Abdomen grey; tuft whitish. Legs fuscous; posterior pair whitish. Forewings with costa scarcely arched, apex rectangular, termen straight, not oblique; in male with a broad costal fold extending beyond middle; whitish with patchy grey

suffusion and fuscous markings; numerous fine oblique costal strigulae; an irregular spot on fold at one-third connected by a line or by suffusion with base; a line from three-fourths costa to midtermen, closely followed and connected with a parallel line; dorsal area except near base whitish, traversed by fine oblique threads, which anastomose confusedly in disc; a wedge-shaped apical dot; cilia white with some fuscous bars. Hindwings grey; cilia grey, on apex white.

New South Wales: Brunswick Heads in December and January (W. B. Barnard); four specimens. Type in Queensland Museum.

Eucosma perversa n. sp.

persversus, askew.

♂, 13 mm. Head and thorax ochreous-whitish. Palpi 2; pale grey. Antennae grey; in male simple. Abdomen whitish; towards apex grey. Legs fuscous; posterior pair whitish. Forewings narrow, costa slightly arched, apex round-pointed, termen straight, oblique; male without costal fold; whitish with some grey sprinkling; markings fuscous; a large basal patch with posterior edge angled; numerous fine oblique lines from costa; a suffused oblique line from midcosta, broadening in middle of disc, connected with a suffused spot before termen; a spot before tornus; a slender line from costa before apex to midtermen; an apical dot; two or three minute longitudinal lines in tornal area; cilia whitish with a median fuscous line. Hindwings and cilia grey-whitish.

Queensland: Yeppoon in June; one specimen.

Eucosma atripunctis n. sp.

tripunctis, with black dots.

♂, 12-15 mm. Head and thorax dark fuscous. Palpi 1½; pale grey. Antennae fuscous; in male simple. Abdomen fuscous. Legs ochreous-whitish; anterior pair fuscous. Forewings narrow, costa almost straight, termen sinuate, not oblique; male without costal fold; whitish more or less heavily sprinkled with dark grey; markings dark fuscous; basal patch undefined; a series of oblique costal streaks, more or less thickened on costal margin; an oblique bar from one-fourth dorsum, not reaching costa, anteriorly suffused, posteriorly well defined, sometimes interrupted; in one example the dorsal bar is succeeded by a broad white patch; two to four minute elongate black dots in an erect line beyond tornus; edged posteriorly by a white line; a tornal spot; cilia fuscous with a whitish basal line. Hindwings grey; cilia grey-whitish, with a sub-basal dark line.

Queensland: Bunya Mountains in March; three specimens.

Eucosma aspersa n. sp.

aspersus, splashed.

♂, ♀, 15-16 mm. Head, thorax and abdomen grey. Palpi 2; pale grey. Antennae grey; in male simple. Legs grey; posterior pair whitish. Forewings slightly arched, apex pointed, termen sinuate, not oblique; in male without costal fold; grey with fuscous markings; a broad longitudinal suffusion from near base to termen beneath apex; a series of fine short oblique costal strigulae; a slender oblique line from midcosta to central suffusion, and a similar line from two-thirds costa to termination of suffusion; a broad white splash in tornal area, containing three or four black dots, and edged posteriorly by a curved silvery line; cilia grey. Hindwings grey; cilia grey-whitish.

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

Eucosma polyplega n. sp.

πολυπληγος, with many stripes.

♂, 13 mm. Head and thorax pale fuscous. Palpi 3; whitish. Antennae grey; ciliations in male minute. Abdomen grey-whitish. Legs whitish; anterior pair grey. Forewings with costa slightly arched, apex rectangular, termen obliquely rounded; in male without costal fold; whitish with pale fuscous markings; some dots in basal area; numerous short oblique lines from costa; central area irregularly suffused, and connected by several oblique lines with dorsum; a subterminal suffusion; an interrupted terminal line; an apical dot; cilia whitish with some fuscous bars. Hindwings pale grey; cilia whitish.

Queensland: Caloundra in September; one specimen.

Eucosma acrosema n. sp.

ἀκροσημος, with apical mark.

♂, 14 mm. Head and thorax grey-whitish. Palpi 4; grey-whitish. Antennae pale grey; in male simple. Abdomen grey; base of dorsum brownish; tuft whitish. Legs grey; posterior pair whitish. Forewings narrow, dilated posteriorly, costa slightly arched, apex pointed, termen sinuate, not oblique; in male with a narrow costal fold reaching two-fifths; whitish with slight fuscous sprinkling; markings fuscous; a median spot at one-third; another at two-thirds, its lower pole with a fine curved process towards tornus; some oblique costal strigulae beyond middle; a blackish apical dot, giving off a slender terminal line not reaching tornus; cilia grey-whitish, on apex blackish.

New South Wales: Brunswick Heads in December (W. B. Barnard); one specimen.

Eucosma leucopleura n. sp.

λευκοπλευρος, with white costa.

♂, ♀, 14-16 mm. Head, thorax and abdomen grey. Palpi 4; grey. Antennae grey; in male simple. Legs grey; posterior pair whitish. Forewings narrow, costa scarcely arched, apex pointed, termen sinuate, oblique; male without costal fold; a broad white or grey-whitish costal streak from base to apex, attenuated at extremities; a series of fine oblique lines from apical half of costa, near apex edged beneath with blackish; a blackish or fuscous median dot at four-fifths; a slender terminal line not reaching tornus; a blackish apical dot; cilia pale grey. Hindwings with 3 and 4 stalked or coincident; pale grey; cilia pale grey.

Queensland: Stanthorpe in September. New South Wales: Brunswick Heads in December. Four specimens (W. B. Barnard). Type in Queensland Museum.

Eucosma leuconota n. sp.

λευκονωτος, with white dorsum.

♀, 14 mm. Head and thorax white mixed with dark fuscous. Palpi 3; fuscous, at base and apex white. Antennae fuscous. Abdomen grey; penultimate segments fuscous. Legs whitish; anterior pair fuscous with whitish rings. Forewings with costa slightly arched, apex pointed, termen sinuate, oblique; white with dark fuscous markings; a small basal patch connected with a central patch extending to three-fourths; a series of costal dots; an oblique wedge-shaped dorsal spot before tornus; an irregular apical patch; an incomplete terminal line; cilia white, on apex dark fuscous. Hindwings and cilia grey.

New South Wales: Brunswick Heads in January (W. B. Barnard); one specimen.

Eucosma austera n. sp.*austerus*, gloomy.

♂, ♀, 14-16 mm. Head, thorax and abdomen grey. Palpi $1\frac{1}{2}$; grey. Antennae grey; in male simple. Legs grey with whitish rings; posterior pair whitish. Forewings with costa slightly arched, apex rectangular, termen sinuate, not oblique; male with costal fold reaching one-third; grey with fuscous strigulae on costa; a slender strongly oblique line from three-fourths costa to termen; sometimes irregular whitish suffusion or blotches and fuscous spots in disc; some fuscous suffusion on tornus; supratornal area grey, edged posteriorly by a white subterminal line, and containing three short longitudinal blackish streaks; a fuscous apical spot and terminal line; cilia grey. Hindwings with 3 and 4 coincident; brownish-grey; cilia grey.

Queensland: Brisbane in December; Toowoomba in October (W. B. Barnard); ten specimens.

Eucosma eurytopolia n. sp.*εὐρυπόλιος*, broadly grey.

♂, 18 mm. Head and thorax grey. Palpi $1\frac{1}{2}$; white with grey dots. Antennae grey; ciliations in male minute. (Abdomen missing.) Legs fuscous with whitish-ochreous rings; posterior pair whitish. Forewings with costa slightly arched, apex rounded, termen obliquely rounded; male without costal fold; pale grey; a fuscous basal spot on costa, not reaching dorsum, connected with an irregular median costal spot; apical half of costa with short pale streaks divided and separated by fuscous; an oblique fuscous subapical bar; cilia fuscous above and grey below middle of termen. Hindwings grey; cilia fuscous.

Queensland: Tweed Heads (Burleigh) in September (W. B. Barnard); one specimen.

Eucosma ceratodes n. sp.*κερατωδῆς*, horn-coloured.

♀, 16 mm. Head, thorax and abdomen fuscous-brown. Palpi 3; grey. Antennae grey. Legs grey; posterior pair ochreous-whitish. Forewings with costa gently arched, apex rectangular, termen sinuate, not oblique; fuscous-brown; a slight fuscous median suffusion connected with a similar subterminal suffusion; a small semilunar tornal spot, brown partly edged with blackish; cilia brown. Hindwings and cilia grey.

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

Eucosma fulva n. sp.*fulvus*, yellowish-brown.

♂, 14 mm. Head and thorax pale ochreous-grey. Palpi $2\frac{1}{2}$; pale ochreous-grey. Antennae fuscous; in male simple. Abdomen ochreous-fuscous; tuft whitish-ochreous. Legs ochreous-grey; posterior pair whitish-ochreous. Forewings with costa gently arched, apex rectangular, termen slightly rounded, oblique; male without costal fold; ochreous-whitish with yellowish-brown suffusion and markings; numerous slender transverse lines in basal half; in apical half these lines are mostly confluent and curved; a slight subterminal fuscous suffusion above dorsum; cilia ochreous-whitish; bases grey. Hindwings dark grey; cilia grey mixed with ochreous-whitish.

Queensland: Stanthorpe in January (W. B. Barnard); one specimen.

Eucosma phaedropa n. sp.*φαιδρωπός*, cheerful.

♀, 14-15 mm. Head and thorax fuscous-brown. Palpi $2\frac{1}{2}$; fuscous.

Antennae grey. Abdomen fuscous. Legs fuscous with whitish rings; posterior pair grey. Forewings with costa scarcely arched, apex round-pointed, termen sinuate, not oblique; brown, numerous minute fuscous and whitish strigulae on costa; basal patch undefined; a short sub-basal fuscous line on dorsum, with some whitish suffusion above; an irregular median dorsal whitish suffusion; a fuscous triangle based on dorsum from two thirds to tornus; a large whitish tornal area with some grey sprinkling, edged posteriorly by a grey terminal line, and above by a thick blackish curved line; a blackish apical dot; cilia whitish, apices partly fuscous. Hindwings and cilia grey.

Queensland: Toowoomba in April and May (W. B. Barnard); two specimens. Type in Queensland Museum.

Eucosma ammopastea n. sp.

ἀμμοπαστεά, sprinkled with sand.

♂, 14-16 mm. Head and thorax whitish-brown. Palpi 2; fuscous, base and apex white. Antennae grey, ciliations in male minute. Abdomen pale ochreous-grey; tuft whitish. Legs grey or fuscous, with whitish rings; posterior pair whitish. Forewings with costa slightly arched, apex pointed, termen almost straight, oblique; male with a narrow costal fold reaching to two-fifths; whitish sprinkled and strigulated with brown; a costal series of strigulae fuscous at their bases; middle of disc with irregular brown markings and sometimes sprinkled with fuscous; a white terminal line closely preceded by a brown or fuscous line; cilia brown. Hindwings with 3 and 4 connate; pale grey; cilia whitish.

New South Wales: Broken Hill in March; two specimens.

Eucosma tornocyclo n. sp.

τορπάκλος, with tornal ring.

♂. ♀. 14 mm. Head and thorax fuscous. Palpi 2; fuscous. Antennae grey; ciliations in male minute. Abdomen grey. Legs fuscous with whitish rings; posterior tibiae and femora whitish. Forewings with costa slightly arched, apex pointed, termen obliquely rounded; male without costal fold; dark grey; basal third suffused with whitish except margins and a median line; numerous dark fuscous costal dots separated by minute white strigulae; a large grey tornal blotch reaching three-fourths across wing, edged with fuscous, containing three minute longitudinal blackish streaks separated by white lines; a dark fuscous apical dot; cilia grey mixed with fuscous and whitish. Hindwings and cilia pale grey.

North Queensland: Eungella in June. Queensland: Toowoomba in April. Two specimens.

Eucosma dasycerca n. sp.

δασικέρκος, bushy-tailed.

♂, ♀. 15 mm. Head and thorax white. Palpi 2; fuscous, terminal joint and apex of second white. Antennae grey, basal joint white; ciliations in male minute. Abdomen grey, ending in a terminal dense tuft of long ochreous-whitish hairs. Legs grey; posterior pair whitish. Forewings narrow, costa slightly arched, termen straight, oblique; in male without costal fold; white with grey and fuscous markings; a grey costal streak from base to near apex; a grey dorsal streak from base to tornus, thickened at three-fifths, where its upper edge is rounded and capped with fuscous; some fuscous suffusion above tornus; a fuscous oblique streak behind termen from apex; a fuscous terminal line; cilia white, bases fuscous except below middle, on tornus grey. Hindwings grey; cilia whitish.

Queensland: Toowoomba in March (W. B. Barnard); two specimens. Type in Queensland Museum.

Eucosma prosphiles n. sp.

προσφίλης, pleasing.

♂, ♀, 10-11 mm. Head, thorax and abdomen pale grey. Palpi 2½; whitish. Antennae pale grey; ciliations in male minute. Legs whitish; tarsi with dark fuscous rings. Forewings with costa gently arched, apex rounded, termen straight, slightly oblique; male without costal fold; white with brown markings and blackish strigulae; a sub-basal transverse line; a narrow transverse fascia at one-fourth; a moderate outwardly curved fascia from before middle of costa to mid-dorsum, its margins strongly dentate, sometimes with a blackish dot or short longitudinal line above middle; a narrow brownish or grey fascia from three-fourths costa to tornus, sometimes interrupted by blackish dots; a series of blackish costal dots, separated by white or brown; a strong curved blackish line from costa to termen cutting off extreme apex; a slender blackish terminal line; cilia white, partly tinged with brown. Hindwings pale grey; a slender blackish line round apex; cilia grey-whitish.

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

Eucosma tapina n. sp.

ταπείνως, modest.

♂, 16 mm. Head pale grey. Palpi 3; white, apex of second joint grey. Antennae grey; in male simple. Thorax brownish-grey. Abdomen ochreous-whitish. Legs whitish; anterior tarsi fuscous with whitish rings. Forewings with costa slightly arched, apex pointed, termen sinuate, scarcely oblique; male without costal fold; grey-whitish with some brownish and fuscous sprinkling, terminal half more suffused; numerous oblique brown costal strigulae, one from middle long; a short erect silvery line from above tornus, and another before midtermen, between these several fine longitudinal blackish lines; cilia whitish-grey, towards apex and above tornus fuscous. Hindwings grey; cilia whitish.

New South Wales: Brunswick Heads in January (W. B. Barnard); one specimen.

Eucosma neurosticha n. sp.

νευρόπτιχος, with lines on veins.

♂, 18 mm. Head and thorax ochreous-grey. Palpi 3; fuscous, upper edge ochreous-grey. Antennae dark fuscous; ciliations in male minute. Abdomen ochreous grey, towards apex fuscous. Forewings narrow, costa slightly arched, apex pointed, termen slightly rounded, oblique; male without costal fold; ochreous-grey-whitish with some fuscous sprinkling and markings; sub-basal median and dorsal dots; irregular median spots at one-third and two-thirds, the former connected with dorsum; slender oblique costal strigulae in apical half; veins in terminal area slenderly fuscous; an ochreous-whitish terminal line preceded by a dark fuscous line; cilia grey with fuscous points. Hindwings with 3 and 4 connate; grey; cilia grey.

Queensland: Murrurundi in February; three specimens received from Dr. B. L. Middleton.

Bactra capnopepla n. sp.

καπνοπέπλα, in dark clothing.

♂, 15 mm. Head and thorax fuscous. Palpi 2; fuscous. Antennae fuscous; ciliations in male minute. Abdomen brownish-grey; tuft grey. Legs fuscous; tarsi with whitish rings; posterior pair grey-whitish. Forewings narrow, costa gently arched, apex pointed, termen sinuate, oblique; whitish suffused and minutely reticulated with fuscous, appearing grey; markings dark fuscous; a

series of minute costal strigulae; a slender slightly curved line from one-third costa just crossing fold, sometimes interrupted; an oblique line from costa beyond middle half across disc, there much thickened and gradually bent upwards to apex; sometimes interrupted; an apical dot and terminal line; cilia grey with whitish and fuscous points. Hindwings and cilia grey.

Queensland: Noosa in October; one specimen.

Bactra ablubes n. sp.

ἀβλαβῆς, harmless.

♂, 16 mm. Head and thorax fuscous. Palpi $1\frac{1}{2}$; grey. Antennae fuscous; ciliations in male one-third. Abdomen brownish-grey; tuft grey-whitish. Legs fuscous (posterior pair missing). Forewings narrow, costa gently arched, apex obtuse, termen straight, oblique; whitish suffused with grey and slightly brownish tinged; markings dark fuscous; numerous short oblique costal strigulae; a small spot in disc at one-third, followed by a terminal fuscous suffusion; an apical dot and terminal line; cilia grey with an ochreous-whitish basal line. Hindwings and cilia grey.

New South Wales: Brunswick Heads in December (W. B. Barnard); one specimen.

Eucosma aulacota n. sp.

αὐλακωτός, furrowed.

♂, 17 mm. Head whitish on crown, sides and face grey. Palpi $2\frac{1}{2}$; whitish, basal half of second joint grey, sharply defined. Antennae grey; in male simple. Thorax whitish; tegulae pale brownish. Abdomen grey. Legs whitish partly suffused with fuscous; posterior pair wholly whitish. Forewings with costa slightly arched, apex rectangular, termen rounded, not oblique; male with a broad costal fold extending to middle; whitish with numerous fuscous lines and strigulae on dorsum and in tornal area; short strigulae on costa, with a small spot on slightly beyond middle; long slender oblique lines in disc, those nearer termen transverse; a small narrow mark on tornus; cilia whitish with fuscous bars. Hindwings and cilia grey.

Queensland: Killarney (Acacia Plateau, 2,000 ft.) in October; one specimen.

Bactra eurysticha n. sp.

εὐρυστίχος, broadly striped.

♂, 16 mm. Head and thorax grey. Palpi $2\frac{1}{2}$; grey. Antennae grey; ciliations in male one-half. Abdomen pale grey; tuft whitish. Forewings with costa gently arched, apex round-pointed, termen slightly rounded, slightly oblique; grey; an ochreous-whitish median line from base to three-fourths, there broadened and directed upwards to apex; cilia ochreous-whitish. Hindwings pale grey; cilia whitish.

New South Wales: Mittagong in February; one specimen.

Herpystis chrysosoma n. sp.

χρυσωσόμητος, with golden markings.

♀, 16 mm. Head whitish-brown. Palpi $2\frac{1}{2}$; brown. Antennae fuscous. Thorax and abdomen brownish-fuscous. Legs fuscous with whitish-ochreous rings; posterior pair whitish-ochreous. Forewings with costa slightly arched, apex rectangular, termen slightly rounded, slightly oblique; whitish-ochreous partly suffused with fuscous; markings deep golden-brown; a basal patch composed of three transverse lines, its posterior edge nearly straight; closely followed by a median spot at one-fourth, connected with a costal spot; a fascia from three-fifths costa, bent inwards above middle, continued to three-fifths dorsum,

preceded and followed by some fuscous suffusion; a pretornal elongate-oblong spot; a line from three-fourths costa to termen above tornus; a parallel subapical line; an apical spot; cilia whitish, bases fuscous. Hindwings fuscous; cilia whitish with a fuscous sub-basal line.

Queensland: Stanthorpe (W. B. Barnard); one specimen.

Gen. *Idiomorpha* nov.

ἰδίωμαρφος, peculiar.

Palpi ascending; second joint thickened with appressed scales and expanded posteriorly at apex; terminal joint minute. Thorax smooth. Forewings with 2 from two-thirds, 7 and 8 separate, 7 to termen. Hindwings with cell long; 3, 4, 5 closely approximated at base, 12 anastomosing with cell from near base to near middle, then diverging. A peculiar and isolated genus.

Idiomorpha reticulata n. sp.

reticulatus, net-like.

♂, 20 mm. Head and thorax fuscous. Palpi 2; fuscous. Antennae fuscous; ciliations in male minute. (Abdomen missing.) Forewings strongly dilated, costa slightly arched, apex rounded, termen slightly rounded, oblique; male with a strong costal fold extending beyond middle; ochreous-whitish sprinkled throughout with fuscous, appearing grey; an irregular fuscous suffusion in disc from middle to three-fourths, containing a whitish-ochreous dot at three-fifths; terminal area finely reticulated with fuscous; a fuscous terminal line; cilia pale brownish with some fuscous bars. Hindwings and cilia grey.

Queensland: Toowoomba (W. B. Barnard); one specimen.

Gen *Anathamna* Meyr.

Proc. Linn. Soc. N.S.W., 1911, 261.

While in *A. plana* Meyr. 3 and 4 of the hindwings are closely approximated at origin, the following species have these veins connate, and in the second they are shortly stalked on one side of the type specimen. Yet they appear congeneric, and, I think, the definition of the genus should be widened so as to include them.

Anathamna psathyra n. sp.

χαθαρος, dry.

♂, ♀, 18-22 mm. Head whitish-ochreous or greyish-ochreous, in female purplish-grey. Palpi 1½; whitish-ochreous or purple-grey. Antennae pale ochreous-grey; ciliations in male one-half. Thorax whitish-ochreous more or less suffused with purple-grey. Abdomen whitish-ochreous. Legs pale ochreous. Forewings with costa moderately arched to one-third, thence slightly, apex rectangular, termen rounded, not oblique; whitish-ochreous more or less suffused with greyish-brown variably disposed; a dark fuscous spot in middle of disc variably developed, sometimes reduced to a short streak, absent in female, sometimes connected by a line with one-fourth costa, and in one example to two-thirds dorsum; a few costal dots; an incomplete fuscous line from costa near apex to midtermen; cilia whitish-ochreous. Hindwings with 3 and 4 connate; whitish-ochreous or grey; cilia concolorous. Variable in colour and markings. It lacks the blackish costal strigulae of *A. plana* Meyr.

North Queensland: Cape York in November (W. B. Barnard); ten males and one female. Type in Queensland Museum.

Anathamna castanicolor n. sp.

castanicolor, chestnut-coloured.

♂, 18 mm. Head and thorax reddish-brown. Palpi 2; white sprinkled with reddish-brown. Antennae grey; ciliations in male minute. Abdomen grey; terminal segments brown; tuft ochreous-whitish. Legs brown-whitish with fuscous rings; posterior pair white. Forewings with costa rather strongly arched, apex rectangular, termen sinuate, not oblique; 3 and 4 connate; whitish obscured by brown and grey strigulae; numerous dark fuscous dots and strigulae on costa; some reddish-brown spots containing some fuscous scales; roundish costal spot at one-fourth and middle; a spot on base of dorsum connected with base of costa and with a large spot on mid-dorsum, and this with a spot on dorsum before tornus; a large subapical spot sending a fine irregular line to mid-termen; an elongate dark fuscous apical dot; three partly confluent dots on mid-termen; cilia fuscous with several pale brownish bars towards tornus. Hindwings with 3 and 4 connate or short-stalked; grey; a broad white costal streak; cilia grey.

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

Gen. *Lobophora* nov.

λοβοφόρος, lobed.

Palpi porrect. Thorax with a posterior crest. Forewings with 7 and 8 stalked, 7 to termen. Hindwings with termen incised, tornus prominently lobed; 3 and 4 coincident, 5 curved and approximated at base, 6 and 7 closely approximated towards base.

Lobophora axiologa n. sp.

ἄξιολογος, remarkable.

♂, 16 mm. Head and thorax dark fuscous. Palpi $2\frac{1}{2}$; fuscous, upper edge grey. Antennae grey; ciliations in male minute. Abdomen fuscous; basal segments and tuft grey. Forewings narrow, posteriorly dilated, costa strongly arched, apex pointed, termen slightly rounded, strongly oblique; pale brownish; markings fuscous-brown; an elongate spot on dorsum from base to one-third, indented above; minute strigulae on basal half of costa, on apical half fuscous dots separated by ochreous-whitish strigulae, each with a minute fuscous centre; an irregular line from one-third costa to middle of disc, there bent at a right angle, and thence longitudinal to near termen; a subcostal parallel line, and between this and preceding two fine longitudinal lines; a fuscous apical dot and another above tornus; terminal area ochreous-whitish; cilia ochreous-whitish, with two fuscous bars above middle. Hindwings sinuate beneath apex, middle of termen widely excavated, termen strongly lobed; pale grey, thinly scaled except towards apex; a slender fuscous line edged with brown on termen beneath apex; cilia whitish, above excavation with a grey basal line.

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

ARGYROPLOCE DELOCHLORA Turn.

This species, though variable in markings, is usually constant in colouration; but there is a remarkable aberration in the Queensland Museum in which the forewings are grey instead of green and the hindwings and abdomen brownish-tinted.

Queensland: Brisbane, Bunya Mountains.

Argyroploce ophiocosma n. sp.

οφιοκόσμας, with serpentine ornament.

♂, 18 mm. Head, thorax and abdomen grey. Palpi 2; grey. Antennae grey; ciliations in male minute. Legs grey; posterior tibiae in male with very dense long hairs on dorsum. Forewings posteriorly dilated, costa slightly arched, apex rectangular, termen rounded, scarcely oblique; pale brownish; basal two-fifths whitish unevenly suffused with grey; the outer edge of this basal patch defined and with a subdorsal tooth; a costal series of dark fuscous strigulae; beyond basal patch a series of costal dots separated by whitish strigulae with minute fuscous centres; a triangular group of small fuscous spots at two-thirds; immediately beyond a narrow serpentine fascia, thrice curved, grey with central fuscous and marginal whitish line, arising from two-thirds dorsum, it ends below costa near apex in a wide grey expansion; beyond this beneath costa a round whitish spot with a central grey dot, edged above by a dark fuscous line, and beneath by an irregular fuscous spot; a narrow leaden-grey irregular-edged fascia from beneath costa near apex to tornus; cilia whitish with a few fuscous bars. Hindwings dark grey; cilia whitish.

North Queensland; Cairns in December; one specimen received from Mr. F. H. Taylor.

Argyroploce niphostetha n. sp.

νιφοστήθα, snowy-breasted.

♂, 21 mm. Head and thorax brown. Palpi 1½; brown, lower edge white. Antennae grey; ciliations in male minute. Abdomen grey; basal two-thirds of undersurface snow-white. Anterior legs fuscous with whitish tarsal rings; middle pair with ventral surface snow-white, dorsal surface partly dark fuscous; posterior pair snow-white, in male with dense tufts of long hairs on tibiae. Forewings with costa strongly arched, apex rectangular, termen rounded, not oblique; ochreous-brown with fuscous strigulae; basal patch densely strigulated except towards costa; costa with alternate dark fuscous dots and minute strigulae; a fuscous suboblong blotch on dorsum from middle to tornus, reaching half across wing, and a spot on midcosta representing median fascia; four slender oblique leaden-grey lines from apical third of costa, the last two connected by a series of longitudinal fuscous streaks; three elongate dark fuscous terminal dots between apex and midtermen edged by a sinuate ochreous line; cilia grey, bases brown. Hindwings grey; a snow-white costal streak not reaching apex; cilia grey.

North Queensland; Malanda, Atherton Tableland, in October; one specimen.

Argyroploce symplecta n. sp.

συμπλεκτος, interwoven.

♂, 16 mm. Head fuscous. Palpi 1½; ascending; whitish. Antennae fuscous; ciliations in male minute. Thorax fuscous; tegulae and crest whitish. Abdomen fuscous; tuft and underside whitish. Legs fuscous with whitish tarsal rings; posterior pair whitish. Forewings with costa gently arched, apex rectangular, termen sinuate, not oblique; white with fuscous strigulae and dark fuscous markings; a narrow basal fascia with a short upward curved median process and another on dorsum; a subcostal dot at one-fourth; median fascia at first narrow, interrupted beneath costa, then widened and very irregular reaching dorsum from two-thirds to tornus, posterior edge with a circular excavation beneath middle; tornal area beyond this white with slight grey sprinkling on anterior edge, upper edge of area subcostal and strongly curved, alternate minute blackish and brown longitudinal lines on posterior edge; oblique strigulae on

posterior two-fifths of costa, blackish at base with brown prolongations; a blackish apical dot edged with white, and this with blackish; cilia on upper half of termen brown, on lower white, but narrowly blackish on apex and tornus. Hindwings grey; cilia grey, beneath apex whitish.

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

Argyroploce toxosema n. sp.

τοξονηματικός, marked with a bow.

♀, 18-19 mm. Head and thorax dark brown. Palpi 2; dark brown or fuscous. Antennae fuscous. (Abdomen missing.) Legs grey; tarsi fuscous with whitish rings; posterior pair whitish. Forewings with costa slightly arched, apex rectangular, termen slightly rounded, not oblique; grey with fuscous strigulae, towards costa purplish-tinged; a broad dark fuscous line from one-fourth costa to apex, dentate beneath, where it approaches mid-dorsum, narrow at apex, its edges irregular; costal edge whitish with fuscous dots and strigulae; an erect purplish tornal spot crossed by three or four dark fuscous longitudinal lines; a dark fuscous spot on midtermen, cilia ochreous-whitish, on midtermen apices fuscous. Hindwings dark grey; cilia grey-whitish.

Queensland: Yeppoon in October; Tweed Heads in January; two specimens (W. B. Barnard). Type in Queensland Museum.

Argyroploce atactodes n. sp.

ατακτωδής, confused.

♂, 18 mm. Head and thorax fuscous-brown. Palpi 1½; grey. Antennae grey; ciliations in male minute. Abdomen grey. Anterior legs ochreous-whitish, tarsi fuscous with whitish rings; middle pair pale brownish; posterior pair white, tarsi grey with fuscous rings. Forewings with costa strongly arched, apex rounded-rectangular, termen slightly rounded, not oblique; 7 and 8 closely approximated at origin; ochreous-whitish with brownish and grey strigulae; markings fuscous-brown; basal patch dark except extreme base, its posterior margin rounded; a spot on midcosta representing median fascia, with some irregular suffusion between this and tornus; a series of dark fuscous dots and strigulae on costa; a double very fine leaden-grey line from two-thirds costa to tornus; two similar lines from costa to termen, the last edged with fuscous, in which terminate three or four short longitudinal fuscous lines; cilia fuscous. Hindwings and cilia grey.

♀, 19 mm. Forewings pale brownish-ochreous without strigulae; a well-defined dark fuscous triangle on base of dorsum extending two-thirds across wing; a sharply defined dark fuscous apical mark from three-fourths costa to midtermen; all other markings absent, except a dot on midcosta; cilia dark fuscous, towards tornus pale brownish-ochreous. This appears an extreme aberration, but probably the species is variable.

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

Argyroploce empyra n. sp.

εμπύρας, scorched.

♀, 18 mm. Head fuscous. Palpi 1; brownish. Antennae grey. Thorax grey; crest dark brown. Abdomen whitish-ochreous mixed with fuscous. Legs fuscous, tarsi with whitish rings; posterior pair grey-whitish. Forewings rather narrow, dilated posteriorly, costa gently arched, apex rectangular, termen

straight, not oblique; whitish obscured by reddish-brown and fuscous strigulae; markings dark fuscous; a series of costal strigulae; a small costal spot at one-fourth, and another in middle; a large oval blotch from tornus almost to costa, its centre leaden-grey; cilia reddish-brown, apices fuscous, around tornus wholly fuscous. Hindwings dark grey; cilia pale grey, towards apex grey with a grey basal line.

New South Wales: Brunswick Heads in December (W. B. Barnard); one specimen.

Argyroploce zophophanes n. sp.

ξοφαγής, gloomy.

♀, 20 mm. Head and thorax fuscous-brown. Palpi $3\frac{1}{2}$; fuscous-brown. Antennae fuscous. Abdomen fuscous-brown; tuft grey-whitish. Legs fuscous; tarsi with whitish rings; posterior pair mostly whitish. Forewings strongly dilated, costa almost straight, apex obtuse, termen slightly rounded, slightly oblique; dark fuscous; a small sub-basal fuscous tuft on dorsum; a whitish dorsal streak from near base to three-fourths strigulated with dark fuscous and brown; a narrow band of whitish and grey suffusion at two-thirds; a dark fuscous fascia, broad on costa before apex, gradually narrowing to a slender line ending on tornus, irregular-edged; a broad white terminal line edged with grey from costa before apex to near tornus, containing three downwardly oblique blackish streaks; cilia fuscous, bases brownish, on apex mostly brownish. Hindwings with 3 and 4 stalked; grey; cilia grey.

North Queensland: Kuranda in September (W. B. Barnard); one specimen.

Argyroploce auchmura n. sp.

ἀδυντος, squalid.

♀, 18 mm. Head and thorax fuscous. Palpi $1\frac{1}{2}$; fuscous. Antennae fuscous. Abdomen grey. Legs fuscous; tarsi with whitish rings; posterior pair whitish. Forewings with costa slightly arched, apex rounded, termen slightly rounded, not oblique; fuscous partly mixed with whitish; a series of dark fuscous costal dots and strigulae; a small whitish spot on one-third costa; an irregularly dentate fascia from midcosta to two-thirds dorsum; a sub-basal dark fuscous line of raised scales from dorsum half across wing; some whitish suffusion on mid-dorsum and in disc at two-thirds; a narrow irregularly dentate subterminal fascia from costa near apex to a grey spot on tornus, edged posteriorly by a fuscous line edged brownish from costa to termen below middle; a similar short line at apex; cilia whitish, towards tornus fuscous. Hindwings grey; cilia grey, from two-thirds termen to apex whitish. This species shows a general similarity to the preceding, but has very different palpi.

Queensland: Tweed Heads in June (W. B. Barnard); one specimen.

Argyroploce nephobola n. sp.

νεφοβόλος, clouded.

♂, 16 mm. Head, thorax and abdomen grey. Palpi 1; second joint smooth, broadly expanded at apex, terminal joint minute. Antennae grey; ciliations in male minute. Legs fuscous with whitish rings; posterior pair whitish. Forewings somewhat dilated, costa gently arched, apex rounded, termen rounded, slightly oblique; grey partly suffused with fuscous; a costal series of dark fuscous dots alternating with minute strigulae; a large costal blotch extending three-fourths across wing, white with some grey suffusion, invaded by a fuscous bar from midtermen ending in a broad central suffusion; between this and tornus two short longitudinal blackish streaks; cilia white with a broad fuscous bar on midtermen and narrower bars above and beneath. Hindwings and cilia grey.

Queensland: Brisbane in April; one specimen.

Argyroploce lychnospila n. sp.

$\lambda\chi\rho\sigma\pi\lambda\sigma$, with shiny spot or blotch.

δ , φ , 14-16 mm. Head and thorax blackish. Palpi $1\frac{1}{2}$; blackish. Antennae fuscous; ciliations in male minute. Abdomen fuscous. Legs blackish with whitish tarsal rings; posterior pair whitish or grey, tibiae in male with long white hairs above and beneath. Forewings suboblong, costa slightly arched, apex rounded, termen rounded, not oblique; leaden-grey mixed with fuscous or blackish; small fuscous or blackish costal strigulae; a leaden-grey suffusion preceding a pale brownish tornal area crossed by a downwardly oblique blackish line changing to reddish-brown as it approaches midtermen, sometimes prolonged to tornus; cilia grey, bases blackish. This is a variable species, for in addition to the aforesaid markings there is frequently a snow-white shining spot on two-fifths costa, or a costal blotch from one-fourth to three-fourths, sometimes prolonged to tornus. Hindwings in male grey; in female brown with grey terminal band; cilia white, towards apex grey with a whitish median line.

Queensland: Noosa in April and May; eight specimens.

ARTICOLLA PROSPERA

Two examples have been bred from the fruit of *Omphalestis queenslandiae* (Euphorbiaceae).

Articolla myriolychna n. sp.

$\mu\rho\rho\lambda\chi\rho\sigma$, with countless lights.

φ , 14 mm. Head and thorax fuscous. Palpi 2; fuscous. Antennae fuscous. Abdomen pale fuscous. Legs fuscous with whitish tarsal rings. Forewings narrow, costa almost straight, apex rounded, termen obliquely rounded; 8 and 9 stalked; dark fuscous sprinkled with numerous minute bluish-white shining scales mostly arranged in circles so as to appear dots; small whitish dots on costa and dorsum; a whitish terminal line from apex not reaching middle; cilia fuscous. Hindwings with 3 and 4 connate; dark grey, cilia grey.

North Queensland: Mossman; one example bred from the fruit of *Hearnia sapindina* (Meliaceae) in Brisbane in August.

Atticolla scioessa n. sp.

$\sigma\kappa\omega\sigma$, gloomy.

δ , 14 mm. Head and thorax dark fuscous. Palpi 1 $\frac{1}{2}$; dark fuscous. Antennae dark fuscous. (Abdomen missing.) Legs fuscous; tarsi with whitish rings. Forewings triangular, costa almost straight, apex pointed, termen straight, oblique; 7, 8, 9 closely approximated at base; dark fuscous to middle, beyond this paler; some whitish suffusion on dorsal and terminal margins; veins in dorsal area outlined with dark fuscous; a median whitish discal dot; costa with dark fuscous and whitish strigulae; cilia fuscous. Hindwings with 3 and 4 stalked; dark grey; cilia fuscous.

North Queensland: Lake Barrine, Atherton Tableland; one example bred from the fruit of *Acronychia vestita* (Rubiaceae) in Brisbane in July.

Laspeyresia cyanosticha n. sp.

$\kappa\omega\sigma\sigma\tau\chi\sigma$, blue-streaked.

δ , φ , 14-16 mm. Head, thorax and abdomen fuscous; face whitish. Palpi 1 $\frac{1}{2}$; white. Antennae pale grey; in male simple. Forewings with costa slightly arched, apex rectangular, termen sharply incised beneath apex, slightly rounded, slightly oblique; fuscous; a short grey-whitish oblique streak with fuscous

central line from dorsum before middle, sometimes obsolete; a broad outwardly curved whitish streak from two-thirds dorsum with a fuscous central line, or sometimes two lines; whitish costal strigulae separated by dark fuscous; the last two larger; a lustrous blue line from midcosta, at first very oblique, curved around end of second dorsal streak, and ending obtusely above tornus; between this and termen three short longitudinal blackish streaks; a similar blue streak from three-fourths costa to terminal incision; a blackish apical dot; a fine fuscous terminal line; cilia white, bases with blue lustre. Hindwings fuscous; cilia whitish.

North Queensland: Koah in December; three examples bred from fruit of *Parinarium nonda* (Rosaceae).

Laspeyresia aetheria n. sp.

ἀιθερίος, heavenly.

♂, 16 mm. Head and thorax dark fuscous. Palpi 1; ochreous-whitish. Antennae fuscous; in male simple. (Abdomen missing.) Legs fuscous. Forewings strongly dilated, costa gently arched, apex rounded, termen incised beneath apex, not oblique; six white costal strigulae, mostly long with blue apices, fourth strigula much longer, curved to termen just above incision, thence bent along termen and white to tornus; a pair of faint oblique grey lines from one-third dorsum to apex of second costal strigula; a similar pair from two-thirds dorsum to apex of fourth costal strigula; a broad curved whitish streak from tornus to fourth strigula, interrupted by a fuscous dot above tornus; cilia fuscous. Hindwings fuscous with slight purple sheen; a broad thinly scaled and translucent central stripe; cilia whitish.

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

Laspeyresia argyroela n. sp.

ἀργυροῦλος, with silvery rod.

♂, 12-13 mm. Head, thorax and abdomen fuscous. Palpi 1½; whitish, upper edge fuscous. Antennae fuscous; in male simple. Legs fuscous; tarsi with whitish rings. Forewings with costa slightly rounded, apex rounded-rectangular, termen slightly rounded, scarcely oblique; brownish-fuscous; numerous long oblique dark fuscous strigulae separated by whitish strigulae; a wide curved whitish streak with central fuscous line from mid-dorsum half across disc; a silvery white erect rod from before tornus half across disc; a lustrous blue line from midcosta to apex of this rod; between rod and termen four or five blackish longitudinal streaks; cilia fuscous. Hindwings dark fuscous; cilia grey-whitish.

Queensland: Tweed Heads in September. South Australia: Flinders Island in November. Two specimens.

Laspeyresia deloxanthia n. sp.

δηλαξανθίος, clear yellow.

♂, 12 mm. Head dark fuscous; face yellow. Palpi 2; yellow, basal half of second joint fuscous. Antennae and thorax dark fuscous. Abdomen grey. Legs fuscous; tarsi with whitish rings; posterior pair whitish. Forewings with costa gently arched, apex obtusely pointed, termen slightly rounded, oblique; clear yellow; a narrow fuscous basal fascia slightly prolonged on costa; some minute fuscous dots on costa before middle, and on dorsum before two-thirds; terminal area fuscous with darker longitudinal lines, its anterior edge nearly straight from three-fifths costa to two-thirds dorsum; some dark fuscous strigulae on apical third of costa separated by ochreous-whitish strigulae; a

slender incomplete yellowish terminal line; cilia fuscous. Hindwings fuscous; cilia ochreous-whitish with a grey submedian line, on tornus and dorsum grey.

North Queensland: Mossman; one example bred from the fruit of *Hearnia sapindaria* (Meliaceae) in Brisbane in July.

Laspeyresia delomilta n. sp.

δηλομιλτα, vivid red.

♀, 12 mm. Head red. Palpi 2; red. Antennae dark fuscous. Thorax dark fuscous; margins of tegulae and crest red. Abdomen fuscous with three pale ochreous transverse lines on dorsum. Legs fuscous with reddish rings; posterior femora grey, towards apices fuscous (tibiae and tarsi missing). Forewings with costa gently arched, apex rounded, termen obliquely rounded; vivid red with fuscous strigulae and markings; a series of dark fuscous and pale ochreous costal strigulae, the latter increasing in length towards apex of wing; a very irregular fuscous line from one-third costa to near tornus; the strigulae in disc above this are longitudinal; a whitish-ochreous line edged with fuscous from two-thirds costa towards one-third termen from apex; cilia dark fuscous with leaden grey lustre in oblique light. Hindwings fuscous with a broad ochreous central stripe to two-thirds; cilia whitish. In colour of forewings this resembles *L. martia* Meyr., but the markings differ. The ochreous centre of the hindwings is also distinctive.

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

Laspeyresia tornosticha n. sp.

ταρνοστιχος, with tornal lines.

♂, 10 mm. Head fuscous; face whitish. Palpi 2; whitish. Antennae fuscous; in male simple. Thorax and abdomen fuscous. Legs whitish. Forewings with costa slightly arched, apex rounded-rectangular, termen rounded, slightly oblique; fuscous; a series of whitish costal strigulae separated by dark fuscous; four outwardly curved whitish lines from middle third of dorsum nearly half across disc; two inwardly oblique slightly diverging whitish lines from tornus, the anterior short, the posterior reaching half across wing; a slender interrupted dark fuscous terminal line; cilia whitish. Hindwings and cilia grey. The tornal lines distinguish this from *L. tetrazancla* Turn.

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

Laspeyresia callilampetes n. sp.

καλλιλαμπετης, beautifully shining.

♂, 14 mm. Head and thorax fuscous. Palpi 2; fuscous. Antennae fuscous; in male simple. Abdomen grey. Legs fuscous. Forewings narrow, posteriorly dilated, costa straight, apex rounded, termen slightly rounded, slightly oblique; fuscous with brilliant purple and blue reflections; cilia fuscous. Hindwings and cilia pale grey.

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

MORPHOLOGY AND ANATOMY OF THE WESTERN AUSTRALIAN SPECIES OF TRIODIA R.BR

BY NANCY T. BURBIDGE, M.SC., WAITE AGRICULTURAL RESEARCH INSTITUTE

Summary

The first paper of this series dealt with the macroscopic characters of the species under discussion (4). The features so described are of interest to ecologists and taxonomists as well as to the anatomist since the variation in form, particularly at the junction of sheath and lamina, is of diagnostic value. As might be expected, this variation is correlated with modification of the internal anatomy which will be described later.

The great diversity in the anatomy of grasses is well known, but few grass leaves, which have been described, are so modified to permit the various life processes to continue despite the aridity of the habitat (8). There is a tendency in ecological work to class the grasses with the herbaceous species, but these tussock grasses play more the part of small shrubs in their particular plant association (3). So far as the Australian environment is concerned they are the tropical counterpart of the chenopodiaceous shrubs which are so important in southern arid country (14). They are, therefore drought enduring species and their anatomy is specialized in accordance with their need.

**MORPHOLOGY AND ANATOMY OF THE
WESTERN AUSTRALIAN SPECIES OF TRIODIA R.Br.**

II. INTERNAL ANATOMY OF LEAVES

By NANCY T. BURBIDGE, M.Sc., Waite Agricultural Research Institute

[Read 13 June 1946]

PLATES XXXI TO XXXVII

The first paper of this series dealt with the macroscopic characters of the species under discussion (4). The features so described are of interest to ecologists and taxonomists as well as to the anatomist since the variation in form, particularly at the junction of sheath and lamina, is of diagnostic value. As might be expected, this variation is correlated with modification of the internal anatomy which will be described later.

The great diversity in the anatomy of grasses is well known, but few grass leaves, which have been described, are so modified to permit the various life processes to continue despite the aridity of the habitat (8). There is a tendency in ecological work to class the grasses with the herbaceous species, but these tussock grasses play more the part of small shrubs in their particular plant association (3). So far as the Australian environment is concerned they are the tropical counterpart of the chenopodiaceous shrubs which are so important in southern arid country (14). They are, therefore, drought enduring species and their anatomy is specialized in accordance with their need.

METHODS AND MATERIALS

The only fresh material available was that of *Triodia pungens* R. Br., which differs, in a number of important features, from all the other species. This was unfortunate, but lack of seed prevented the growing of any other species. As a result herbarium specimens were utilised. The material was treated in alcohol according to the method described by McLean (9). Leaves which had been so prepared proved much better for cutting than boiled material, though satisfactory mounts were made from the latter. The sections of the laminae were taken about 1-1·5 cm. above the petiole. All sections were cut free-hand.

GENERAL STRUCTURE

SHEATH

As was stated in Pt. I, the leaf arises spirally from the node. In his work on *Saccharum officinarum* Artschwager (2) described how the leaf traces descending from the leaf took a horizontal course at the level of the node and then passed down the centre of the stem. In *Triodia* a similar condition exists. The culm, which will be more fully described at a later date, has a central core of vascular tissue bounded by an endodermis and often possesses a small hollow pith. There is a narrow cortex.

For the sake of convenience the development in *Triodia* will be described from just below the node up to the lamina.

The first leaf traces which become distinguishable from the vascular core are found in the cortex about 2-4 mm. below the insertion of the sheath on the node. The distance varies according to the length of the internode, and also with the species. These primary traces are small (pl. xxxii, fig. 6) and consist of little more than one or two protoxylem elements and a few fibres. At the level of the node a number of larger traces become recognisable as they pass almost hori-

zontally across the nodal plexus and into the cortex, where they take up positions between the primary traces (pl. xxxii, fig. 7). At this stage the outer margin of the sheath breaks free, followed by the inner. The last portion to become free from the culm is that part of the sheath into which the last trace passes from the nodal plexus. In some species this is the median nerve, e.g., *T. secunda* (pl. xxxii, fig. 8) and *T. longiceps*, but in *T. pungens* it is the first lateral on the side towards the inner margin. When the sheath has become separated the bundles have the following status. The median nerve is usually large, as are the first laterals on either side, while between the median and each lateral is a subsidiary nerve which represents the continuation of one of the original primary nerves. In some species there are two subsidiaries, and this condition is further discussed below. Outside the first lateral on either side is another small bundle (primary) followed by a large one, and then the bundles rapidly decrease in size towards the margin (pl. xxxi, fig. 1-8).

Immediately above the junction of sheath and node the tissue is pulvinal (false node of some authors). The bundles are free in the general parenchyma and the associated fibres are not fully lignified. The condition in *T. pungens* is shown in pl. xxxi, fig. 2-3). There is a large number of siliceous cells in the abaxial epidermis.

Above the pulvinus the parenchyma between the bundles becomes loose and then breaks down, leaving spaces (pl. xxxi, fig. 3-6; pl. xxxii, fig. 9). These cavities extend up the sheath for more than three-quarters of its length. Then they gradually decrease until they disappear just below the orifice. Such cavities occur in many other grasses. They have been figured for *Lolium rigidum* (7), *Saccharum officinarum* (2) and in *Agrostis tenuis* (1), and appear to be a normal feature of sheaths. From the pulvinus to the orifice there is a progressive increase in the relative amount of sclerenchyma present. The fibres associated with the bundles become linked with the abaxial epidermis, while other fibres develop in the central portion of the adaxial surface (pl. xxxi, fig. 5-8; pl. xxxii, fig. 9).

In species other than *T. pungens* the abaxial surface of the sheath is smooth or has shallow grooves due to the presence of fibres over the bundles. In *T. pungens*, as the sheath emerges above the ligule of the preceding sheath, the median abaxial portion becomes definitely grooved. In the cavities so formed the epidermal cells carry papillae with either blunt or acute apices and chlorenchyma is developed along the sides (pl. xxxi, fig. 5-7; pl. xxxii, fig. 1). Cells containing chloroplasts are found throughout the general parenchyma at all levels of the sheath in all species, but only in *T. pungens* is there any well-defined tissue similar to that found in the laminae.

T. pungens is also peculiar in having a resin secreting epidermis. This special tissue is found along the abaxial epidermis of the flange of the sheath. The best development occurs on exposed portions, i.e., in the same part as the chlorenchyma described above but on either side. The resiniferous tissue continues up the margin to the auricular ridge (4), where it is interrupted by the auricular hairs (also epidermal in origin). It is found again on the petiole, but disappears at the base of the lamina (pl. xxxi, fig. 5-13).

THE ORIFICE AND THE PETIOLE

At the orifice the margins of the sheath become thinner, while the central portion becomes thickened and more or less triangular in section. At the same time the nerves which will pass up into the lamina are found grouped in this central part. They usually consist of the median, subsidiary and first, third and fourth laterals. The number of laterals involved varies in different species. In *T. secunda* three marginal veins on either side pass into the fringed auricular appendage (4), whereas in *T. pungens* the number of laterals varies from one

form of the species to another. Open lamina forms have more nerves than closed lamina ones (i.e.) (pl. xxiv, fig. 3, and pl. xxxvii, fig. 1). Compare also *T. lanigera* in pl. xxxiv and xxxv. The second laterals disappear.

The behaviour of the subsidiaries was found to vary in different species. In *T. pungens*, as is shown in pl. xxxi, one subsidiary is present in the sheath, but in the petiole a second pair develops as an off-shoot from the first laterals (pl. xxxi, fig. 11). This second pair becomes associated with the sclerenchyma which linked the first laterals to the abaxial epidermis. Thus ultimately all laterals are attached to adaxial groups of fibres (pl. xxxi, fig. 12 and 13). *T. irritans* is anomalous in this part of its anatomy. In the sheath there is one pair of subsidiaries but the blade is variable, a common condition being one subsidiary on one side of the median nerve and two on the other (pl. xxxiv, fig. 7). Occasionally there are two pairs of subsidiaries or the sheath condition is continued up into the petiole. These differences are due to the amount of branching which may or may not take place in the petiole (pl. xxxii, fig. 4). If the median alone branches a state of asymmetry is found, while in other specimens studied both the first lateral's and the median nerve had branched. In this case one of the lateral branches was very small and soon died out (pl. xxxii, fig. 5). As this was produced on the same side as the median off-shoot the resultant lamina appeared symmetrical (pl. xxxvii, fig. 2). In *T. Basedowii* and *T. lanigera* two subsidiary nerves are present on either side of the median in the sheath as well as in the lamina (pl. xxxii, fig. 2-3; pl. xxxiv, fig. 1-2). In the remaining species the single subsidiary of the sheath continues up into the lamina.

The length of the petiole varies in different species and on different leaves of the same plant. It is always highly sclerenchymatous and triangular in section. The development of the petiole which, of course, is not a true petiole in the ontogenetical sense, determines the angle between the sheath and the leaf blade. Strength at this point is essential if the whole organ is to survive a prolonged period at or near the wilting point.

The ligular hairs are unicellular but the hairs of the auricular ridge and petiole, when developed, are multicellular though the septa are few. In tomentose forms like *T. Basedowii* and *T. lanigera* the hairs are coiled and tangled together.

As the petiole passes into the lamina the adaxial and abaxial surfaces (adaxial only in *T. pungens*) become lobed between the bundles. The proportion of sclerenchyma to parenchyma decreases (pl. xxxi, fig. 11-13) and chlorenchyma is developed on the sides of the grooves, so that there is a gradual transition into the condition found in the lamina.

LAMINA

The general arrangement of tissues is much the same in all species except *T. pungens*. Plate xxxiv shows a series of diagrams representing the structure of the lamina in all species. It will be noted that *T. pungens* is quite outstanding (pl. xxxiv, fig. 3). It should be compared with fig. 6 which represents *Plectrachne Schinsii*, a member of a closely related genus. Species of *Plectrachne* were formerly grouped under *Triraphis* R. Br., though very different from Robert Brown's type species *T. mollis*. They are coarse tussock-forming grasses of the same type as that found in *Triodia*, and they have a similar distribution. The two genera are separated mainly on the length of the lobes of the lemma. In *Plectrachne* the lobes are elongated into long awns, whereas in *Triodia* they vary from obtuse or acute lobes longer than the base of the lemma (*T. pungens*, *T. lanigera* and *T. Basedowii*) to mere indentations of the apex of the lemma (*T. irritans*, *T. angusta* and *T. secunda*). In view of the variation within *Triodia* the distinction between the genera is not wholly satisfactory and it is interesting to find such an affinity in the leaf anatomy.

The variations in internal structure of the lamina agree with the affinities deduced during the taxonomic study (5) and expressed in the key based on floral structure. Thus *T. pungens*, *T. Basedowii* and *T. lanigera* which, as stated above, have deeply lobed lemmas all have two pairs of subsidiary nerves. *T. Wiseana* and *T. brisioides* share a number of characters. The main difference is that in the former the inner faces of the lamina (i.e., the adaxial or upper face) have two instead of one groove unopposed to a corresponding one on the outer face (pl. xxxiv, fig. 4-5). It is doubtful whether such a character could be regarded as diagnostic.

T. irritans and *T. Fitzgeraldii* are remarkable for the amount of sclerenchyma which is developed. It will be noticed that in the former the bundles are linked to the abaxial sclerenchyma, and in the latter to the adaxial. Also, as has already been mentioned, *T. irritans* is often asymmetrical. Leaves of this type were found on specimens available from both Western and South Australia, so the condition cannot be regarded as a mere abnormality. *T. irritans* shares with *T. Wiseana* and *T. brisioides* the character of having the chlorenchyma comparatively free from the sclerenchyma, whereas in *T. Fitzgeraldii* and *T. longiceps* the groups of chlorenchyma, with their associated parenchyma sheath, are practically enclosed in fibres, particularly on the abaxial surface (pl. xxxiv, fig. 8-9).

In *T. angusta* and *T. secunda* sclerenchyma has been reduced to a minimum and the chlorenchyma is bounded by mesophyll cells. It is significant that both these favour habitats where moisture is likely to be available for a longer period than is the case for the other species. Thus *T. angusta* grows on the upper banks of rivers and creeks subjected to periodic flooding in the wet season, while *T. secunda* is found near drainage channels or on wide flats which are also subject to occasional flooding in good years (pl. xxxiv, fig. 10-11, and pl. xxxvi, fig. 1).

It was stated in the first paper of this series that when the leaf was fresh the blade was more or less open, i.e., V-shaped in section, whereas when dry the blade closed up and became U-shaped. In pl. xxxvii, fig., a section made from fresh material of *T. pungens* illustrates the former condition, while pl. xxxvi, fig. 1, shows the latter in *T. angusta*. The section in this case was prepared from a boiled leaf which had been taken from a herbarium specimen. *T. angusta* though, with *T. secunda*, among the least xeromorphic in internal structure, never has a very open lamina. Consideration of the diagrams on pl. xxxiv and the photographs will explain why *T. pungens* exhibits the most marked changes in the degree of open-ness.

Towards the apex of the lamina the lateral nerves die out one by one, commencing with the marginal pair until the median, subsidiaries and the first laterals remain. In species having two pairs of subsidiaries the outer ones are the next to disappear, then the inner followed by the laterals, leaving only the median. At the same time there is a progressive reduction in the amount of mesophyll and chlorenchyma, so that finally in all species the pungent point is formed of the median nerve surrounded by sclerenchyma.

HISTOLOGY

EPIDERMIS

The cells of the epidermis may be subdivided as follows:—(1) normal epidermal cells, (ii) siliceous and suberised cells, (iii) secretory cells (*T. pungens* only), (iv) hairs, and (v) stomates.

(i) *Normal epidermal cells*—In surface view the majority of the epidermal cells have the same undulating wall as has been described and figured for many other grasses. In vertical section they appear about as wide as deep, but the outer wall is thickened and the central cavity is consequently more or less oval.

Epidermal cells above a vein or on the adaxial surface of the sheath are simpler in outline (surface view) than are those between the veins or in the grooves of the laminae.

(ii) *Siliceous and suberised cells*—These are short and occur together either in pairs or two siliceous cells separated by a suberised one. The latter cells are always more or less square or shortly rectangular, but the siliceous cells vary from rough squares to double axe-shaped bodies. The shape is simplest in epidermis covering sclerenchyma, i.e., above a nerve. In section the cells are shorter than the surrounding cutinised ones. They are absent from the abaxial face of the sheath.

(iii) *Secretory cells*—These have been mentioned in the description of the sheath in *T. pungens*, and are responsible for the production of a sticky resin which is visible to the naked eye as a line down the margins of the sheath. If the production of resin is very vigorous, as it is in good seasons and after rain, drops of the substance may fall on to other parts of the leaves, including the lamina. The function of the resin is obscure. The modified epidermis is always produced on the outer margins of the sheath and on the portion which will project above the preceding sheath. The development is commonly interrupted above a vein (pl. xxxiii, fig. 3). The thin-walled secretory cells are supported by thick-walled ones whose projecting tops form minute flanges. In surface view (pl. xxxii, fig. 10) these stand slightly above their neighbours, which, like them, are short and wide.

Secretory epidermis is rare among grasses, but resin is produced in other species of *Triodia*, e.g., *T. Mitchellii* and *T. stenostachya*, which are not known to occur in Western Australia.

(iv) *Hairs*—The hairs developed from the epidermal cells are of three types: *a*, papillae or unicellular hairs in which there is a projection of the cell wall; *b*, long multicellular hairs in which several septa are present, and *c*, two-celled hairs which are found only in the grooves of the laminae.

The papillae may be blunt or sharp-pointed, but the walls are always thickened in the same manner as those of the normal epidermal cell (pl. xxxv, fig. 1 and 2; and pl. xxxvi, fig. 1). These papillae are found on all parts of the adaxial surface in all species. They do not develop on the exposed parts of the abaxial surface but are abundant in all grooves except in *T. pungens* (pl. xxxiii, fig. 1). In the grooves the papillae interlock with those on the opposite face. This must prevent complete collapse of the grooves when the leaf is in a state of wilting. If the grooves were fully closed there would be serious interference with transpiration and respiration. Rigid papillae are also present in the grooves of the leaf sheath in *T. pungens* (pl. xxxii, fig. 1).

Multicellular hairs occur in pubescent species such as *T. lanigera* and *T. Basedowii*, and also on the auricular ridges of all other species. They may be stiff and more or less straight as in *T. pungens* or coiled and tangled as in the two last-named species.

The hairs of the ligule are intermediate between the last two types. The hairs are divided off from the epidermal cell, but other septa were absent in those inspected.

The two-celled hairs are found at intervals along the bases of the grooves on laminae of all species. Their relative abundance varies considerably from species to species, as does their size. They are scarce in *T. lanigera* and *T. Basedowii*, and abundant in *T. angusta* and *T. secunda*. The hairs consist of a bulbous-based cell imbedded between the epidermal cells and epidermal in origin and an apical cell. Both cells are thin-walled (pl. xxxiii, fig. 2; pl. xxxvi, fig. 1 and 2). In pl. xxxv the drawing of the T.S. lamina of *T. Fitzgeraldii* also shows some

of these hairs, but the cut has not passed directly through their bases. These organs are the same as those described by Prat (11) as being characteristic of his Chloridoid type of epidermis, under which he classes the Eragrostideae. *Triodia* has been placed in this sub-family by some authors. Prat's hypotheses concerning the relationships of grasses are extremely interesting, but it is possible that some of his affinities may be due to parallel development in similar habitats as well as to phylogeny. That a large group of Australian arid species would come under his Chloridoid type is a case in point.

The fact that these two-celled hairs are (except in *T. pungens*) in direct contact with the thin-walled mesophyll tissue between the bundles (pl. xxxiii, fig. 2; pl. xxxvi, fig. 2), makes it possible that they are associated with the response of the tissues to changes in atmospheric moisture content. However, since the hairs occur in other genera and subfamilies which do not have such specialised laminæ, the point cannot be settled without the aid of the physiologist.

In *T. pungens* the hairs occur only on the upper surface and only in grooves between lateral nerves. They are placed directly above chlorenchyma and are smaller with a less bulbous base than in other species.

(v) *Stomates*.—These are of the normal grass type. They are to be found only on protected surfaces. They are present in grooves in the sheath of *T. pungens* and on the overlapping flanges of the margins as well as in the grooves of the lamina adjacent to the chlorenchyma in all species.

VASCULAR TISSUE AND ASSOCIATED SCLERENCHYMA

The vascular bundles are of the fascicoid type, since there is a mestome sheath as well as a parenchyma one. An unusual feature is the breaking-up of the phloem into two, or sometimes three, groups in the larger bundles such as the median and first laterals. The division occurs as a result of the formation of small fibres, and is found in all bundles of sufficient size whether in the sheath or the lamina. In the section of *T. lanigera* (pl. xxxv) the phloem is not completely intruded, but in pl. xxxvi, fig. 1, the phloem groups in the lamina of *T. angusta* are quite distinct. Subdivision of the phloem occurs in other Australian xerophytes.

The arrangement of the peripheral sclerenchyma developed between the epidermis and the bundle varies from species to species (pl. xxxiv). Whether this sclerenchyma is in direct contact with the mestome sheath or whether the two are separated by the parenchyma sheath varies not only with the species but also from one bundle to another (pl. xxxv, fig. 1-2).

CHLORENCHYMA AND ASSOCIATED PARENCHYMA

The chlorenchyma is formed in bands along the sides of the grooves on the laminae. The tissue is by no means extensive. If the ratio between the amount of chlorenchyma and the amount of vascular tissue per unit area be taken as a measure of xeromorphy, then these leaves must be placed high among the sclerophylls.

The detail of the cells was very difficult to discern even in fresh material. The walls are thin and the contents dense, so that staining of tissues is even. In the various drawings they are stippled to distinguish them from the adjacent mesophyll cells. While the general arrangement of the cells is compact, there are always air spaces immediately below the stomates.

The cells of the parenchyma sheath of the bundle are extended as arms of a single cell in thickness around the chlorenchyma (pl. xxxv) and divide the latter from the peripheral sclerenchyma. These mesophyll cells contain plastids and, in fresh material, large compound starch grains. The cell walls adjoining the

chlorenchyma are pierced by innumerable pits. Rhoades and Carvalho (12) found that plastids in the parenchyma sheath of the maize leaf were directly concerned in the elaboration of starch. They state that the plastids in *Zea Mays* are different from those of members of the Pooidae. Nevertheless, a similar function is probably carried on by the plastids in the chlorenchyma sheath in *Triodia*.

MESOPHYLL

The tissue of the leaf between the parenchyma sheaths of adjacent bundles is formed of thin-walled cells with occasional thick-walled fibres which appear to be sclereid in function. The latter are particularly evident in *T. Fitzgeraldii* (pl. xxxv, fig. 2).

It is believed that shrinkage of this tissue would result in the reduction of the width of the groove, with consequent interlocking of the epidermal papillae and the protection of the stomates. The transverse bands of tissue are clearly recognisable in all sections (pl. xxxv, fig. 1-2; pl. xxxvi, fig. 1) except in *T. pungens*, which is again different from the remaining species (pl. xxxvii, fig. 1). Owing to the lack of grooves development of the thin-walled tissue occurs only between the median and the subsidiaries (pl. xxxiii, fig. 1). As indicated in the figures the cells are commonly shrunken in prepared mounts, though they are turgid in pl. xxxvii, fig. 1, which was from fresh material. The mesophyll cells pass without demarcation into the epidermal cells which, though thin-walled inside, have a cutinised and sometimes papillose outer wall (pl. xxxiii, fig. 1). In pl. xxxv it can be seen that there is a similar modification of the epidermis at the bases of the grooves adjacent to the median and subsidiary nerves. It is at these points that the closing and opening of the lamina causes the greatest strain, and these modified epidermal cells are homologous with the bulliform cells of Duval-Jouve and figured by him for *Sesleria caerulea* (7). Similar cells have also been figured by Arber (1) for *Desechampsia caespitosa*.

In species where there is comparatively little sclerenchyma the body of the leaf is made up of parenchyma cells similar to those of the parenchyma sheath (pl. xxxv, fig. 1). In *T. pungens* there is a parenchyma zone below the lateral nerves. In fresh material the cells contain plastids and are rich in compound starch granules. This provides some explanation of the fact that this species, coarse though it is, provides a nutritious reserve fodder for sheep.

DISCUSSION

Very little has, as yet, been published concerning the anatomy of the Australian grasses. One of the most detailed studies was that of Vickery (13), who discussed a number of species from the Andropogoneae, Zoysieae and Tristagineae occurring in New South Wales. As all of these have a panicoid anatomy direct comparison with *Triodia* is difficult.

Turning to overseas work, the contrast between the structure of the lamina in the Australian *Triodia* spp. with that illustrated for *Sicylingia decumbens* Benth. (= *Triodia decumbens* Beauv.) by Burr and Turner (6), supports Stapf's view that *Triodia* should be restricted to the Australian species. On the other hand, if resemblances are sought there is a likeness between the furrowing of the lamina in *Triodia* and that in *Psamma arenaria* (L.C.), in various South American species of *Heirochloe* (10) and in the South African *Aristida vestita* (1). Since the four genera concerned belong to three sub-families of the Gramineae, the similarity between them can only be due to parallelism. It is interesting that the habitats in which the two former grow share certain ecological features.

Consideration of the behaviour of the lamina in *Triodia* during periods of wilting make it clear that mere folding together of the two halves of the leaf is

not sufficient. Such a folding would expose, not protect, the stomates in the grooves of the outer (*i.e.*, the lower) surface. This is in contrast to the condition in the species mentioned above, where there is no furrowing of the lower surface. Since the closing of the blades is known to take place as the leaf is drying, there must be some mechanism to prevent over-exposure of the outer grooves. This is probably the reduction in volume of the thin-walled tissue between the bundles. Shrinkage of this mesophyll would have the desired result without seriously interfering with the efficiency of the more important chlorenchyma and vascular tissue. The large amount of mechanical tissue must act as a support against permanent collapse during such periods of strain.

Discussion of the course of the leaf traces in the culm from the node down must be left until this part of the plant is described in Part III. The fact that the minor bundles are free only in the internode immediately below their sheath, while the major bundles continue down the culm for some distance, is in accord with other work (2).

SUMMARY

The manner in which the leaf traces pass between the sheath and the node has been described. It differs only slightly from one species to another.

The bundles within the sheath have a definite arrangement, and only the number of minor veins on either side varies.

A number of the marginal veins are lost at the orifice. The remainder pass up through the petiole into the lamina, and then at the tip die out from each side until only the median one continues into the terete pungent point.

The lamina is deeply grooved and stomates occur only in the grooves. The differences in structure from species to species could be of value in diagnosis if so desired.

Chlorenchyma is scanty in the lamina, and in the sheath occurs only in *T. pungens*. Mechanical tissue is abundant except in *T. angusta* and *T. secunda*.

T. pungens is different from all other species and anatomically stands quite apart. The lamina is very similar to that of *Plectrachne Schinzii*. It is also peculiar in having a resin secreting epidermis on the margins of the sheaths. This character is shared with several non-Western Australian species.

Resemblances with some other genera are discussed briefly, as is the mechanism which permits the closing of the grooves on both sides of the lamina during periods of water shortage.

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EXPLANATION OF PLATES XXXI TO XXXVII

PLATE XXXI

T. pungens, a series of diagrammatic sections from the node to the upper part of the petiole; a.h., auricular hairs; c., cavities in mesophyll; l., ligule hairs; m.n., median nerve; n.p., nodal plexus; r.e., resiniferous epidermis; scl., sclerenchyma; v.b., vascular bundle; 1st s. and 2nd s., first and second subsidiary nerves.

PLATE XXXII

1. *T. pungens*, transverse section of part of the sheath showing grooves with chlorenchyma. $\times 150$; c., cavities in mesophyll; ch., chlorenchyma.
2. *T. Basedowii*, diagrammatic section of sheath showing two pairs of subsidiary nerves; m.n., median nerve; s.n., subsidiary nerve. $\times 20$.
3. *T. Basedowii*: T.S., petiole. $\times 20$.
4. *T. irritans* " showing one pair subsidiaries. $\times 20$.
5. " " showing median and first laterals each with a small off-shoot. $\times 20$.
6. *T. secunda*: T.S. culm, just below junction of sheath and node. $\times 20$.
7. " }
8. " stages above, 6. $\times 20$.
9. " T.S., higher up sheath. Note single pair of subsidiary nerves. $\times 20$.
10. *T. pungens*, surface view of resiniferous epidermis. $\times 400$.

PLATE XXXIII

1. *T. pungens*: T.S., central portion of lamina showing the thin-walled mesophyll and bulliform cells on the upper epidermis between the median and subsidiary nerves and between the latter and the first laterals. chlor., chlorenchyma; b.c., bulliform cells.

2. *T. angusta*: T.S., portion of lamina showing bulbous based two-celled hairs in the grooves.

3. *T. pungens*: T.S., outer portion of sheath showing resin secreting epidermis.

PLATE XXXIV

Diagrams illustrating the variation in construction of the lamina: 1, *T. lanigera*; 2, *T. Basedowii*; 3, *T. pungens*; 4, *T. Wiseana*; 5, *T. brizoides*; 6, *Plectrachne Schenckii*; 7, *T. irritans*; 8, *T. Fitzgeraldii*; 9, *T. longiceps*; 10, *T. angusta*; 11, *T. secunda*. All approx. $\times 80$.

PLATE XXXV

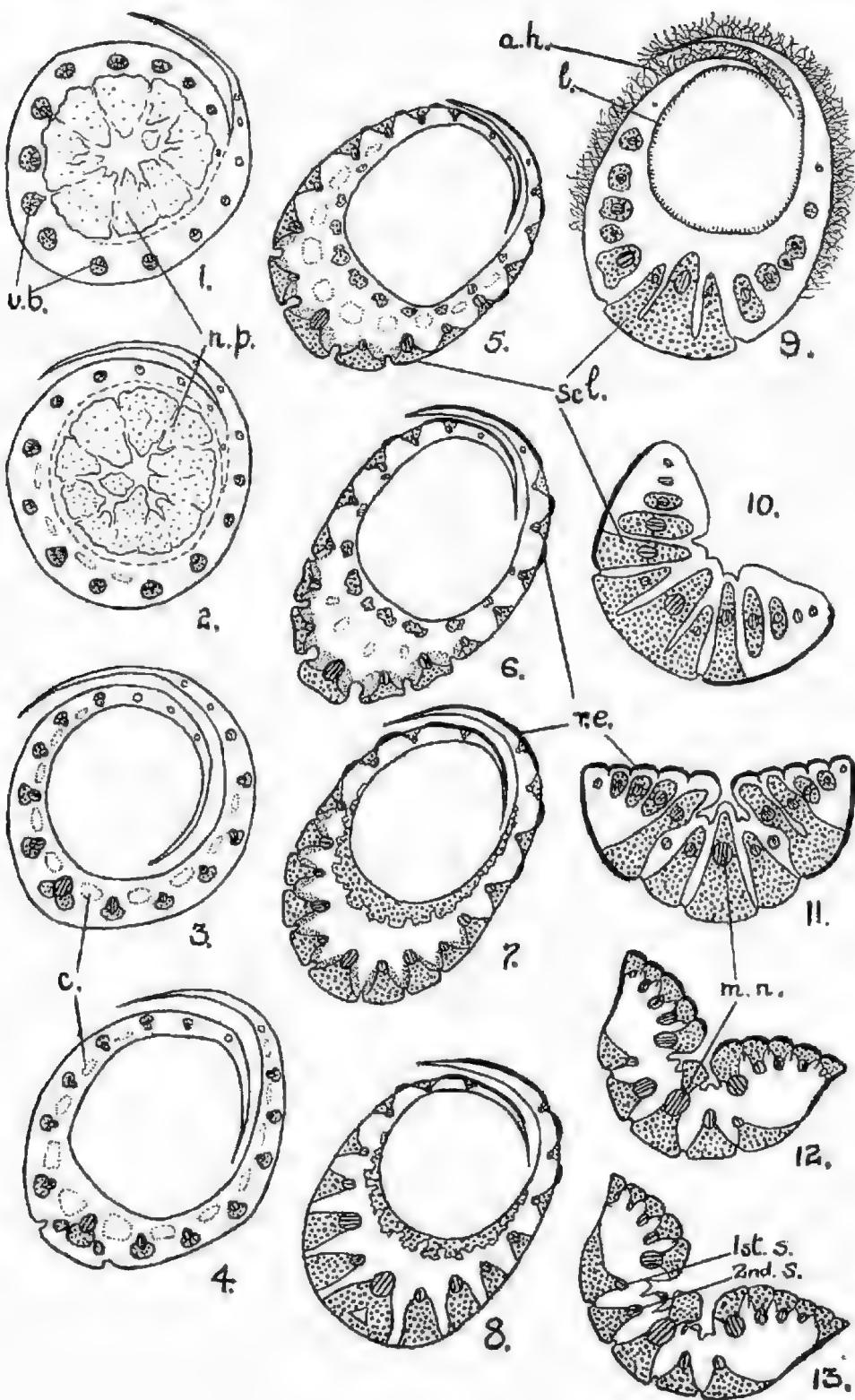
1. *T. lanigera*: T.S. lamina. $\times 170$.
 2. *T. Fitzgeraldii*: T.S. lamina. $\times 170$.
- b.c., bulliform cells; h., hair; g., groove; m., mesophyll; p.s., parenchyma sheath; scl., sclerenchyma; st., stomate; v.b., vascular bundle; m.n., median nerve; 1st s. and 2nd s., first and second subsidiary nerves; 2nd l., second lateral.

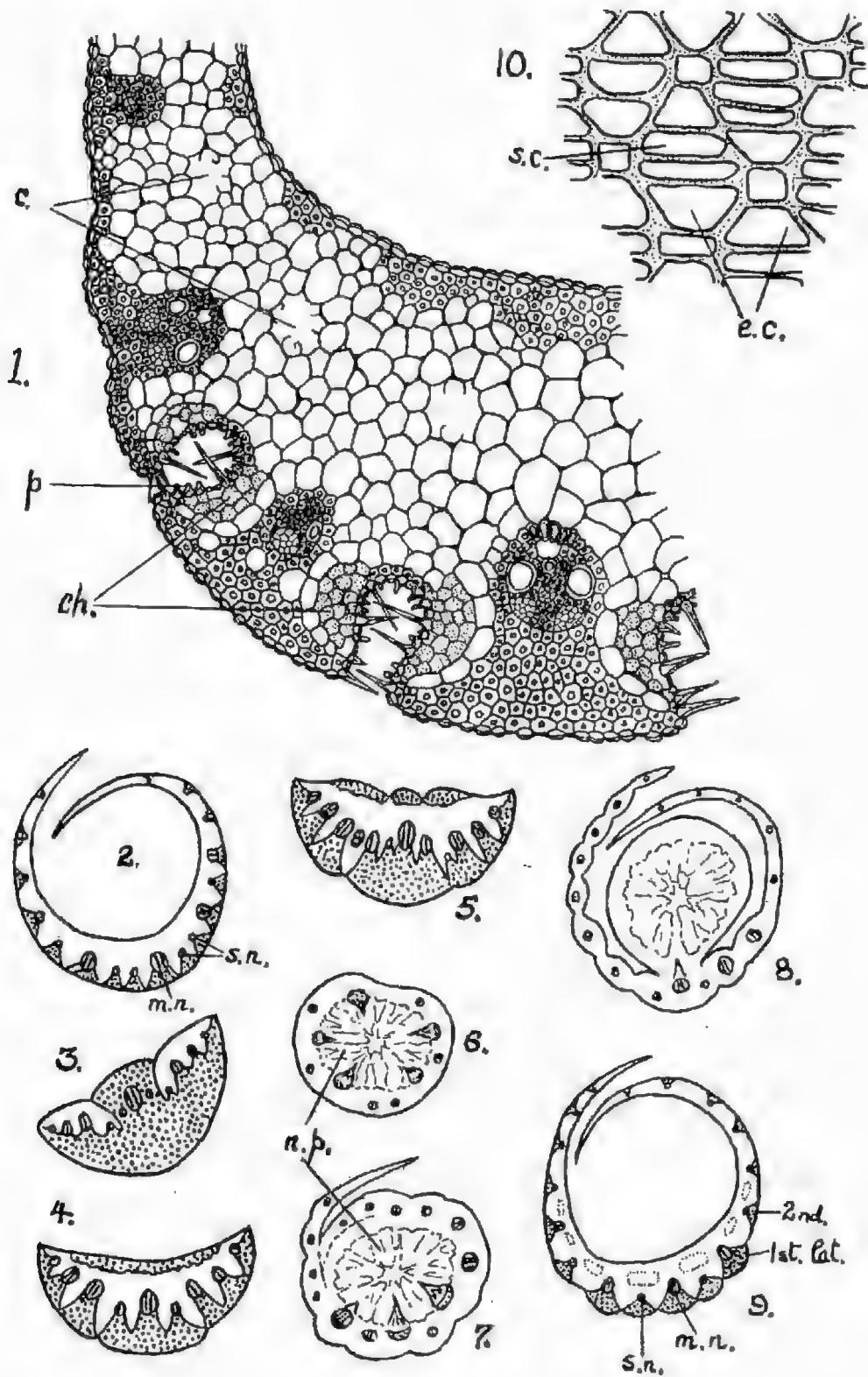
PLATE XXXVI

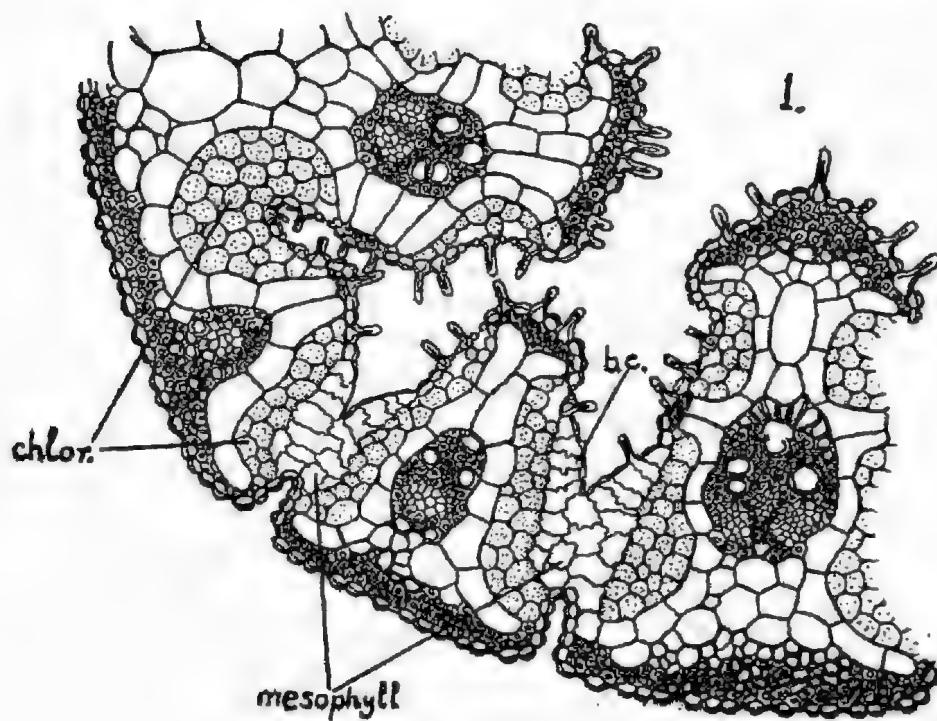
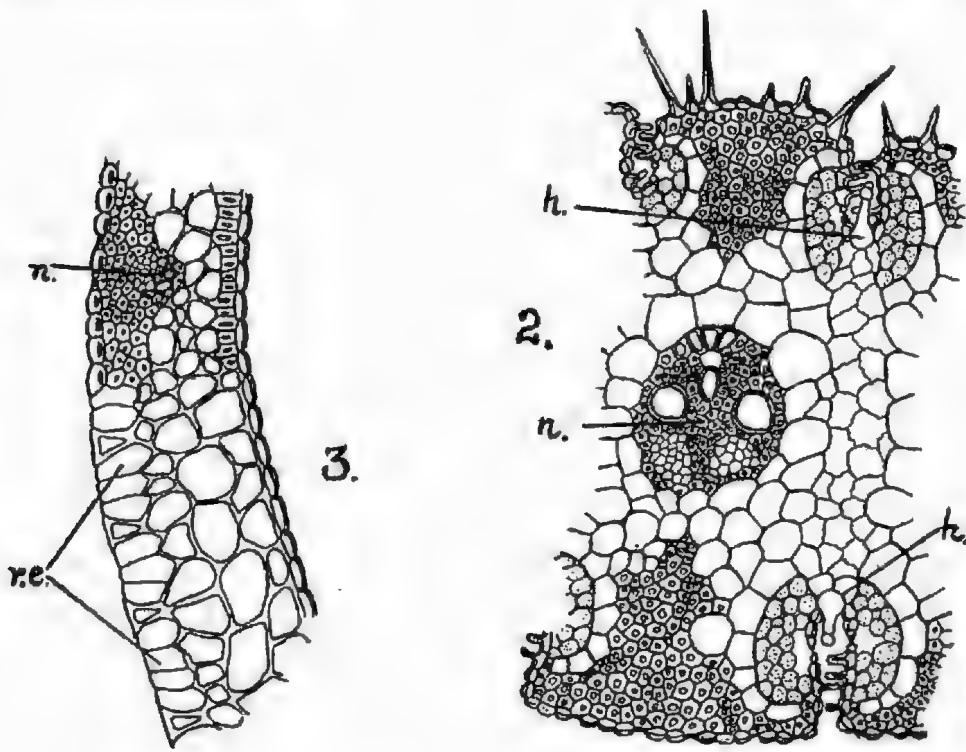
1. *T. angusta*: T.S. lamina (note double phloem and transverse bands of thin-walled mesophyll).
2. *T. angusta*: portion of above showing detail of bulbous based hair in groove.

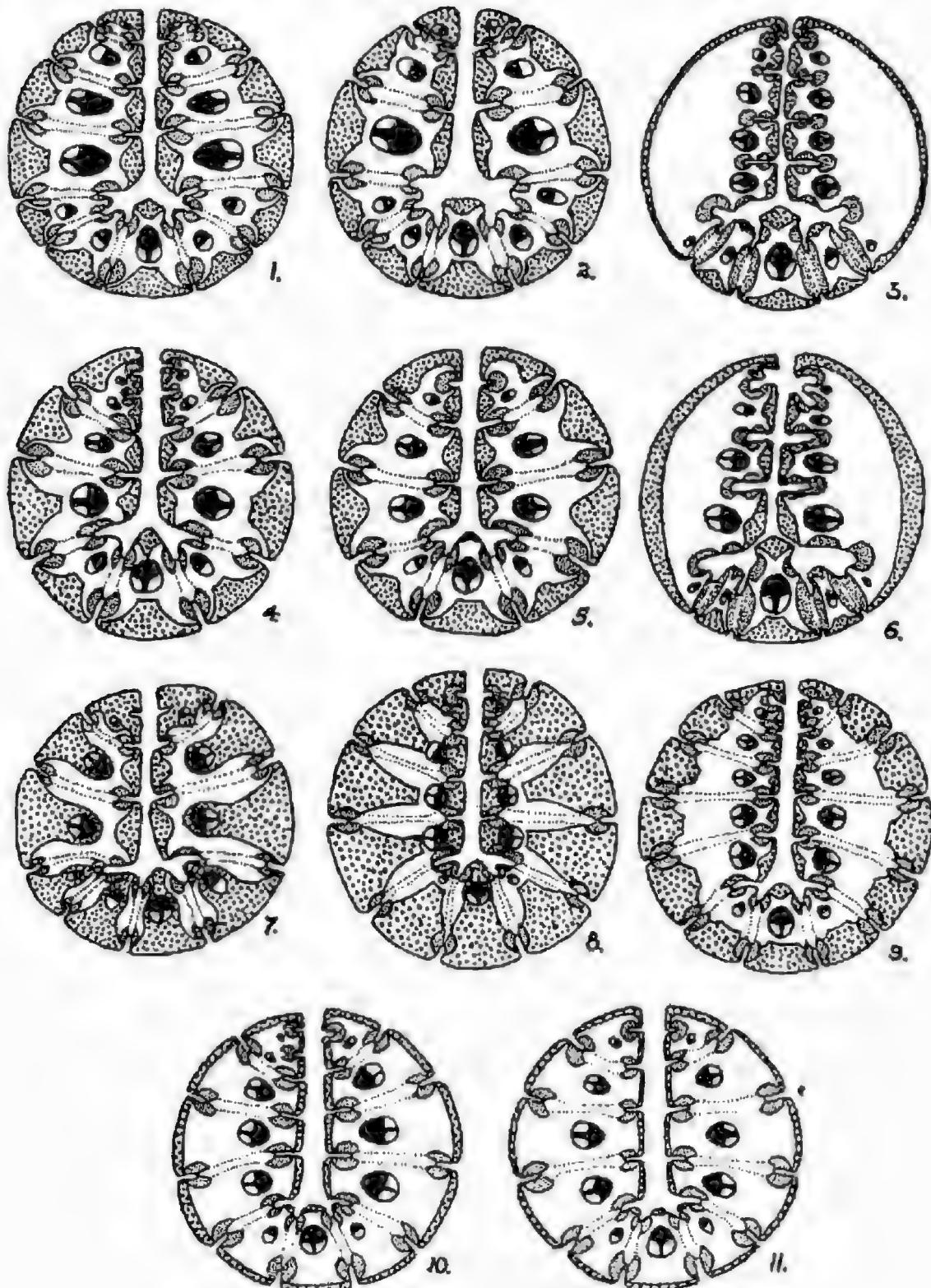
PLATE XXXVII

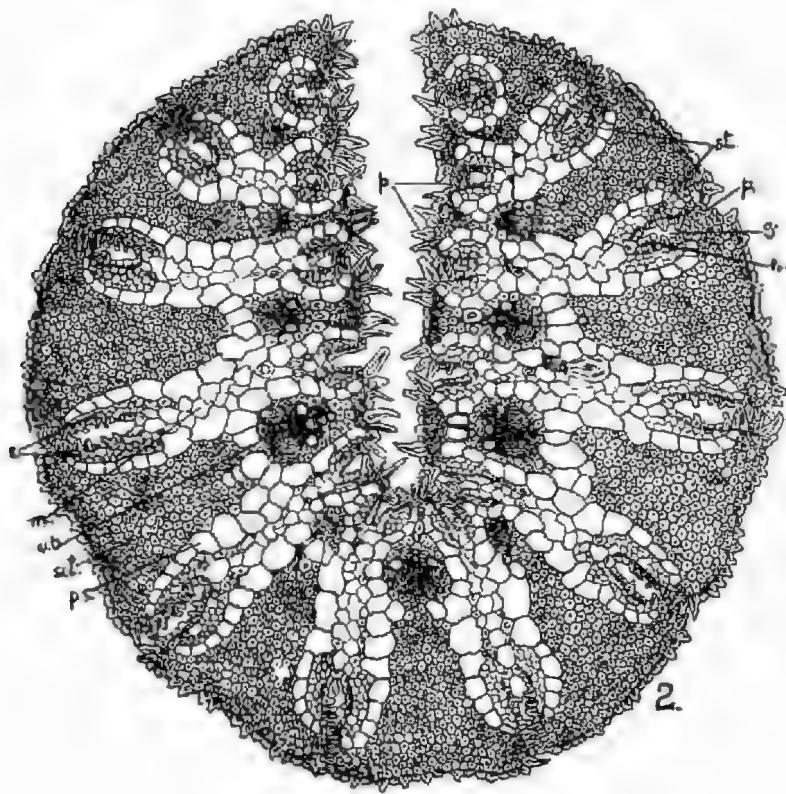
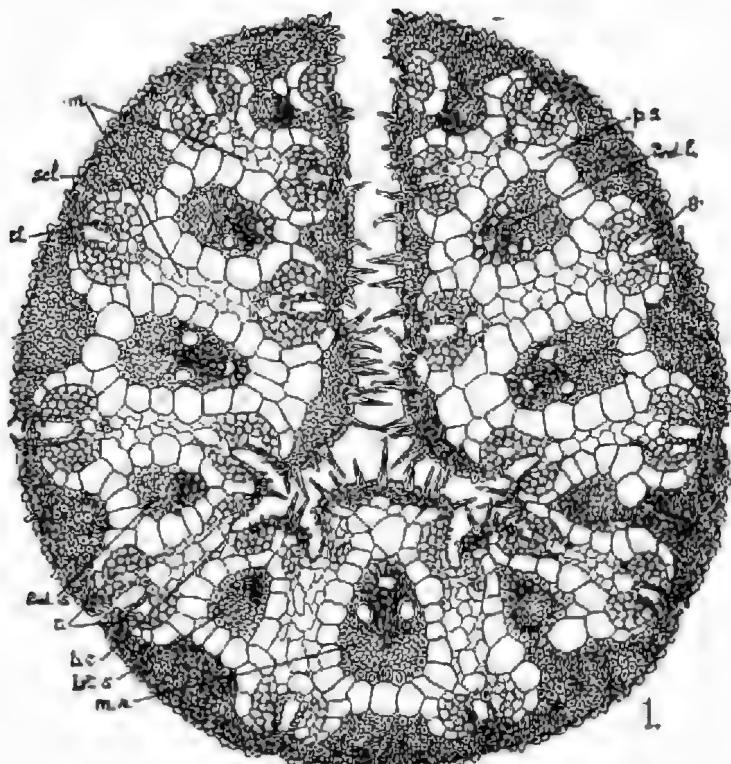
1. *T. pungens*: T.S. lamina.
2. *T. irritans*: T.S. lamina showing two pairs of subsidiary nerves.











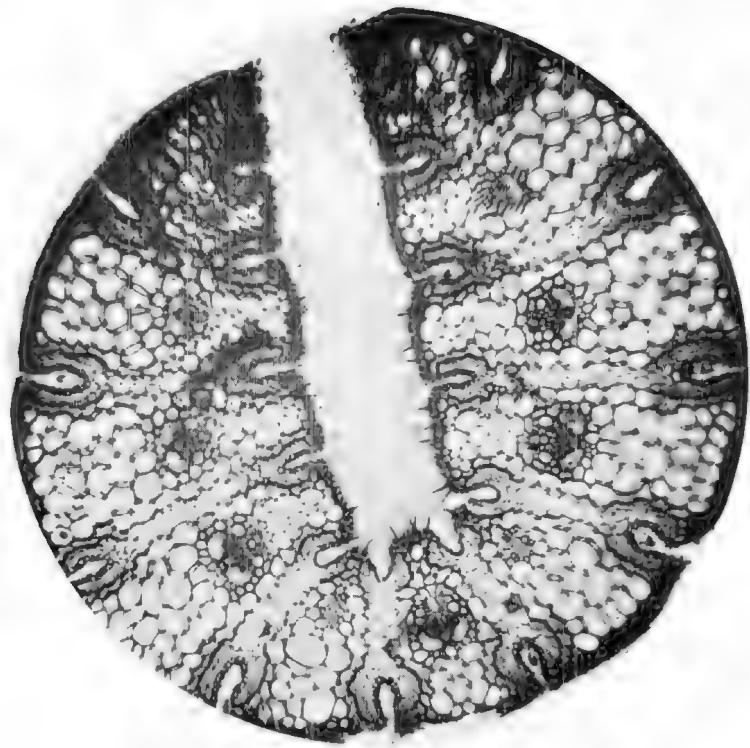


Fig. 1

T. angusta: T.S. lamina (note double phloem and transverse bands of thin-walled mesophyll)

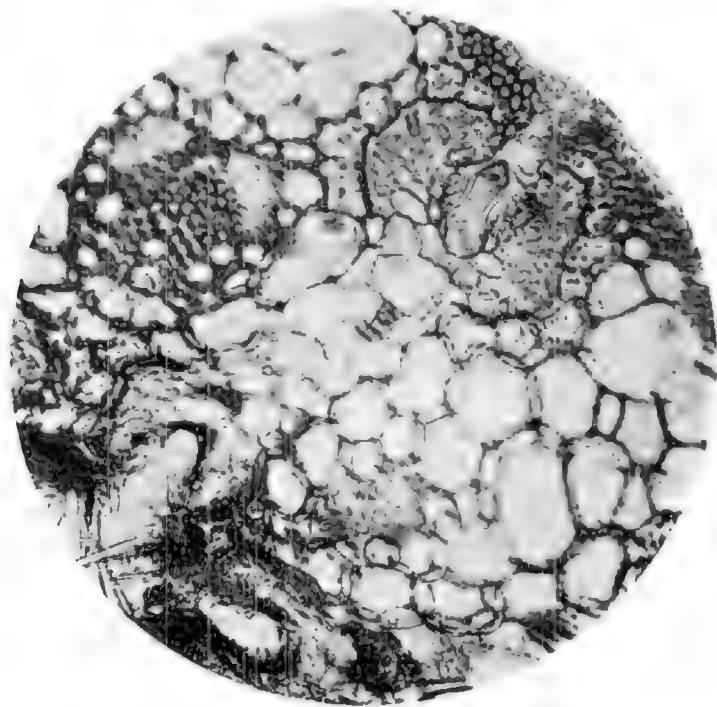


Fig. 2

T. angusta: portion of above showing detail of bulbous based hair in groove.



Fig. 1
T. pungens: T. S. lamina.

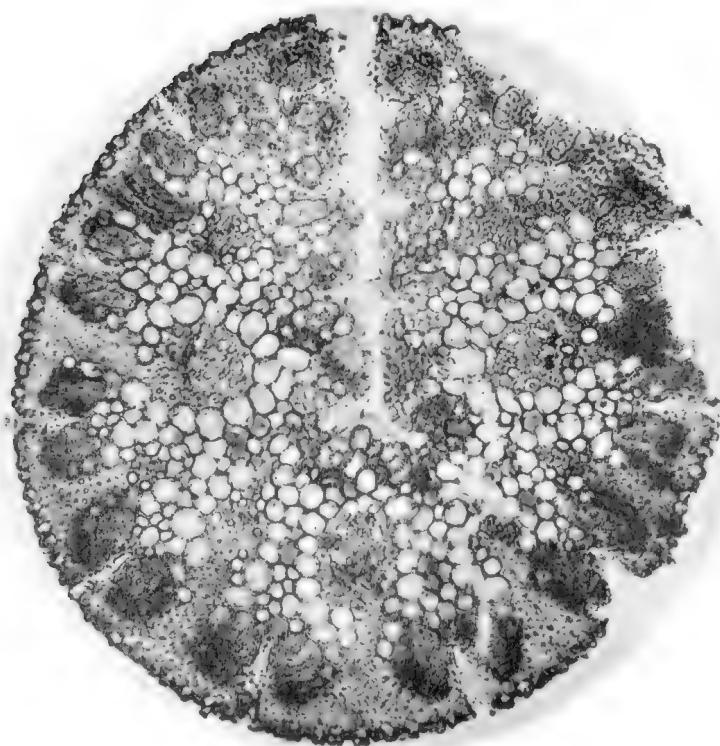


Fig. 2
T. irritans: T.S. lamina showing two pairs of subsidiary nerves.

**THE SIMPSON DESERT EXPEDITION, 1939 SCIENTIFIC REPORTS:
NO.8-THE SOILS AND VEGETATION OF THE SIMPSON DESERT AND
ITS BORDERS**

BY R. L. CROCKER, M.SC.

Summary

In spite of the isolation and inaccessibility of the Simpson Desert, its flora has been very well collected about the fringes. This collection began with the early explorers – Sturt, Warburton, Lewis and Winnecke – and has more recently been added to by a large number of botanists, most prominent of whom have been J. B. Cleland, S. T. Blake and G. H. Clarke.

THE SIMPSON DESERT EXPEDITION, 1939 SCIENTIFIC REPORTS: No. 8—
 THE SOILS AND VEGETATION OF THE SIMPSON DESERT
 AND ITS BORDERS

By R. L. CROCKER, M.Sc.⁽¹⁾

PLATES —————

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INTRODUCTION

In spite of the isolation and inaccessibility of the Simpson Desert, its flora has been very well collected about the fringes. This collection began with the early explorers—Sturt, Warburton, Lewis and Winnecke—and has more recently been added to by a large number of botanists, most prominent of whom have been J. B. Cleland, S. T. Blake and G. H. Clarke.

The only published ecological study of the Simpson Desert has been made by Blake (1937), who touched the south-east portion when classifying the plant communities of western Queensland. The present paper is the result of a rapid transect across the centre of the desert and a journey along its south-eastern fringe in 1939, together with notes made during an earlier visit to the northern portion in 1937. The floristics, insofar as the important perennials are concerned, are very complete. The collection of annuals and ephemerals are as complete as was possible under the seasonal conditions prevailing.

During both the 1937 and 1939 expeditions a limited number of soil samples were taken.

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GEOLOGY AND PHYSIOGRAPHY

The geology and physiography have already been very fully reviewed by Madigan (11) and will only be outlined briefly here.

The Desert extends some 300 miles north of Lake Eyre and is approximately 250 miles across at its greatest width. It is predominantly sandy. Roughly triangular, it is bounded by the Finke River in the west, the Diamantina and Mulligan Rivers in the east and the Eastern MacDonnell, Harts, Jervois and Adam Ranges in the north.

The west, south-west, east and south-east of the Desert is surrounded by gibber plains, claypans and watercourses interspersed with tableland remnants of early Tertiary (Eyrian series) and late Mesozoic (Jurassic-Cretaceous) rocks. In the north-west the Archaean and early Palaeozoic rocks of the Eastern MacDonnell and Harts Ranges outcrop, and to the north the Cambro-Ordovician of the Jervois, Tarlton and Toko Ranges [Madigan (11), Whitehouse (19)].

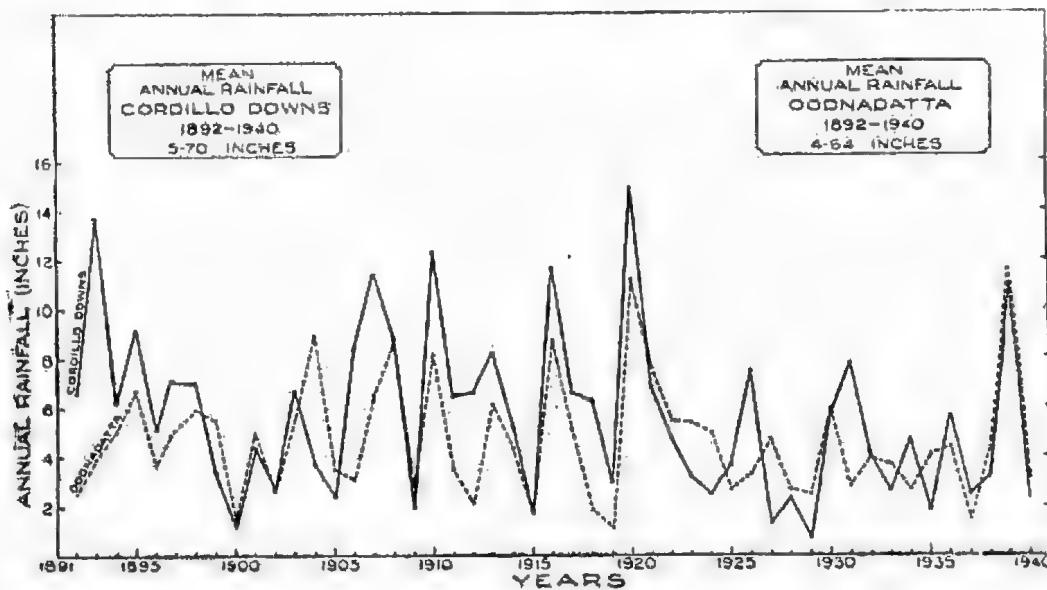


Fig. 1

The principal physiographic feature of the Desert is formed by the parallel sandridges which vary for the most part from 25 to 100 feet in height and trend north-west—south-east; that is parallel to the direction of the prevailing winds [Madigan (10), (11)]. The ridges, which may be more than 150 miles long, are approximately 300-600 yards apart and are almost always unstable at the crests. The inter-ridge areas, including the lower slopes are fixed by sparse vegetation. The eastern slopes are invariably steeper than the western. In the extreme north of the desert the ridges lose themselves in a featureless sandplain.

Claypans and saline lakes are common about the south-west, south and south-east parts of the region.

All the southern rivers and watercourses flow into Lake Eyre, as also do the Finke, Diamantina and Mulligan. However, the Hale, the Todd and the Hay Rivers, and a number of additional minor creeks from the north and north-west, are lost in the Desert sands. During exceptional floods the Hale and the Todd probably link with the Finke and ultimately reach Lake Eyre.

CLIMATE

Practically the whole of the area falls within Davidson's (8) Hot Desert Zone, with P/E greater than 0·5 for nil months of the year and mean annual temperatures higher than 70° F., with an amplitude of 15-16° F. and a phase lag of some 18-22 days behind solar radiation (15).

Very little accurate data on the climate is available, as meteorological stations about the fringes are exceedingly rare and the records not entirely reliable. The rainfall, however probably averages between four and ten inches annually, and increases from south to north due to the increasing influence of summer monsoons. Its most conspicuous feature is its unreliability. This is well illustrated in fig. 1 which gives the annual distribution of rainfall for two stations, Oodnadatta and Cordillo Downs, for the years 1892-1940.

Rainfall expectation figures for several stations about the edge of the Desert have been calculated by E. A. Cornish,⁽²⁾ and are listed below.

TABLE I
Rainfall Expectation Desert Margin Centres

| Station | Once in the same 20 years annual rainfall (R) | | Rainfall Expectation Once in the same 10 years (R) | | Once in the same 5 years (R) | |
|----------------------------|--|-------------------------------|--|-------------------------------|---------------------------------|-------------------------------|
| | will equal or exceed | will equal or be less than | will equal or exceed | will equal or be less than | will equal or exceed | will equal or be less than |
| Mulloorina Stn. (21 years) | 10·30 | 1·23 | 8·00 | 1·57 | 6·01 | 2·09 |
| Cowarie Station (19 years) | | | 11·99 | 1·04 | 7·79 | 1·59 |
| Birdsville (41 years) | 15·00 | 1·30 | 11·38 | 1·72 | 8·20 | 2·39 |
| Cordilla Downs (53 years) | 16·83 | 1·61 | 12·93 | 2·10 | 9·44 | 2·87 |
| Oodnadatta (44 years) | 9·65 | 1·73 | 7·95 | 2·10 | 6·31 | 2·65 |

THE SOILS

The soils of the Simpson Desert and its borders fall into three major groups:—

- (1) *Sands*—which predominate in the desert proper and range from the very deep and unstable sands of the ridge crests to the shallower sands of both the inter-ridge areas and the northern sandplain.
- (2) *Brown soils*—associated with surface gibbers and derived directly from the break-up of the old pre-Pleistocene peneplain, which is still represented by isolated mesas and buttes.
- (3) *Alluvial soils*—of the floodplains. These are chiefly grey and grey-brown and are very variable in texture.

No discussion of the soils of the Simpson Desert and its borders could be initiated without reference to the quite revolutionary and important suggestions made by Whitehouse (19) in his studies of the late geological history of Queensland. Briefly, he considers practically all the soils west of the Great Divide in Queensland to be laterites or laterised to some degree, or to be secondary soils derived from various horizons of an original laterised profile.

This laterisation is considered to have occurred at two periods in the Pliocene when high temperatures coincided with high rainfall conditions. The laterites began to form on a gently sloping plain from the Great Divide to the Lake Eyre region. Later, pluvial periods of the Pleistocene, which coincided

⁽²⁾ Officer in charge, Division of Biometrics, Council for Scientific and Industrial Research.

with low (ice-age) temperatures, initiated the break-up of this peneplain and the redistribution of the laterised horizons. This process is continuing today, though at a much retarded rate. Thus the red loams and redistributed red loams are considered remnants of the uppermost or (ferruginous) zone of a lateritic profile, and the gibbers and "billy" remnants of a once widespread siliceous zone—in places probably a continuous sheet—a fossil B horizon.

1. THE SANDS

(i) DISTRIBUTION AND FORM OF THE SANDRIDGES

The limits of the sandridges have been defined by Madigan (11), and in Queensland by Blake (4). In a new soil map of Australia Prescott (16) has shown the approximate limits of both sandhill and sandplain areas. On the south, east and west fringes the sand desert is bordered by gibber plains and rolling stony downs, with isolated flat-topped tableland remnants. The dunes are orientated parallel to the direction of the prevailing winds [Madigan (10 (11)], trending north-north-west and south-south-east. As has been shown by Madigan (11) the individual sandridge may be two hundred miles long, and over large distances the ridges preserve remarkable parallelism and repetition. They are stable except for the crests of the higher ones, and definite movement takes place only along their length. Probably only with very high wind velocities from a direction approximating right angles to their length is there likely to be actual movement of sand from off the ridge, and in these cases it is not likely to be great. Although there may be a loss or gain of sand, the dune itself is quite fixed.

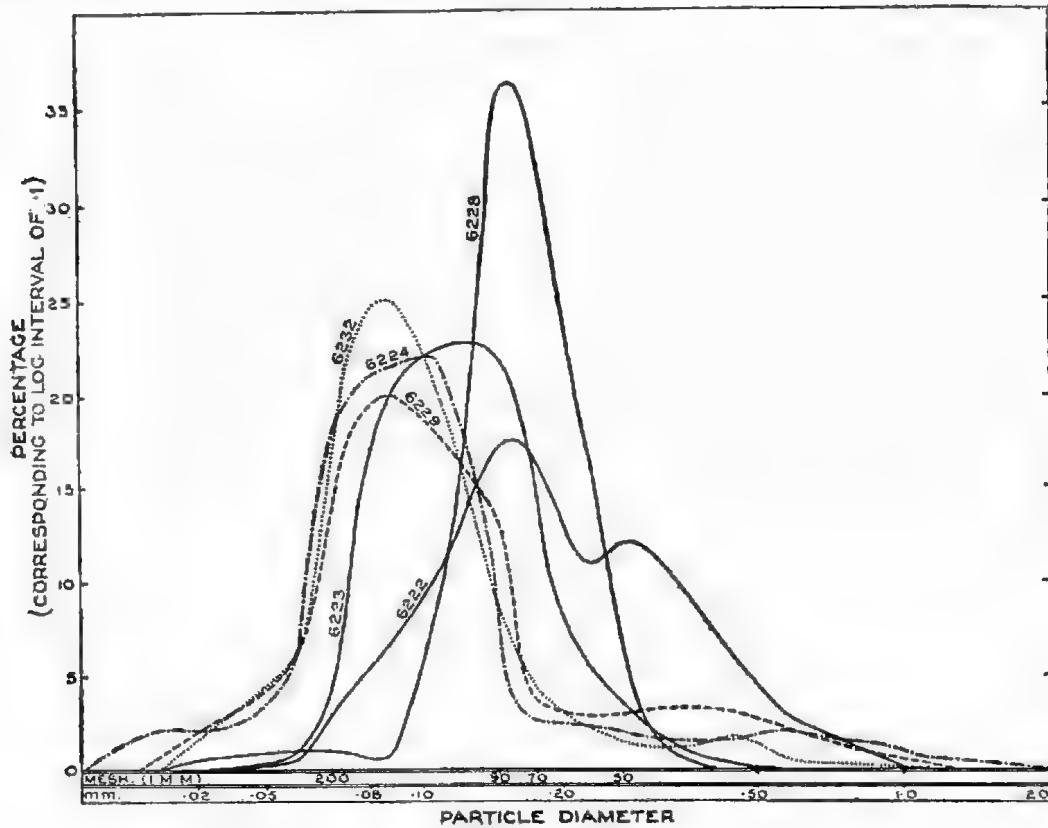


Fig. 2

The mean repetition distance is approximately $\frac{1}{4}$ mile. The sand grains are predominantly quartz (*Carrol loc. cit.*), and were no doubt derived from quartz-bearing rocks, including certain horizons of the Pliocene laterised profiles and their foundation rocks. The occurrence of heavy minerals of a dominantly metamorphic and granitic assemblage indicates, however, that the contributions from the arenaceous Eyrian series, which have been suggested as the source of the sands (*Whitehouse loc. cit.*), are only partial.

(ii) LABORATORY EXAMINATION⁽³⁾

Mechanical Analysis—

Mechanical analysis of a number of the soil samples taken in the Desert have been carried out. As far as the dune sands were concerned, the percentage of clay (*i.e.*, fraction less than '002 mm. diameter) was so low that it was not considered worth while carrying out a full mechanical analysis. The samples were therefore first dispersed with sodium oxalate or sodium hydroxide and the clay decanted off, following standard soil sedimentation methods. After oven drying, the sand was sieved through a series of I.M.M. sieves using Smith's (7) technique, except that six shakings were given instead of four. The following sieves were used: 2 mm., 1 mm., 0·5 mm., 50, 70, 90 and 200 mesh.

The various fractions were then plotted on a summation percentage diagram (summation percentage against log particle diameter), from which percentage distribution diagrams were constructed using a log interval of 0·1 on the particle diameter scale. The advantage of using this technique is that much more detail can be shown in the distribution curves which are, in this case, drawn from some 18 points, instead of only seven had direct plotting from the sievings been made.

The general results are illustrated in fig. 2, 3, 4, 5. In fig. 2 the distribution of a number of surface samples taken in a traverse across a series of ridges at Camp 8 in the centre of the Desert, together with one or two additional samples,

⁽³⁾ The following samples were taken. The principal soil collection was carried out at Camp 8, about the centre of the Desert, where a series of samplings was made across several dunes. The position of these (A-E) is shown in a section drawn by Dr. C. T. Madigan (*Trans. Roy. Soc. S. Aust.*, 70, (1), 47).

| Catalogue number | Depth | Location |
|------------------|--------|---|
| 6,221 | 0-12" | Goyders Lagoon, Floodplain of Diamantina R. |
| 6,222 | 0-26" | Sandridge crest, Mulligan R. |
| 6,223 (Sample A) | 0-46" | Sandridge crest, Camp 8, towards centre Desert. |
| 6,224 (Sample B) | 0-5" | |
| 6,225 (Sample B) | 5-37" | Inter-ridge corridor, Camp 8. |
| 6,226 (Sample B) | 37-46" | |
| 6,227 (Sample C) | 0-45" | Sandridge slope, Camp 8. |
| 6,228 (Sample D) | 0-18" | Sandridge crest, Camp 8. |
| 6,229 (Sample E) | 0-5" | |
| 6,230 (Sample E) | 5-26" | Inter-ridge corridor, Camp 8. |
| 6,231 (Sample E) | 26-45" | |
| 6,232 | 0-12" | |
| 6,233 | 16-27" | Inter-ridge corridor, Camp 19. |
| 6,234 | 27-32" | |
| 6,235 | 32-46" | |
| 6,236 | 0-6" | Gypseous hollow between sandhills, near confluence of Macumba and Warburton Rivers. |
| 6,237 | 6-20" | |
| 5,199 | 0-1" | |
| 5,200 | 1-16" | Sandplain at north end of desert. |

are shown. Samples 6,223⁽⁴⁾ and 6,228 are unstable crest samples, and samples 6,224 and 6,229 inter-ridge corridor samples in the Camp 8 series. It is seen at once that the peak (modal) diameters of the crest samples are coarser than those of the corridors. 6,227 (fig. 3), a slope sample, taken between the sites 6,224 and 6,228, shows a peak diameter intermediate between these two. It is also apparent that the greater part of the sand in the corridors has a particle diameter of less than 0.1 mm., and that the greater portion of the sand of the crests has a particle diameter greater than 0.1 mm.

The other samples taken support the general conclusions from those taken at Camp 8; for example (in fig. 2), 6,222, a sandhill crest along the Mulligan adjacent to old Kaliduwarry Station homestead, and 6,232, a corridor sample from about 16 miles west of this.

This is extremely interesting, as Bagnold considers it is the finest sands that collect at the top of dunes and the coarsest at the bottom, Bagnold (1935) (1941).

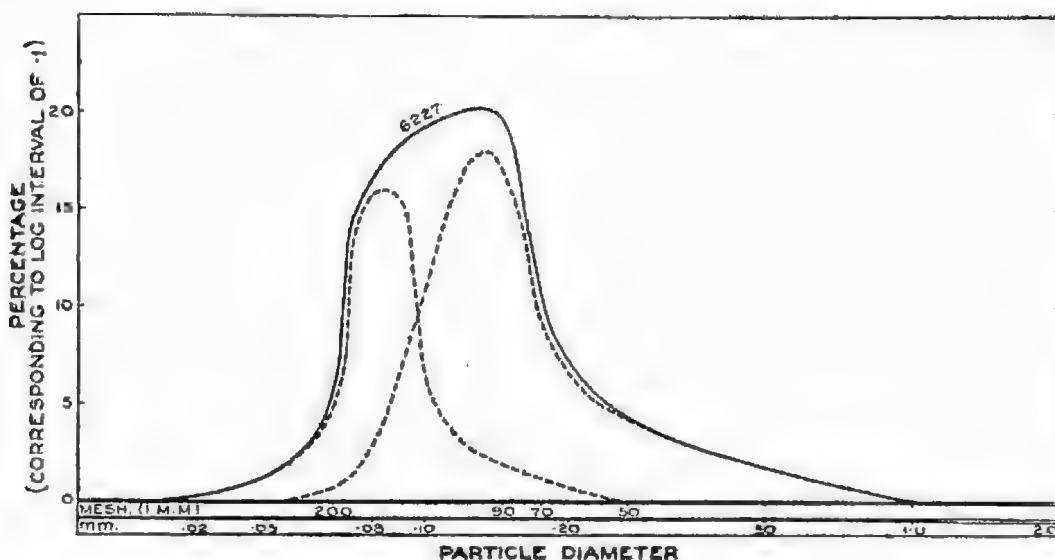


Fig. 3

It is to be noted that the particle size distributions for the crest sands is much more restricted in range than those of the inter-ridge areas, particularly in the coarse sand range. In the samples from the interior of the Desert there was no sand present in the crests with a diameter as large as 0.5 mm. 6,222, situated on clay flats of the Mulligan flood plain, is a more recent dune, lighter in colour than the ridges of the Desert, and obviously a mixed sand. Recent dunes in desert regions are apparently always lighter in colour (Gautier).

The heterogeneity exhibited in the sands, see fig. 2, 3, 4, 5, is only to be expected in view of the fact that steady meteorological conditions never last long enough to build up any great thickness of uniform sand. The fact that the crest sands are much more restricted in their particle diameter range, evidences the greater wind winnowing to which they have been subjected. 6,228 is a regular sand indicating steady conditions of wind and sand supply for a reasonably long time, while 6,223, the adjacent ridge crest, does not show anywhere near the

⁽⁴⁾ The numbers are the catalogued numbers of the samples in the Soil Library of the Division of Soils, C.S.I.R., at the Waite Institute, Adelaide.

same degree of sorting. This is probably due partly to variation within the dunes themselves, accentuated by the fact that the former is the mean of a vertical section only 18 inches deep, while the latter section was 46 inches. These samples, although from unstable ridge crests, were taken about a day after a very steady fall of some $1\frac{1}{2}$ inches of rain, when the sand was quite coherent and at about field capacity to at least 15 inches. The fact that the former sample was able to be bored out with a soil auger below the depth of moisture penetration indicated a much firmer packing of the particles below—in other words, 6,223 is a mixture of accretion layers (typical of the dip slope) and sand which has been subject to avalanching, whereas 6,228 is composed almost entirely of the latter. The indications are from 6,223 that a change of slip slope of the small unstable crest from east to west is by no means unusual, that is, the strong winds must blow from two almost opposite directions. This may be only occasional, but there is further evidence for it in the almost symmetrical nature of some of the crests. However, there is no doubt that during the building up of the greater

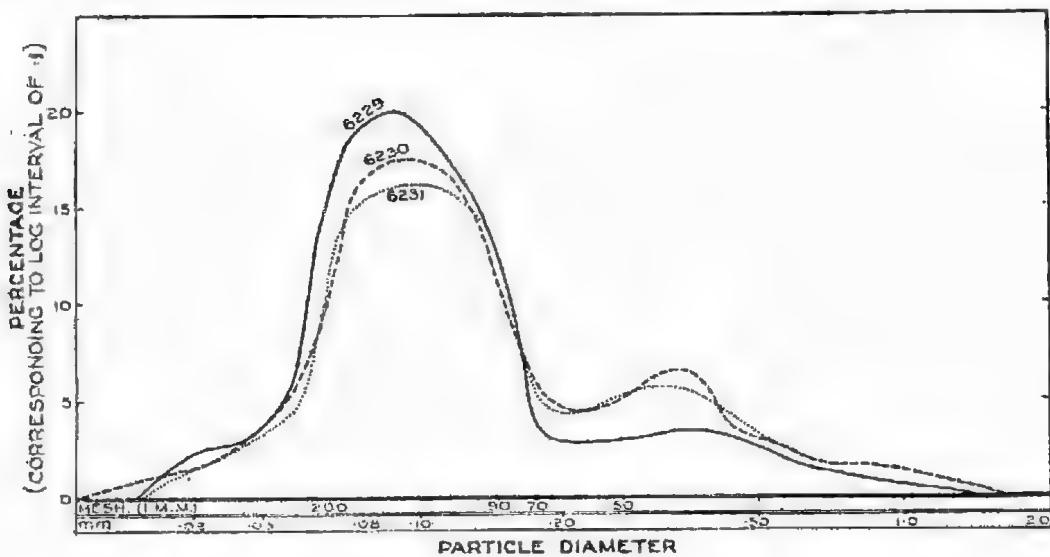


Fig. 4

part of the dune (which is now quite stabilised) the strong winds were from the west or south-west. Most probably only occasional east or north-east winds are strong enough to reverse the minor slip slopes of the crest today.

The broadness of the distribution about the modal diameter in most of the sands indicates either lack of sorting or a mixture of two sands of slightly differing dominant diameters. This has already been mentioned in connection with 6,223, which it was suggested was a mixture of both avalanched and accretion deposits. Mixed sands always indicate some change in conditions, either a change in the long term wind regime, or a change in the continuity of sand supply. Bagnold (1941) mentions that the possibility of change in conditions is so great that it is not surprising that on occasions the grading of a sand may differ greatly at the surface and a few inches below.

6,227, a dip slope sample (0-45"), exhibits this broad distribution about the peak diameter, and could quite easily be the result of a mixture of two sands with differing predominant diameters. Two hypothetical sands, which when mixed would give the distribution curve of 6,227, are shown by the dotted lines in fig. 3 above. 6,225 (fig. 5), a subsurface sample 5-37 inches, below 6,224, is

almost certainly a mixed sand of the above type. The presence of mixed sands would indicate, as would indeed be expected, that the conditions which governed sand accumulation, principally wind regime and supply of raw material, varied considerably during the building up of the Simpson Desert dune system.

Some of these variations, especially sand supply, probably had a purely local effect. Indeed, the variation met with does not mask general similarities such as the dominant diameters of the corridor as compared with the crest sands. The sands may be relatively uniform for a considerable depth, and even minor peculiarities in the distribution may occur throughout. This is well illustrated in fig. 4 where the frequency distribution of a corridor profile taken in three horizons, 6,229 (0-5 inches), 6,230 (5-26 inches), 6,231 (26-45 inches), is shown. The repetition of certain features as the second small peak diameter in all three horizons, and the general similarity between the three, would indicate uniformity of sand supply and wind conditions.

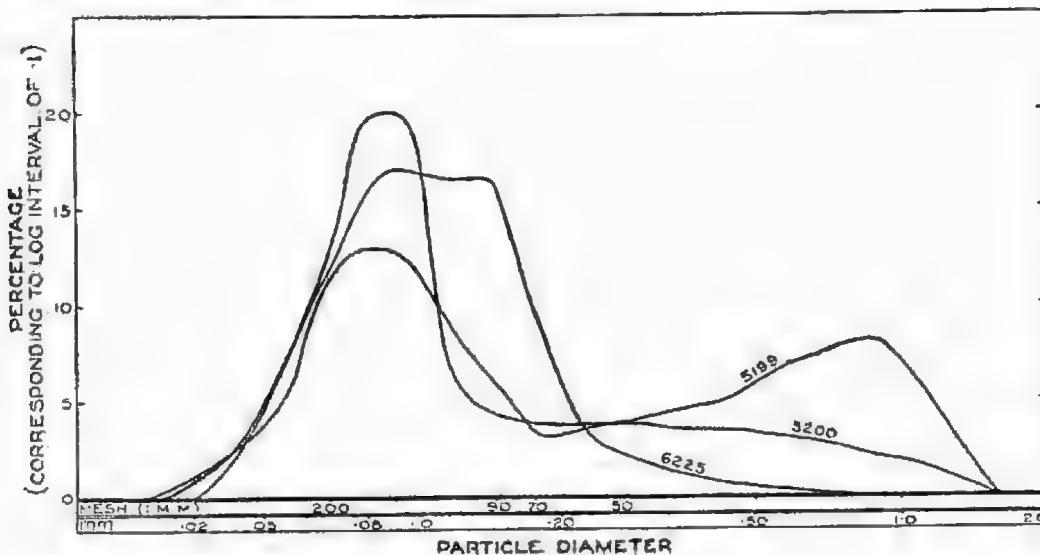


Fig. 5

A special case of a mixed sand is that where the peak diameters of the two sand components are widely separated. Bagnold, *loc. cit.*, has shown that this is so in sand sheets, and suggests that if the ratio of the two peak diameters is of the order of 10 to 1, the sand will remain a relatively immobile sheet. Under these circumstances the coarser grains are too heavy in comparison to the smaller to move even by surface creep, they tend to become uniformly dispersed and protect the finer material from the normal eddies of turbulence. As a result, the sand sheet remains ripple-less and becomes stabilised.

It was thought that it might be interesting to see how far these conditions were fulfilled in an Australian sandplain. During an earlier expedition with Dr. C. T. Madigan (1937), a soil sample had been taken by the author in the featureless sandplain at the north end of the Desert about six miles south of the junction of the Arthur and the Thring (see pl. xlii, fig. 12). The frequency particle size distribution of the surface $\frac{1}{2}$ inch is in entire agreement with Bagnold's theory (5.199, fig. 5, above).

The two peak diameters correspond to a particle size of approximately 0.08 mm. and 0.8 mm. respectively, that is, one is almost exactly ten times as great as the other.

The distribution of 5,200 (4-16 inches, below 5,199) has interesting implications when considered in conjunction with 5,199, and helps to explain the method by which the sand sheet was stabilised. Apparently the sand originally had a peak diameter slightly higher than .08 mm., but the distribution curve was skew with a greater extension into the coarser diameters, very much in fact like the curve for 5,200. Under the influence of moderate to strong winds the finer material has been removed by saltation and suspension, and to a lesser degree by surface creep. Much of the coarser material was of too large a diameter and too heavy to be shifted far in surface creep under the bombardment of the smaller particles in saltation, and the proportion of these relatively immobile grains therefore continued to increase in the surface layer until they were sufficiently numerous to protect the finer materials. The distribution of 5,199 can be looked upon as the equilibrium state, when even in the strongest wind practically no sand would be removed from the sheet.

The sandplain at the north end of the Desert was, therefore, probably the first portion to become perfectly stable and be colonised by vegetation.

Reference to fig. 2 and 5 shows that the distribution about the peak diameters for the typical corridor sands and those of the northern sandplain (excluding the surface $\frac{1}{2}$ inch) are almost identical. The peak diameters are practically the same, barely higher than .08 mm.; and in both cases the curves are skew with a noticeable extension to the coarse side. The corridor samples 6,229, 6,224 and 6,223 all show tendencies to slight second maxima on the coarse side. These similarities are borne out by a close relationship in the vegetation of the corridors and the sandplain (see later). This may indicate that originally the sand-sheet was more widespread and occupied much of the Desert. Absence of sufficient coarse grains in the more southerly regions, together with perhaps other differences dependant on the supply of sand material, could lead to increased mobility and the building up of the complex sandridge system there, while gradual loss of mobility was causing the stabilisation of the sheet to the north. It is unlikely that this was the only mechanism, and it is certainly not necessary to have a sand-sheet preceding the formation of a sandridge as Madigan (10) has pointed out and as is so clearly demonstrated by the chains about the margins, with their clean gibber flats and sand-free corridors.

The particle size-frequency distribution curves of the Simpson Desert sands agree with Bagnold's theories in most respects. The only serious disagreement seems to be in the relative dominant particle diameter of the crest and corridor samples. He has found in his Libyan Desert studies that with seif dunes the finest sands collect at the crests, and the coarser sands in the hollows, and that with ripples the reverse is the case. In the Simpson Desert this generalisation breaks down, and we find the crest samples have coarser peak diameters than those in the hollows, which are all of the order of .08 mm. Carroll's⁽⁶⁾ (*loc. cit.*) sievings of the same sands collected by the author, together with four additional crest samples collected by Madigan, indicate the same relationship. Bagnold says the finest sand-dune material known has a peak diameter of .08 mm.; for particles below this diameter the minimum wind velocity required to shift the grains actually increases. It is suggested that the extreme fineness of the Simpson Desert sands has an important bearing on the reversal of the relationship he postulates as being general. There can be no doubt that 6,224, 6,229 and 6,232, our corridor samples, were taken within the plinth, as he has defined

⁽⁶⁾ Carroll has plotted the quantities retained on the various sieves directly above the sieve size, instead of midway between that size and the next coarsest.

it. It is again to be noted, however, that the crest samples have a much narrower distribution than corridor samples, and larger grains, too heavy to move in surface creep, collect in the hollows. There are relatively few of these heavier grains.

The extreme fineness of the Simpson Desert sands suggests that previously abraded material has made the bulk of the contribution, and there can be little doubt that the arenaceous beds of the Eyrian series supplied most of it. Unfortunately, practically nothing is known of the mineralogy of the Eyrian series.

Full mechanical analyses were carried out on a few samples, and together with other analytical data are summarised in Tables II, III and IV. The extremely low silt figures (mostly less 1%) with somewhat larger amounts of clay are interesting, and have already been commented on by Prescott and Skewes (17) who mechanically analysed a number of desert sands. The presence of 1 to 6% of clay, and almost complete absence of silt, is apparently a characteristic feature of even the most highly sorted desert sands, and is no doubt the result of the almost complete removal, as loess, of the silt fraction through constant wind winnowing. The very fine material, less than .002 mm. diameter (the clay fraction, or part of it), apparently has too high a fluid threshold to be lifted up as readily by the ruling wind conditions. Bagnold, *loc. cit.*, has quoted the case of a wind strong enough to move pebbles 4.6 mm. in diameter being unable to shift particles from a loosely scattered layer of Portland cement.

Calcium carbonate, as measured by loss on acid treatment, is uniformly low. 6,235, a subsoil sample (32-46 inches) of a corridor soil type carrying an association of gidgee (*Acacia Cambagei*) and saltbush (*Atriplex vesicarium*) is an exception.

TABLE II
Analytical Data on Dune Crest Samples

| Sample number .. | .. | .. | 6,222 near Mulligan River | 6,223 | 6,227 ^(a) | 6,228 |
|--|----|----|------------------------------------|---------------------|----------------------|---------------------|
| Location .. | .. | .. | <i>S. paradoxus</i> | <i>S. paradoxus</i> | <i>T. Basdeorii</i> | <i>S. paradoxus</i> |
| Vegetation .. | .. | .. | <i>S. paradoxus</i> | <i>S. paradoxus</i> | <i>T. Basdeorii</i> | <i>S. paradoxus</i> |
| Depth (inches) .. | .. | .. | 0.26 | 0.46 | 0.45 | 0.18 |
| Chemical data— | | | % | % | % | % |
| Total soluble salts .. | .. | .. | .01 | .13 | .259 | .01 |
| Sodium chloride .. | .. | .. | — | .05 | .110 | — |
| Nitrogen .. | .. | .. | .003 | — | — | .005 |
| Phosphate (P ₂ O ₅) .. | .. | .. | .008 | — | — | .014 |
| Reaction (pH) .. | .. | .. | 7.3 | 6.5 | 6.6 | 7.0 |
| Mechanical analysis (as percentage fine earth)— | | | | | | |
| Coarse sand .. | .. | .. | 57.0 | — | — | 55.3 |
| Fine sand .. | .. | .. | 40.9 | — | — | 43.2 |
| Silt .. | .. | .. | 0.1 | — | — | 0.0 |
| Clay .. | .. | .. | 1.4 | — | — | 1.1 |
| Loss on acid treatment .. | .. | .. | 0.3 | — | — | 0.1 |
| Moisture .. | .. | .. | 0.2 | — | — | 0.2 |
| Loss on ignition .. | .. | .. | 0.4 | — | — | 0.6 |

(a) Dip slope sample.

TABLE III
Analytical Data on Inter-dune Corridor Samples

| Sample numbers | .. | 6,224 | 6,225 | 6,226 | 6,229 | 6,230 | 6,231 | 6,232 | 6,233 | 6,234 | 6,235 |
|--------------------------------|------|-------------------------------------|-------|-------|---------------------------------|-------|-------|-------|-------|---|-------|
| Location .. | .. | Camp 8 | | | Camp 8 | | | | | Camp 19 | |
| Vegetation .. | .. | <i>Triodia</i> and <i>Grevillea</i> | | | <i>Triodia</i> and <i>Hakea</i> | | | | | <i>Acacia Cambagei</i> and <i>Atriplex vesicarium</i> | |
| Depth (inches) .. | 0-5 | 5-37 | 37-46 | 0-5 | 5-26 | 26-45 | 0-12 | 16-27 | 27-32 | 32-46 | |
| Mechanical analysis— | | | % | | | | % | % | % | % | |
| Coarse sand .. | .. | | 16.6 | | | | 8.4 | 10.1 | 11.3 | 8.6 | |
| Fine sand .. | .. | not | 66.7 | | not | | 85.0 | 75.7 | 67.2 | 86.2 | |
| Silt .. | .. | deter- | 1.6 | | | | 0.1 | 1.0 | 1.7 | 2.7 | |
| Clay .. | .. | mined | 13.6 | | determined | | 5.5 | 12.0 | 17.1 | 17.8 | |
| Loss on acid treat- ment .. | .. | | 0.7 | | | | 0.3 | 0.7 | 1.5 | 23.9 | |
| Moisture .. | .. | | 2.0 | | | | 0.6 | 1.6 | 2.9 | 2.9 | |
| Chemical data— | | | | | | | | | | | |
| Total soluble salts | .08 | .07 | .338 | .02 | .02 | .04 | .01 | .179 | .783 | .570 | |
| Sodium chloride .. | .03 | .03 | .144 | — | — | — | tr. | .069 | .340 | .245 | |
| Nitrogen .. | .019 | .013 | — | .019 | — | — | .010 | .011 | — | — | |
| Phosphate (P_2O_5) | .018 | .018 | — | .020 | .017 | — | .017 | .017 | .021 | — | |
| Reaction (pH) .. | 6.4 | 6.9 | 7.3 | 6.9 | 6.8 | 7.1 | 7.7 | 8.6 | 8.3 | 8.8 | |

(iii) ADDITIONAL ANALYTICAL DATA

Soluble salts and chlorides are relatively unimportant in the sand-dune crest samples, at least in the first two feet. The concentrations for the deeper samples 6,223 and 6,227 (Table II) indicate, however, that beyond the depth of penetration of the normal rains moderate salinity is likely and concentrations of 15-35% should not be unusual. In the inter-dune corridors, soluble salts are low in the surface horizons, but may be very high in the subsoil. 6,234 is an extreme case where the conditions are apparently more favourable to saltbush than *Triodia*, which is replaced entirely. Prescott and Skewes (*loc. cit.*) found saltbush soils of the north-east and northern pastoral areas of South Australia more saline than the *Triodia* soils, although the latter can be more saline (*e.g.*, 6,227) than they expected.

The moderate salinity of 6,223 supports the arguments made earlier that this sample is a mixture of accretion and avalanche material. 6,227, a dip slope sample, is entirely of accretion sand. Water tends to percolate along the accretion layers.

Soil reaction was determined with the normal glass electrode method. The gidgee-saltbush hollows are the most alkaline, increasing from pH 7.7 in the surface foot to pH 8.8 at 32 inches. The sands generally, other than this profile, are acid to neutral. The lowest value obtained was pH 6.4, and the Simpson Desert sands do not apparently reach the very low values recorded for the Gibson Desert sands (17), which may mean that the former have not previously been through such extreme leaching (laterisation). There is normally a slight increase in pH with depth.

Nitrogen values are as expected, extremely low, and conform with those recorded for arid aeolian deposits elsewhere in Australia. The ridge crest samples are lower in total nitrogen than the corridor samples.

Phosphates (as P_2O_5) are also very low, varying between .008 and .021% in the samples analysed. The figures for 6,232, 6,233 and 6,234 of the gidgee-saltbush profile indicate that P_2O_5 content alone is not a sufficiently reliable index

of fertility for the generalisations made by Prescott and Skewes (*loc. cit.*). It is seen by reference to Tables II and III above that there is no significant difference in the P_2O_5 figures for saltbush (*Atriplex vesicarium*) as against porcupine grass (*Triodia Basedowii*) in these samples. The high alkalinity (pH 7.7-8.8), and the quantity of free calcium carbonate (23.9% at 32-46 inches) of the subsoil of this profile may, in conjunction with the P_2O_5 level, be of more importance.

TABLE IV
Analytical Data on a Simpson Desert Sandplain Profile and a Profile from a
Gypseous Hollow near Lake Eyre

| Sample number | .. | .. | .. | 5.199 (1) | 5.200 (1) | 5.201 (1) | 5.236 | 5.237 |
|------------------------|----|----|----|--|--|-----------|-------|-------|
| Location | .. | .. | .. | sandplain, Simpson Desert | near confluence of War- | | | |
| | | | | | burton, Macumba R. | | | |
| Vegetation | .. | .. | .. | <i>Triodia</i> and <i>Eucalyptus</i> <i>pachyphylla</i> | <i>Nitraria Schoberi</i> , <i>Salsola kali</i> , <i>Bassia</i> , etc. | | | |
| Depth (inches) | .. | .. | .. | 0-1 | 1-16 | 16-30 | 0-6 | 6-20 |
| Mechanical analysis— | | | | % | % | % | % | % |
| Coarse sand | .. | .. | .. | 42.3 | 25.0 | 23.6 | 11.6 | 23.1 |
| Fine sand | .. | .. | .. | 52.2 | 64.0 | 64.2 | 47.3 | 57.3 |
| Silt | .. | .. | .. | 0.6 | 0.5 | 1.0 | 0.6 | 0.6 |
| Clay | .. | .. | .. | 4.1 | 9.4 | 10.2 | 18.1 | 9.2 |
| Loss on acid treatment | .. | .. | .. | 0.2 | 0.2 | 0.2 | 17.7 | 8.7 |
| Moisture | .. | .. | .. | 0.4 | 0.9 | 1.0 | 6.0 | 2.6 |
| Chemical data— | | | | | | | | |
| Total soluble salts | .. | .. | .. | tr. | tr. | .01 | .77 | .845 |
| Sodium chloride | .. | .. | .. | tr. | tr. | nil | .003 | .016 |
| Nitrogen | .. | .. | .. | .023 | .024 | — | .007 | — |
| Phosphate (P_2O_5) | .. | .. | .. | .015 | .016 | — | — | — |
| Reaction (pH) | .. | .. | .. | 7.0 | 6.6 | 6.5 | 8.1 | 8.0 |

2. BROWN SOILS ASSOCIATED WITH SURFACE GIBBERS

As mentioned earlier, brown soils associated with surface gibbers are very extensive about the sand desert margins, and there is little doubt that they are more or less continuous beneath the desert sands. The sand is entirely superficial. Evidence for this is the frequent occurrence of gibber flats between the sandridge on both the eastern and western sides of the Desert, and the limited occurrence of gibbers in the corridors near Camp H. Colson also reports that in crossing the Desert along the 26th parallel in 1936, stony corridors were frequent during the western two-thirds of the journey. Very strong evidence of a greater extent of these soils in the past is also presented by the distribution of the spectacular tree, waddy, or, as it is sometimes locally called, "Casuarina" (*Acacia peuce*). This tree occurs on gibber downs in two very restricted localities: (1) near Birdsville, (2) near Andado bore No. 1, and in each case there are only a hundred or two trees. The two localities are now separated by more than two hundred miles of sand.

In origin the soils are secondary, having been derived from the break-up and erosion of the Pliocene peneplain. The gibbers are in part remnants of the B horizons of the laterite or lateritic profile developed over this plain (Whitehouse 1940), that is, they are in part a fossil horizon. It is unlikely, however, that all the gibbers have had this origin, as duricrust gibbers with their "patina" and high polish are very characteristic of desert regions generally.

(1) Taken from J. A. Prescott and H. R. Skewes. Trans. Roy Soc. S. Aust., 62, (2), 1938.

The gibbers, which reach their maximum dimensions in Sturt's Stony Desert (*Blake loc. cit.*), are very variable in size.

The soils of this group need more thorough investigation before their variation will be fully understood. No sampling of them was done on the 1939 expedition. Crabholes are of frequent occurrence, especially about Birdsville and on the south and west sides of the Desert, and where they occur the gibber shelf is almost devoid of vegetation. In places, over very large areas, the soils are crabhole-free, but every gradation occurs between the two extremes. The sampling of these soils, carried out by various workers earlier, was for the most part in connection with studies on crabholes (normally gibber-free) to the south and west of the Desert.

The soils are all heavy with clay loam and clay surfaces, or very rarely a lighter surface (e.g., loam or sandy loam), which rapidly becomes heavier. There is usually slight lime in the subsoil, and gypsum is frequent in the B2 horizon.

It has already been shown in studies on soils derived from outliers of the Arcoona Tableland in South Australia (6) that the gibber shelf soils are highly saline, while the greater leaching in the nearby crabholes has washed down the soluble salts to greater depths. This is no doubt the case wherever the crabholes occur, and is demonstrated by a wide collection of profiles taken by J. K. Taylor⁽⁸⁾ in 1938, the soluble salts and pH of two of which are given below (Table V), together with samples collected by the author at Mutooroo (South Australia) in 1939. In this latter case the shelf gibbers are milky quartz.

TABLE V

| Soil number | .. | .. | 5,602 | 5,603 | 5,604 | 5,605 | 5,606 | 5,607 | 5,608 | 5,609 | 5,610 | |
|-------------------------|----|----|---|-------|-------|-------|---|-------|-------|-------|-------|--|
| Location | .. | .. | 12 miles west of Coward Springs, crabhole | | | | | | | | | |
| Depth (inches) | .. | .. | 0-4 | 4-10 | 10-33 | 33-42 | 0-9 | 9-15 | 15-24 | 24-33 | 33-42 | |
| Total soluble salts (%) | .. | .. | ·044 | ·049 | ·975 | 2·108 | 3·468 | 3·455 | 3·283 | 3·308 | 3·394 | |
| Chloride (as % Cl.) | .. | .. | ·003 | ·005 | ·021 | ·315 | 1·44 | 1·51 | 1·40 | 1·36 | 1·31 | |
| pH | .. | .. | 8·7 | 8·0 | 8·0 | 8·2 | 7·6 | 8·0 | 8·0 | 8·0 | 8·1 | |
| Soil number | .. | .. | 6,240 | 6,241 | 6,242 | 6,243 | 6,244 | 6,245 | | | | |
| Location | .. | .. | North Plain Paddock, Mutooroo, crabhole | | | | Quartz gibber shelf, $\frac{1}{2}$ chain from 6,240 | | | | | |
| Depth (inches) | .. | .. | 0-7 | 7-23 | 23-36 | 0-11 | 11-24 | 24-36 | | | | |
| Total soluble salts (%) | .. | .. | ·059 | ·985 | 1·85 | ·422 | 2·00 | 2·46 | | | | |
| Chloride (as % Cl.) | .. | .. | — | ·018 | ·265 | ·184 | ·93 | ·69 | | | | |
| pH | .. | .. | 8·6 | 7·9 | 8·2 | 8·0 | 8·3 | 8·1 | | | | |

It has been suggested by Crocker and Skewes (6) that the high soluble salt content of gibber shelf soils, together with the very great edaphic aridity of which it is indicative, is the cause of the scarcity and even complete absence of vegetation on these soils. The soluble salts are principally sodium chloride, sodium sulphate, and calcium sulphate. There is no doubt that except in local depressions large areas of gibber soils are never wet beyond two or three inches, otherwise there would be much more evidence of downward leaching of the salts. J. K. Taylor⁽⁹⁾ considers that the mechanical action of raindrops on an already wet surface may

⁽⁸⁾ The author is grateful to Mr. Taylor for making the data on these samples available.

⁽⁹⁾ Personal communication.

materially disperse the sodium saturated clay of the surface layer, to form an almost impervious soil surface. This may well be the reason for lack of penetration, and the fact that gibber profiles with a lighter textured surface have a much lower soluble salt content supports this suggestion, as, for example, that collected on the 1937 expedition, 100 miles north-west of Oodnadatta: 0-2" .01%, 2-10" .01%, 10-46" .01% (17).

Although the very saline gibber soils are more or less impervious to water, the crabholes, which collect considerable quantities during rains in run-off, and some other areas (most likely with a lighter textured surface) are less saline.

Soil salinity is probably the most important index of fertility in these soils, because in addition to the question of toxicity of high salt concentration it is a measure of the water relationships. However, single value factors for the assessment of fertility are very dangerous. It is suggested that the following soil-vegetation relationships for the stony deserts be tentatively accepted.

| | Surface 12 inches | Vegetation |
|---|-------------------|--|
| (1) High salinity | | No vegetation or occasional samphires and <i>Bassias</i> . Ephemerals on small sand shadows. |
| (2) Moderate salinity (e.g., edge of crabhole) | | Saltbush, grasses and various <i>Bassia</i> spp. |
| (3) Low salinity | | Saltbush, bluetbush, wealth of grasses (especially <i>Eragrostis</i> , and in northern parts <i>Astrebla</i> and ephemerals. <i>Acacia</i> spp., <i>Eremophila</i> spp. |

Soil reaction is markedly alkaline in the stony desert soils, usually with surface pH values between 7.5 and 8.7, and subsoil values of the same order. There are, however, one or two anomalous soils in the samples collected by Taylor with subsoil pH values as low as 6.4.

3. SOILS OF THE FLOOD PLAINS

These soils, as is readily understandable, are very variable. They are chiefly grey or brown in colour, and are normally medium to heavy textured. This is the "channel country" of Blake and others. Prescott has grouped them as "grey and brown soils of heavy texture" in his new soil map.

Analytical data on a typical sample from Goyder's Lagoon, a flood plain of the Diamantina River, is given below.

| Sample number | 6,221 | Mechanical analysis— | % |
|----------------------|--------------|---------------------------|-----|
| Depth (inches) | 0-12. | Loss on acid treatment .. | 1.6 |
| Description | grey clay | Moisture | 6.6 |
| Vegetation | lignum, etc. | Chemical data— | |
| Mechanical analysis— | % | Total soluble salts .. | .03 |
| Coarse sand | 2.3 | Nitrogen | .03 |
| Fine sand | 35.5 | Phosphate (P_2O_5) .. | .07 |
| Silt | 4.0 | Reaction (pH) | 8.1 |
| Clay | 50.9 | | |

V. THE VEGETATION

The vegetation of that portion of the Simpson Desert in Queensland has already been described by Blake, *loc. cit.*, but in his studies on this Desert fringe it was not possible for him to see in perspective the desert as a whole.

In the desert proper, although the sandhill communities are varied, they retain on sandridge crest and inter-ridge corridor a remarkable consistency. This is to be found across the whole region. The relative abundance of species varies a great deal, but the most important ones are the same practically throughout. Some prominent species present on the eastern side, like *Crotalaria Cunninghamii* (parrot bush), occur only sparingly or are apparently absent in the west, and *vice versa*, but such species are relatively few.

The principal communities have been divided into associations and grouped as edaphic complexes, and are summarised in Table VI as below. The distribution of the edaphic complexes is shown on the generalised map, which has been compiled from information from all available sources including original survey diagrams of the Lands Department, Adelaide, and in Queensland that published by Blake (4). The base map is after that of Madigan (13) but has been simplified, only the actual Desert camp sites being shown. His original map should be consulted for greater detail..

TABLE VI
Vegetation Associations

| Association | Habitat | Edaphic Complex |
|---|--|---|
| 1. <i>Spinifex paradoxus</i> (1) | Unstable sandridge crest | |
| 2. <i>Triodia Basedowii</i> | Inter-ridge corridors and lower slopes | |
| 3. <i>Nitraria Schoberi</i> | Inter-ridge areas near Lake Eyre | |
| 4. <i>Triodia Basedowii</i> — <i>Grevillea juncifolia</i> — <i>Eucalyptus pachyphylla</i> | Sandplain | <i>Triodia Basedowii</i> — <i>Spinifex paradoxus</i> |
| 5. <i>Acacia Cambagei</i> — <i>Atriplex vesicarium</i> | Restricted inter-ridge areas | |
| 6. <i>Acacia peuce</i> — <i>Bassia</i> spp. | Gibber downs | <i>Astrebla pectinata</i> — <i>Atriplex vesicarium</i> — <i>Bassia</i> spp. |
| 7. <i>Astrebla pectinata</i> — <i>Bassia</i> spp. | Gibber downs | |
| 8. <i>Atriplex vesicarium</i> — <i>Bassia</i> spp. | Gibber downs | |
| 9. <i>Eucalyptus coolabah</i> | Fringing channels and floodplains | |
| 10. <i>Atriplex nummularium</i> | Floodplains | <i>Eucalyptus coolabah</i> — <i>Atriplex nummularium</i> |
| 11. <i>Chenopodium auricomum</i> | Floodplain swamps | |
| 12. <i>Muchlenbeckia Cunninghamii</i> | Floodplains and swamps | |

1. TRIODIA BASEDOWII—SPINIFEX PARADOXUS EDAPHIC COMPLEX

(1) *Spinifex paradoxus* association (see pl. xxxviii, fig. 2, and pl. xliv, fig. 13)

Throughout the Desert the sandridge crests, except in the case of very low sandrises, are unstable and practically devoid of vegetation. The most important and consistent perennial is *Spinifex paradoxus* (cane-grass), a moderately good sand-binder, which usually grows to about four feet high and has rigid much-branched stems (pl. xxxviii, fig. 2).

A few other perennial or semi-perennial species which occur are *Ptilotus latifolius* and *Sida corrugata* var. *pedunculata*. In places, particularly on sand-

(1) The bulk of the systematic work on the Simpson Desert material was done by Miss C. M. Eardley, who is presenting the results in separate papers. She arranged and supervised the whole of the identifications. Only one family, the Chenopodiaceae, was done by the author.

(1) Now *Zygochloa paradoxia* (R. Br.) S. T. Blake.

ridge crests in the western portion of the Desert, the creeping herbaceous binders *Triumfetta Winnekeana* and *Tribulus hystrix* are found. *Crotalaria Cunninghamii* (parrot bush) and *C. dissitiflora*, although most prominent on sandridge slopes just below the unstable crests, nevertheless are frequently conspicuous on the crests themselves; the former was only observed from the region of the Hay River and east thereof, and the latter, which occurs across the whole Desert, is much more hoary and pubescent in the eastern than western parts. In the latter it is almost glabrous. The most important annual plants are the chenopod, *Salsola Kali* (buck-bush or roly-poly), two grasses *Plagiosetum refractum* ("drooping oat grass") and *Eriachne aristidea*, and *Trichodesma zeylanica* (water bush). All four species grow very rapidly after rain and are drought escaping rather than drought resistant. *Salsola Kali*, after dying off, remains as an important sand-binder for some time, and on sandridges adjacent to the eastern side of Lake Eyre individual plants five feet high and nine feet in diameter were common.

Blennodia pterosperma and *Goodenia cycloptera* are particularly prominent after rains on the lower horizons of the unstable crest near the stable slope—unstable crest interzone. The former is very colourful and good camel fodder while it lasts, but dies off and disappears very rapidly.

(2) *Triodia Basedowii* association (pl. xxxviii, fig. 1; pl. xxxix, fig. 4; pl. xl. fig. 6)

Triodia Basedowii (commonly called "spinifex" or porcupine grass) is the most important species of the whole desert, occurring as it does in all the sandy inter-ridge areas, on the lower ridge slopes and on the northern sandplain. The individual plants are very much branched, and the leaves spiny. Spreading out from the centre, it grows as dense tussocks, which apart from the flowering panicles supported on a slender stem, are rarely more than two and a half feet high, but varying greatly in diameter and often dying in the centre. In the hollows the individual plants are sometimes so close together that camels dislike walking amongst them; usually, however, they are more widely spaced. The species flowers relatively quickly after rains, sending up slender stalks terminating in the spikelet panicles and very much resembling a field of wheat (fig. 6). It is a drought resistant plant.

Throughout the Desert a great number of other species occur associated with the "spinifex," but their incidence is very spasmodic and they only rarely add anything to the physiognomy of the association as a whole. For convenience (see Table VI), the spinifex communities have been divided into two: (1) those of the inter-ridge corridors and lower slopes, and (2) those of the northern sandplain. The general similarities of the two edaphic habitats have already been referred to. The division into two associations is an arbitrary one, and a large number of species of the sandplain (e.g., the Grevilleas) are often conspicuous in the inter-ridge corridors and on lower ridge slopes. Although "spinifex" is present in both the hollows and on the slopes, the relative abundance of associated species in these two situations varies a good deal—one grades, of course, gradually into the other.

In the sandy hollows very few plants other than *Triodia Basedowii* are found. Occasionally there are shrubs or small trees, e.g. (see pl. xxxix, fig. 4; pl. xl, fig. 6), clumps of needlework (*Hakea leucoptera*), scattered Grevilleas (*Grevillea strobilifera*, *G. juncifolia*) or Eremophilas (*E. longifolia*, *E. Latrobei*), and sometimes growing under the shelter of these larger shrubs or small trees are *Rhagodia spinescens* and *Enchylaena tomentosa*. Two small shrubs of the Euphorbiaceae, *Euphorbia Wheeleri* and *Adriana Hookeri* are often prominent, while *Euphorbia*

Drummondii and *E. eremophila* were recorded. *Trichinium alopecuroides* was common in corridors near the western edge of the desert but rapidly disappeared going east. The composites *Helichrysum roseum* var. *Davenportii* and *Helipterum moschatum* may be locally conspicuous after rain, but they are very short-lived, as also are the grasses, *Eragrostis eriopoda*, *Aristida Muellerae*, *A. arenaria*, *Eragrostis Dielsii*, *Enneapogon cylindricus* and *Enneapogon asperatus* (the latter three only prominent during the expedition east of Lake Eyre). Practically the only other plants of the hollows worth mention here are *Scurvula depauperata*, *Thryptomene Maisonneuvei* and *Portulaca intraterranea* ("munyetoo," an excellent camel fodder).

The sandridge slopes, that is the regions between the hollows proper and the unstable crests, are fixed by *T. Basedowii*. A much larger number of associated species (rarely abundant enough to give a particular facies to the community) occurs here than in the hollows; although all the perennials present there are also found in varying degree on the slopes. The most prominent woody shrubs or small trees to occur are *Grevillea stenobolys* and *G. juncifolia* (especially in the easterly portion of the Desert), *G. stricta* (?) (rare, only seen in the western part), *Atalaya hemiglaucia* (whitewood), *Hakea leucoptera* (needlebush), *Eremophila Streblouni*, *E. Macdonnellii* var. *glabriuscula*, *E. Macdonnellii* (this species recorded in western side of Desert only), *E. Willsii*, *E. strongylphylla*, *Dodonaea viscosa* (occurs sparingly across the whole desert), *Acacia ligulata* ("sandhill wattle"), *A. dictyophleba*, *A. patens*, *A. Murrayana* and *Cassia pleurocarpa* (sandhill cassia). *Acacia Wattsiana* (?) and *Owenia acidula* (emu apple) were recorded only along the eastern edge of the desert (i.e., east of the Queensland border). Other plants occurring on the slopes are *Sida corrugata*, *S. virgata*, *Hibiscus Krichauffianus*, *Amarantus grandiflorus*, *Scaevola ovalifolia*, *S. depauperata*, *Leschenaultia divaricata*, *Crotalaria novae-hollandiae*, *Goodenia cycloptera*, *Trichodesma zeylanica*, *Myriocephalus Stuartii*, *Newcastlia cephalantha*, *Calotis erinacea* and *Euphorbia Wheeleri* and the grass *Eriachne aristidea*.

Acacia brachyphylla was common on some of the low dunes and dune slopes at the western side of the Desert.

Present to varying degrees but more or less confined to upper slopes in the interzone between the stabilized slope and unstable crest, are *Sida corrugata* var. *pedunculata*, *Sida virgata*, *Ptilotus latifolius*, *Trichinium obovatum* var. *grandiflorum*, *Blennodia pterosperma*, *Crotalaria dissitiflora*, *C. Cunninghamii* (parrot bush), *Panicum reversum* (*Paractaenium novae-hollandiae*) and some species very common on the crests, like *Salsola Kali* (buck bush) and *Plagiosetum refractum* (drooping oat grass).

A large number of species has been collected from sandhill and sandridge slopes about the Desert fringe that do not apparently occur throughout the Desert as a whole. More extensive work, however, may reveal the presence of some in the Desert. The most important of these on the western side were *Abutilon otocarpum*, *Sida inclusa*, *Triaanthema pilosa*, *Heliotropium tenuifolium* var. *parviflorum*, *Polanisia viscosa*, *Bassia bicornis*, and the grasses *Eragrostis laniflora*, *E. Dielsii*, *Aristida Browniana* and *Ichnanthus australiensis*. On the eastern and south-eastern side of the Desert, adjacent to the channel country, gibber plain or dissected tableland, are found *Zygophyllum humillimum*, *Lepidium rotundum*, *Babugia acropetra* (lower slopes only), *Bassia uniflora* (very common in places at edge of sandhills along the Diamentina), *Ptilotus murrayi* var. *major*, *Acacia* sp. (probably *A. colletioides*), *Triaanthema decandra*, *Atriplex velutinellum*, *A. spongiosum*, *Swainsona rigida*, *Psoralea eriantha*, *Plantago varia*, and the grasses *Eragrostis Basedowii*, *E. Dielsii*, *E. eriopoda* (on sandy slope near Hay River) and *Setaria Brownii*. A single specimen of *Codonocarpus cotinifolius*

was seen on a sandslope adjacent to the Hay River floodplain. These fringe desert species, although important locally, are not typical of the Desert proper. Many of them are making the most of a temporarily favourable sand slope habitat and have little chance of gaining a foothold in the Desert itself, as they are species of the floodplains or gibber tableland (e.g., *Plantago varia*, *Eragrostis Dielsii*, *A. velutinellum* and *Bassia bicornis*).

Although *Triodia Basedowii* is the most important species throughout the hollows and sandy slopes, and the other species present occur too sporadically to influence the general appearance of the association, there is a considerable area west of the Hay River where the sandridges are much lower (frequently less than 30 feet) and the relative abundance of the species quite different. Here many species which occur only sparingly in other parts are more abundant, and the elsewhere prominent *T. Basedowii* is much less conspicuous (pl. xxxix, fig. 5). The crests of these rises are not unstable as with the higher ones, but fixed chiefly by species which throughout the remainder of the Desert occur sparingly on the upper slope-ridge crest transition zone, together with plants of the unstable crests proper. The most prominent species are *Cassia pleurocarpa*, *Eremophila Streblowii*, *Eremophila* sp., *Spinifex paradoxus*, *Acacia Murrayana*, *Grevillea stenobotrya*, *Calotis erinacea* ("sand hill daisy"), *Leschenaultia divaricata*, *Adriana Hookeri*, *Euphorbia Drummondii*, *Ptilotus latifolius*, *Crotalaria dissitiflora*, *Sida virgata*, *S. corrugata*, *Trichodesma zeylanica*, *Plagiosetum refractum*, *Triodia Basedowii*, *Eriachne aristidea*, *Eragrostis* sp. Less frequent are *Acacia ligulata*, *Grevillea juncifolia*, *Dodonaea viscosa* and *Salsola Kali*. The short-lived *Portulaca intraterranea* ("muyeroo") was common in this area.

(3) *Nitraria Schoberi* association

In the sandhills about Lake Eyre where the soil is gypseous and more saline, vegetation is very scarce. *Triodia Basedowii* (spinifex) does not occur, and in its stead in both inter-ridge areas and on lower slopes *Nitraria Schoberi* (dillon bush, nitre bush) is found. Other shrubs and small trees are practically absent except for occasional clumps of low needlebush, *Hakea leucoptera*.

On the sandridge crests in this region *Spinifex paradoxus* (cane-grass) occurs very sparingly, and the most conspicuous feature at the time of the expedition was the large bushes of *Salsola Kali*. Annuals and ephemerals prominent after rains include *Crotalaria dissitiflora*, *Trichodesma zeylanica*, *Myriocephalus Stuartii*, *Blennodia pterasperma*, and *Goodenia cycloptera*. On the lower slopes *Sida virgata* is often prominent. *Swainsona stipularis* grows in profusion on the slopes and in the gypseous hollows shortly after rains.

(4) *Triodia Basedowii* - *Grevillea juncifolia* - *Eucalyptus pachyphylla* association (pl. xlvi, fig. 12)

At the northern edge of the Desert, as described previously, the sandridges give way to a featureless sandplain—particularly south of the Jervois and Tarlton Ranges. The principal species on this sandplain are *Triodia Basedowii* (spinifex) and a few scattered stunted trees and large shrubs, of which two mallees *Eucalyptus pachyphylla* and *Eucalyptus* sp. (probably *E. oxymitra*) and *Grevillea juncifolia* are most important.

On the 1937 expedition a journey was made about eight miles south from the junction of the Arthur and the Thring Rivers to take a soil sample on the sandplain. At that time a fairly severe "dry spell" was in progress, and annuals and ephemerals were non-existent.

As discussed previously this community is very closely linked, edaphically and floristically, to the *Triodia Basedowii* association of the inter-ridge corridors.

(5) *Acacia Cambagei* - *Atriplex vesicarium* association:

Acacia Cambagei (gidgee or stinking wattle) is to be found in a few hollows in the Simpson Desert, but is very rare west of the Queensland border. East of that longitude it is much more frequent, and reaches its greatest importance (at the latitude of our crossing) twelve to eighteen miles west of the Mulligan River at Old Kaliduwarry Station. Here it is associated with *Atriplex vesicarium* as an under-shrub (see pl. xl, fig. 7; pl. xli, fig. 8). The soil has a red fine sand surface horizon of about twelve inches, increasing in texture to a sandy clay with abundant amounts of free soft calcium carbonate at three to four feet (see Table III). The subsoil contains moderate quantities of sodium chloride (~25-34% as Cl).

Associated with the saltbush are a number of other chenopods, principal of which are *Kochia lanosa*, *Enchytraea tomentosa*, *Bassia uniflora*, *B. paradoxa*, *B. bicornis* and *B. intricata*. The principal grasses are *Aristida* sp., *Eragrostis Dielsii* and *Enneapogon* sp.

At the edges of the hollows and lower slopes, the saltbush is replaced by *Triodia Basedowii* and other common species of the sand slopes like *Acacia Murrayana*, *Grevillea juncifolia*, *Trichodesma seyanica*, *Cassia pleurocarpa* and *Crotalaria*, etc.

2. *ASTREBLA PECTINATA* - *ATRIPLEX VESICARIUM* - *BASSIA* spp.
EDAPHIC COMPLEX

The associations in this edaphic complex are very variable. They are the associations of the gibber flats, the stony downs, and the lower stony rises. The edaphic factors influencing the principal variations are not fully known, and a more thorough investigation will have to be made to elucidate them. However, microclimate, determined through topography, as has already been shown by Andrewartha (1), is no doubt very important. Soil salinity is also a most important factor and has a large influence on the distribution of mitchell grass, samphire and the chenopods generally. In the crabhole country much of the gibber shelf is too saline and too arid to support vegetation at all.

(1) North-east of Lake Eyre

The vegetation of the gravelly downs area in south-western Queensland has already been very fully dealt with by S. T. Blake (1938). He pointed out that the dominant grass in that area is *Astrebla pectinata* (barley mitchell grass). This grass, however, becomes less prominent southwards as one follows the downs north-east and east of Lake Eyre. It occurs in only restricted habitats in South Australia, where the principal gibber downs grasses are *Enneapogon polyphyllus*, *E. avicinaceus*, *Sporobolus actinocladus*, *Iseilema vaginiflorum* and *Triopogon loliiformis*.

Certain shrubs of the Chenopodiaceae are frequently locally important on the gibber country, especially *Kochia tomentosa*, *K. pyramidata*, *K. aphylla*, *K. planifolia*, *K. pentagona* and *Atriplex vesicarium*. The species of *Bassia* and annual saltbushes may be very abundant in good seasons, e.g., *Bassia divaricata*, *B. intricata*, *B. lanicuspis*, *B. quinquecuspis* var. *glabra* (?), *B. patenticuspis*, *B. Tatei*, *Atriplex spongiosum* (pop saltbush), and less abundantly, *A. halimoides* and *A. angulatum*. Other annuals and ephemerals, common after rains, are *Salsola Kali*, *Blennodia filifolia*, *Helichrysum podolepidium*, *Helipterum floribundum*, *H. pterochaetum* and *Minuria leptophylla*. Other plants recorded during the expedition included *Scaevola spinescens*, *Sida intricata* and *Malvastrum* sp.

On the low stony ridges larger shrubs and small trees occur spasmodically. Of these the most important are *Acacia Cambagei*, *A. tetragonophylla* (dead finish), *Cassia desolata*, *C. Sturtii* var. *involucrata*, *Acacia Victorias* (usually

confined to wetter parts), *Acacia peuce* (very limited distribution), *Eremophila Duttonii* and *E. Freelingii*.

In places there is little vegetation other than the burrs and bindyis (*Bassia* spp.), but this was very rare in July 1939.

Eremophila Latrobei occurs at the head of small stony gullies, as already recorded by Blake (*loc. cit.*).. In these small creeklets off the stony rises a wide and interesting variety of plants occurs. Of those recorded, the most important trees and shrubs are *Acacia aneura* (mulga), *A. Cambagei* (gidgee), *Santalum lanceolatum* var. *angustifolium* (sweet bush), *Cassia cremophila*, *Grevillea striata* (beefwood), *Acacia ligulata* and *Eremophila maculata*. *Didiscus glaucifolius*, *Zygophyllum fruticosum* and *Pimelea trichostachya* were frequent near Mount Gason. Of the more ephemeral and herbaceous species the following are noteworthy as occurring in this habitat: *Nicotiana Goodspeedii*, *Trichinium obovatum* var. *grandiflorum*, *Helichrysum semifertile*, *Helipterum floribundum*, *H. pterochaetum*, *Atriplex spongiosum*, *Trichodesma seyanica*, *Chloris pectinata*, *Iseilema vaginiflorum*, *Goodenia subintegra* and *Lotus australis* var. *parviflora*.

In small sandy pockets or shallow accumulations of sand on the gibber downs, annuals, most of which are normally associated with sandridges, occur. Of the grasses, *Eriachne aristidea*, and less abundantly *Plagiosetum refractum*, associated with *Aristida Browniana*, *A. arenaria* and *Iseilema vaginiflorum* are to be found. Probably the most important ephemals are *Portulaca* spp. (munyeroo), *Helipterum moschatum* and *Goodenia cycloptera*.

In places crabholes occur; these are both a wetter and less saline habitat than the surrounding gibber downs and support abundant vegetation.

Marsilia (nardoo) occurs in many local wetter situations.

(2) North-west of Lake Eyre

Only limited opportunity was afforded of studying and collecting on the gibber downs on the south and western side of the desert. Collecting was limited to the immediate neighbourhood of Abninga and Charlotte Waters, and an area near Andado Bore No. 2.

It is interesting to see many plants common on the eastern downs present here also. Important species common to both areas include *Atriplex vesicarium* (saltbush), *Kochia aphylla*, *K. planifolia*, *Cassia desolata*, *Acacia Cambagei*, *Acacia peuce* ("waddy"), *Bassia lanuginosa*, *B. divaricata*, and the grasses *Enneapogon* spp., and *Eragrostis leptocarpa*.

Acacia peuce ("waddy"), occurring as it does in two such restricted and widely separated localities, one on either side of the Desert (Andado Bore No. 2) and near Birdsville), has special significance. There is little doubt these two occurrences are remnants of what was probably previously a wide belt before the aridity from which the sands accumulated and piled up over the gibber downs between.

Pachyvernia tenuis (samphire), which is quite common on the gibber downs about Abninga, was not recorded between Goyder's Lagoon and Cowarie Station. Its presence indicates very high soil salinity.

3 EUCALYPTUS COOLABAH—ATRIPLEX NUMMULARIUM EDAPHIC COMPLEX (Pl. xxxviii, fig. 2; pl. xli, fig. 9)

This complex includes all the associations fringing river channels and flood-plains. For simplicity these are divided into four associations:—

- Eucalyptus coolabah* association;
- Atriplex nummularium* association;
- Chenopodium auricomum* association;
- Muehlenbeckia Cunninghamii* association

Eucalyptus coolabah fringes the channels and occurs on the floodplains of all the rivers which flood into, or border, the Simpson Desert—the Finke, Hale, Todd, Hay, Georgina, Diamantina, Warburton and Kalikoopah Rivers. Coolabah was also noted between some sandhills east of the Hale, where it no doubt represented the extreme flood limits of some creek from the Flinders Ranges.

Beyond the fringing forest, associations dominated by *Atriplex numularium* (old man saltbush) are common. Local swamp communities of *Eragrostis australasica* (cane-grass), *Muehlenbeckia Cunninghamii* (lignum), or, associated with the north-eastern rivers, *Chenopodium auricomum*, also occur.

Bauhinia Carronii (bean-tree) and *Acacia salicina* are fairly common along the channels of the Georgina, and *Eremophila bignoniiflora* and *Acacia salicina* are found about waterholes in both the Diamantina and Warburton Rivers. Local fringing communities dominated by paperbark titree (*Melaleuca glomerata*) grow along the Finke and *Eremophila Macdonnellii*, *E. Macdonnellii* var. *glabrinervula*, *E. longifolia*, *Acacia salicina* and *A. estrophiolata* occur on the floodplain of the Hale, Todd and Finke Rivers.

Other species of particular prominence along floodplains, and about channels and waterholes of the Diamantina, Georgina, Warburton, Finke, Hale and Hay Rivers, include *Psoralea patens* ("verbine"), *P. cinerea*, *Scoevola uvalifolia*, *Alternanthera nodiflora*, *Rhagodia parabolica*, *Gnephosis eriocarpa*, *Tenuerium racemosum*, *Halorrhagis heterophylla*, *Lavatera plebeja* and *Morgania glabra*. In addition a large number of other species, principally ephemerals, were collected and will be listed elsewhere.

In the Finke and Hale floodplains a large number of grasses were collected. There include *Panicum decompositum*, *Aristida Muellieri*, *A. anthoxanthoides*, *Eriochloa* sp., *Iseilema vaginiflorum*, *I. membranaceum*, *Eulalia fulva*, *Dichanthium humilius*, *Leptochloa digitata*, *Chloris virgata*, *C. pectinata*, *Eragrostis confertiflora*, *E. Dielsii*, *E. japonica*, *Triraphis mollis*, *Enneapogon polyphyllus*, *Brachiaria praetervisa*, *Setaria oplostepnoidea*, and *Eriachne ovata* var. *pallida*.

The following species were recorded in a sandy inter-ridge watercourse near Andadu homestead: *Eragrostis Basedowii*, *Enneapogon polyphyllus*, *Aristida Muellieri*, *Iseilema membranaceum*, *Panicum Whitei*, *Sida corrugata*, *Lepidium rotundum*, *Muehlenbeckia Cunninghamii*, *Pterigeron latirostris*, *Dysphania littoralis*, *Plantago varia*, *Boerhavia diffusa* and *Helipterum floribundum*.

As being typical of a number of moderate-sized sandy creeks off the gibber downs about Charlotte Waters and Abminga, the following species occur: occasional *Eucalyptus coolabah* and *Acacia Cambagei* (gidges), together with *Cassia Sturlii*, *Acacia brachystachya*, *Threlkeldia inchoata*, *Kochia coronata*, *Atriplex spongiosum*, *Bassia uniflora* var. *incongruens*, *Eriochloa* sp., *Panicum decompositum*, *Iseilema vaginiflorum*, *Eulalia fulva*, *Dactyloctenium radulans*, *Chloris virgata*, *C. pectinata*, *Eragrostis Basedowii*, *E. japonica*, *E. leptocarpa*, *E. setifolia*, *Diplachne Muellieri*, *Triraphis mollis*, *Cyperus Victoriae*, *C. dactylotes*, *Swainsona oligophylla*, *Cologyne herardiana*, *Nicotiana ingulba*, *Lepidium rotundum*, *Blennodia pterosperma*, *Gnephosis eriocarpa*, *Helipterum floribundum*, *H. pterochaetum*, *H. moschatum*, *Myriocephalus Stuartii*, *Senecio Gregorii*, *Minuria integrerrima*, *M. denticulata*, *Pterigeron latirostris*, *P. adscendens*, *Neptunia monosperma*, *Zygophyllum Howittii*, *Portulaca oleracea*, *Trianthema decandra*, *Amaranthus grandiflorus*, *Trichinium exaltatum*, *Euphorbia Drummondii*, etc.

The vegetation of Seven Mile Creek, near Goyder's Lagoon Bore, can be taken as typical of many of the larger creeks off the gibber tableland in that region. The principal trees are *Eucalyptus coolabah* (box) and *Grevillea striata* (heefwood), together with occasional *Acacia Victoriae*, *Eremophila* sp. and

Santalum lanceolatum. Amongst the associated species *Bassia bicornis* (goat-head), *Salsola Kali* (buck bush), *Goodenia subintegra*, *Wahlenbergia quadrifida*, *Calandrinia ptychosperma*, *Blennodia lasiocarpa*, *Menkea sphaerocarpa*, *Minuria* sp., the grasses *Chloris pectinata*, *Chrysopogon* sp., and in the more sandy parts, *Crotalaria dissitiflora*, are most common.

Echinochloa Turneriana (cane-grass) grows along most of the numerous small channels that intersect the flood plain of the Diamantina River at Goyder's Lagoon. Beyond the cane-grass, and liable to less frequent floodings, are lignum (*Muehlenbeckia Cunninghamii*) and saltbush (*Atriplex nummularium*) flats. Much of the saltbush is now dead and only old sticks remain. The principal grasses apart from cane-grass are *Eriochloa* sp. and *Agrostis avenacea*. Other species recorded were few and practically limited to areas adjacent to the small channels. *Craspedia chrysanthia*, *Ixioldena leptolepis* and *Sonecio laetus* were particularly common, together with *Atriplex limbalatum* (annual saltbush), *Blennodia eremigena*, *Lepidium rotundum*, *Alternanthera nodiflora*, *Lotus australis* var. *parviflorus* and *Trigonella suavissima*. *Chenopodium auricomum* (blue bush) swamps are frequent adjacent to the southern edge of Goyder's Lagoon. The grasses, *Eragrostis australasica* (cane-grass) and *Panicum decompositum*, are commonly found in these swamps.

4 VEGETATION OF BORE DRAINS

The vegetation along bore drains at Mount Gason and Goyder's Lagoon is practically confined to a grass *Diplachne Muelleri*, together with *Scirpus maritimus*, *Cyperus laevigatus* and *C. gymnocaulos*.

VI. SOIL-VEGETATION RELATIONSHIPS

Soil factors, including the moisture regime, appear to be the most important environmental factors governing the distribution of the vegetation in and about the Simpson Desert.

The general similarity between the corridor and northern sand-plain soils is paralleled by a very close relationship between the floristic composition of the communities associated with each. On the gravelly downs the moisture relationships (and consequent soluble salt status) appear to be particularly important in the distribution of the associated communities.

The effect of soil fertility is much more difficult to assess than the other environmental factors. It is quite possible that much of the sand has not been transported far by wind, and that local variations in mineralogy of the sands, dependant upon fluctuations or differences in supply and composition of parent material, is reflected in their fertility. Unfortunately, chemical methods of assessing soil fertility are very restricted in both range and application. The use of single value factors, as has been shown earlier for the phosphate (P_2O_5) status, as a fertility index, is extremely dangerous.

But in any case on a survey of this type, carried out on only two short visits to the region, only broad generalisations on the soil-vegetation relationships can be made. The associations fall very neatly, however, into edaphic complexes, and can be conveniently mapped as such.

No mention has been made in the text of the *Casuarina decaisneana* (desert oak)—*Triodia Basedowii* association that occurs on an undulating sandy off-shoot of the Desert south and east of the Finke River, west of Rumbulara and Alice Well; or of the *Astrebla* spp. (mitchell grass) and *Acacia Cambagei* (gidgee) downs north of the Desert sandplain. The former is a variant within the *Triodia Basedowii*—*Spinifex paradoxus* edaphic complex, and the latter has many affinities with Blake's "Ashy Downs association."

The distribution of certain species on one side of the Desert and apparent absence on the other, e.g., *Crotalaria Cunninghamii* on the eastern side, probably indicates their spread from a surviving centre.

VII. SUMMARY

The general ecology and climate of the Simpson Desert and its margins has been briefly reviewed and the soils described. The soils fall into three main groups: (1) aeolian sands; (2) brown soils associated with surface gibbers; and (3) alluvial soils associated with floodplains of the principal rivers and watercourses.

Some analytical data on the soil types has been presented, and in the case of the Desert sands a series of sieveings carried out. Unfortunately, the number of samples taken on the expedition were limited.

The most important feature of the brown gibber soils is their high salinity, which varies considerably with micro-climate.

The Desert sands are predominantly quartz and near the extreme limit of fineness for aeolian sands ('08 mm. diameter).

The peak diameters of the sands are coarser on the ridge crests than in the inter-ridge corridors, and the reverse therefore of the relationship found for the Libyan Desert sands and postulated as general. It is suggested that the extreme fineness of the Simpson Desert sands is responsible for this reversal.

The extreme fineness of the sands suggests that they consist of previously abraded material, probably having passed through several cycles of erosion, and the arenaceous Eyrian series were probably the principal source of supply. The limited presence of minerals of a predominantly metamorphic and granitic suite (Carrol) show that contributions from other sources have also been made.

There is a conspicuous absence of the silt ('02-'002 mm. diameter) fraction in the sands. This has no doubt been removed as loess, and deposited further afield—chiefly to the north and east.

The sand gradings are variable and many of them have the characteristics of mixed sands. The surface half inch from the northern sandplain is a special mixed sand with two peak diameters, one approximately ten times as great as the other.

It is suggested that the reason for the development of a sandsheet in the north, and the typical sandridge system in the south, may rest in a difference in grading of the parent sand, which it is supposed contained more coarse sand in the former.

The principal vegetation communities are described under twelve associations. These have been grouped for convenience of demonstrating the major habitat linkages, and for ease of mapping into edaphic complexes.

The chief communities on the Desert sands are dominated either by *Triodia Basedowii* or *Spinifex paradoxus*.

One of the most interesting vegetation assemblages is an association of the gibber downs dominated by *Acacia peuce* (waddy). This occurs as two small relict areas on either side of the Desert now separated by more than 200 miles of superficial sand.

A tentative vegetation map of the area, drawn from all the information available, is presented. The base map used was that of Dr. C. T. Madigan.

VIII. ACKNOWLEDGMENTS

Some of the analytical work on the soils was carried out by laboratory assistants under the direction of Dr. C. S. Piper, and in which H. R. Skewes also assisted. I am especially grateful to Dr. C. T. Madigan for the opportunity of

accompanying him on both the 1937 and 1939 expeditions, and the many pleasant and interesting associations and experiences resulting therefrom. I have unconsciously absorbed from these associations a large number of ideas and much stimulating philosophy.

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Fig. 1

Triodia Basedowii association in inter-ridge corridor near Camp 6. The dead grasses
are *Eragrostis* and *Arenaria* spp.

Photo, D. Marshall



Fig. 2

Spinifex paradoxus association on crest of high sandridge adjacent to flood-plain of
Diamantina River. The crucifer flowering so profusely is *Blennodia pterosperma*
Eucalyptus coolabah fringing the Diamantina channels.

Photo, C. T. Madigan



Fig. 3.—*Spinifex paradoxus*, *Salsola kali* and *Acacia Murrayana* towards crest of a low dune. The dead grasses are chiefly *Plagiosetum refractum* and *Eriachne aristidea*.



Fig. 4.—*Triodia Basedowii* association in inter-ridge corridor, with dead *Acacia* sp. about small claypan. Serrated crests of "tear drop" sandridges in background. Camp 9.

Photo, D. Marshall



Fig. 5.—*Triodia Basedowii*, *Salsola kali*, *Cassia pleurocarpa*, *Crotalaria dissitiflora*, *Adriana Hookeri*, *Acacia Murrayana*, etc., on low sandhill west of the Hay River.

Photo, D. Marshall



Fig. 6

Triodia Basedowii and *Grevillea stenobothrys* on dune corridor west of the Hay River,
near Camp 14.

Photo, D. Marshall

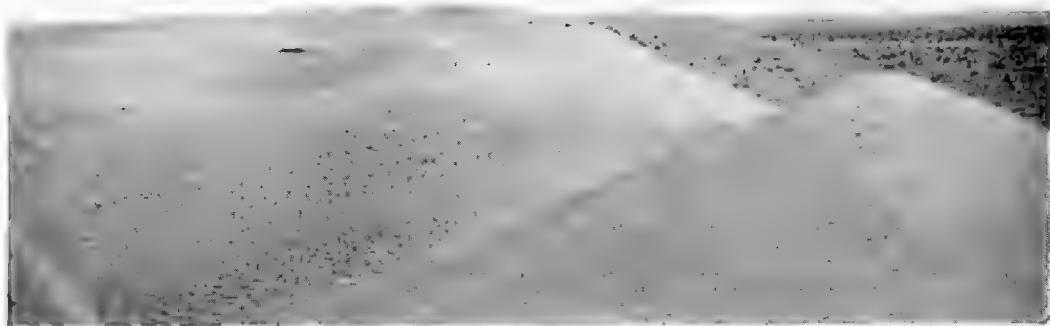


Fig. 7

Alectra Umbellata in inter-dune corridor (right) with *Trichtia Eriocoleum* stabilising
the slopes of a large unstable ridge (left foreground).

Photo, D. Marshall



Fig. 8

A. Gumbagei-Atriplex vesicarium association in corridor between Camps 18 and 19.

Photo, D. Marshall



Fig. 9

Flood plain of Hay River. *Eucalyptus coolabah* with *Scavola ovalifolia* as the most prominent undershrub. Principal grasses *Aristida* and *Eragrostis* spp.

Photo, D. Marshall



Fig. 10—Shores of Lake Eyre North. *Salsola kali* (roly-poly) at base of sandhill (foreground) with *Nitraria Schoberi* and *Salsola Kali* the principal vegetation nearer the lake.

Photo, C. T. Madigan



Fig. 11.—*Acacia feneei* (wattle) + *Bassia* spp. on gibber downs north of Birdsville.

Photo, D. Marshall



Fig. 12.—*Trifolia Basedowii*—*Grevillea juniperina*—*Eucalyptus parviflora* association on sandplain south of junction of Marshall and Thring Rivers at north end of Simpson Desert.

Photo, C. T. Madigan



Fig. 13

Low sandridge near Camp 12. *Spinifex paradoxus* association on ridge crest (foreground) and *Triodia Basedowii* in corridor.

Photo, D. Marshall



Fig. 14

Sandridges flanking a flood-plain offshoot of the Mulligan River near old Annandale Station. The trees skirting the flood plain are *Acacia Cambagei*.

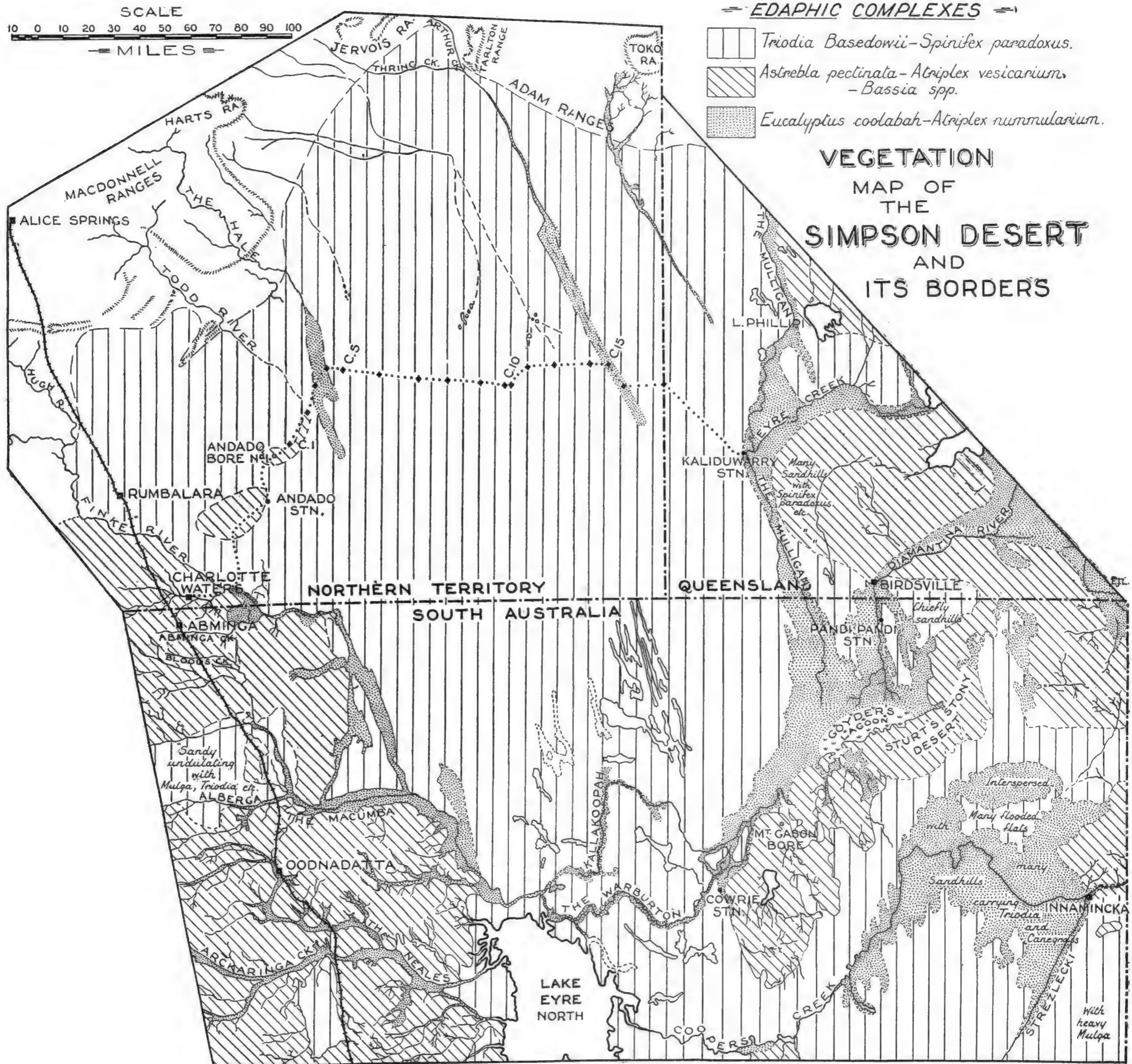
Photo, D. Marshall



Fig. 15

Eucalyptus coolabah lining a small creeklet off the gibber downs at Andado Bore No.2. The ground flora is mainly grasses (*Enneapogon* spp. and *Sporobolus actinocladus*) and bindyi (*Bassia* spp.).

Photo, D. Marshall



THE VEGETATION OF THE SOUTHERN FLINDERS RANGES, SOUTH AUSTRALIA

BY C. D. BOOMSMA

Summary

This paper contains an account of the vegetation of a portion of the Southern Flinders Ranges. The area is the hinterland of the coast from Port Pirie to Port Augusta, extending inland for a distance of approximately 20 miles. The area comprises about 650,000 acres, in the whole of which the vegetation associations were mapped; in addition detailed mapping of vegetation types was carried out in a smaller area of about 15,000 acres situated in the Hundreds of Darling and Howe.

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SOUTH AUSTRALIA**

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[Read 8 August 1946]

This paper contains an account of the vegetation of a portion of the Southern Flinders Ranges. The area is the hinterland of the coast from Port Pirie to Port Augusta, extending inland for a distance of approximately 20 miles. The area comprises about 650,000 acres, in the whole of which the vegetation associations were mapped; in addition detailed mapping of vegetation types was carried out in a smaller area of about 15,000 acres situated in the Hundreds of Darling and Howe.

PHYSIOGRAPHY AND GEOLOGY

This larger area contains five topographic regions, and the smaller area contains three of these regions, *viz.*, a coastal spur of the Flinders Range with the associated foothills and hillocks in the east. Numerous high peaks are present, but the absence of lakes and swamps is noteworthy in an area which receives up to 30" annual rainfall. The topographic regions are:—1, Coastal Plain; 2, Coastal Spur of the Flinders Ranges; 3, Eastern Foothills; 4, Eastern Hillocks; 5, Eastern Plain.

COASTAL PLAIN

The plain varies in width from one half mile to six miles, being widest near Baroota and narrowest near Yatala Harbour. It occurs along the full length of the coast from Port Pirie to Port Augusta and is bounded in the east by the coastal spur of the Flinders Range. Because of the gradual slope to the west drainage is generally impeded, as indicated by restricted communities of mangroves at Port Pirie and salt tolerant herbs in the northern portion of the coastal plain. Nevertheless, numerous creeks and smaller watercourses have their outlets to the sea.

COASTAL SPUR OF THE FLINDERS RANGES

This spur forms the most prominent topographic feature of the area and contains peaks of considerable altitude—the Bluff, Mount Remarkable (3,178'), Mount Brown (3,152'), together with numerous steep-sided peaks of lower altitude.

Advanced dissection contributes to the rough nature of this region, the hill slopes being steep and abrupt with few gaps in the ridge line to permit crossing from side to side. The western side is the steeper and is frequently a scarp face, but the eastern side grades into foothills. Drainage is free, there being numerous steep-sided creeks and several long gorges cut through the resistant quartzites. In general the ridge tops are rounded to flat rather than angular, although access is reduced to a minimum.

EASTERN FOOTHILLS

Unlike the western side, in the east the coastal spur grades into foothills with broader, less steep-sided valleys. The foothills are round-topped when isolated, but minor flat-topped ridges are frequent. Drainage is adequate and free, there being numerous creeks flowing north, south, east and west. In the south, Beetaloo Reservoir receives the flow from several creeks, while several others flow eastwards into the Rocky River. Willochra Creek flows inland and

northwards, and receives many eastward flowing tributaries such as the Beautiful Valley Creek, Mount Brown Creek and Richman Creek. Access is possible over most of this region.

EASTERN HILLOCKS

The eastern foothills grade into the eastern plains as small hillocks. The topography is undulating and the hillocks are pleasantly rounded. The hillocks are more noticeable in the south than in the north of this area. Drainage is adequate, creeks being numerous and flowing in all directions. In the south of the region the Rocky River flows southwards into the Broughton River, whilst in the north, numerous eastward flowing creeks flow into Spring Creek. Access is free, there being few topographic obstacles other than the watercourses.

EASTERN PLAIN

The eastern plain is elevated to 1,200' and lies between the eastern hillocks and the Pekina Ranges which are east of the area under discussion. The plain is traversed by numerous sub-parallel watercourses, which adequately drain this region. In the south of the region drainage is to the south, and in the north drainage is to the north. Access is free, there being few topographic obstacles other than watercourses and low ranges.

GEOLOGY

The geology of Counties Frome and Victoria is continuous in a north-south direction, there being similar upland ridges of resistant quartzite beds often separated by intervening softer beds. The softer beds yield more readily to water erosion, so that the watercourses tend to follow the strike of these beds. Zones of weakness are found in the more resistant quartzite beds, and there the watercourses are able to cross into the adjoining softer beds.

Stephens *et al.* (15) produced a list of the rock types occurring in County Victoria, as well as a table showing the relation between rock type and physiognomy. They discussed Fenner's conclusions that the prevailing structures were due to tilted fault blocks, and also Howchin's theory of the relation of present topography to ancient watercourses. The authors' views were not conclusive as they observed ancient stream gravels, but no major strike faults. However, folding is general in County Victoria and also in County Frome, the axis of the folds being in a north-south direction, the folds being anticlines or domes, and synclines or basins, e.g., Caltowie is located along the axis of a syncline and Jamestown is situated on an eroded anticline.

The Pre-Cambrian succession in County Frome forms the backbone of the ranges and is widespread in its occurrence. To obtain the correct order of the beds in County Frome, detailed field work is necessary, as the numerous faults and folds cause many variations in the normal order of succession. Segnit (14) has mapped in details considerable areas of the Flinders Ranges and includes several areas of County Frome. Segnit (14) and Howchin (9), as well as others, have recorded the basins, pounds and the domes. Some of the basins have been utilised as sites for reservoirs, viz., Baroota and Beetaloo Reservoirs. It is notable that the main features of this vast geological series are maintained in an unique fashion over vast areas.

Parallelism, which leads to a duplication of the beds, is frequent and sometimes the correlation with forest types is remarkable, e.g., a basal transition bed of purple-grey quartzite occurs well up in the thick quartzite bed in Sections 19, 10, 8 and 4, Hundred of Darling, over a distance of 10 miles and supports an exclusive forest type of *E. leucoxylon*.

The publications concerning rock-types of the area provide a more complete picture of their distribution and relationships than is possible in this paper. Briefly, rocks of the middle Pre-Cambrian to lower Cambrian are present and include such rock-types as sandstones, quartzites, conglomerates, siliceous slates, dolomitic limestones, grey shales and felspathic sandstones. The absence of igneous rocks, volcanic rocks, laterite and extensive mineralization is notable. Segnit (14) measures a thickness of over 10,000 feet from Pichi-Richi Pass and Horrocks' Pass areas. The coastal spur of the Flinders Ranges is mainly composed of the resistant Flinders Range quartzite and purple slates with a general dip to the east, while the eastern foothills are mainly composed of the middle group of the upper Pre-Cambrian. Sturtian tillite is found outcropping in the eastern hillocks, and travertine limestone is found on the plains.

CLIMATE

To adequately describe the climate reliable records are required from many stations for a considerable period of time. Unfortunately, there are but few stations, so that climatic data are extremely limited. Consequently, the division of the subject area into small climatic zones is problematical.

It is convenient to describe the climate under:—1, Rainfall; 2, Temperature.

RAINFALL.

Because of the important relationship between annual rainfall and forest formation, all available gaugings were collected from both official stations and reliable settlers. The data were used to draw an inch gradient isohyet map. By comparing the maps the trend of saltbush to mallee, to peppermint, to grey-box, to long-leaved box associations is seen to follow the trend of low annual rainfall areas to those of higher rainfall.

The characteristics of the annual rainfall may be divided into reliability, sources, effectiveness, period of wet season, fogs and snow.

Reliability—Although the greater part of the smaller subject area receives more than 20" mean annual rainfall, droughts are frequent and severe. The expectation of receiving the average rainfall is relatively high in this area, but is low over a great part of the larger subject area. Drought occurs when the annual rainfall is much below the mean, with consequent disastrous results on the growth of annual plants. Large woody plants like the eucalypts, which may have a tap root up to 50' long are well fitted to survive periods of drought, but the nature of the effect of drought on eucalypt associations would require a considerable amount of regular field observations extending over a period of years. It is noted that *E. cladocalyx* is tolerant and even drought resistant when planted out of its natural habitat. It grows naturally on areas receiving 33" rainfall, but will grow when planted on areas receiving 12" rainfall, e.g., at Loxton. Many smaller plants have specialized structures to aid drought resistance.

Sources—During the winter the greater proportion of the rainfall results from the normal west to east procession of the pressure systems. Showers are frequent and light rain may extend over several days, but in summer monsoonal storms from the north may produce floods in a few hours.

Effectiveness—The soil receives a higher proportion of moisture from a 5" rainfall extending over days than from a 5" rainfall extending over a few hours. A small shower of 25 points has little effect on the percentage of soil moisture during the hot summer, as evaporation is so rapid. Various equations

have been advocated to express the effectiveness of a mean rainfall. The most efficient and convenient to use is that of Trumble (17), which requires the rainfall to be greater than one-third of the evaporation from a free water surface. On that basis the rainfall is effective for the five months, May to September, over the whole of the smaller subject area. In the eastern vicinity of the uplands of the coastal spur and eastern foothills the period of effective rainfall may be as long as six months. Farther east, on the eastern plain, beyond the rain shadow effect of the uplands, the effective rainfall period is no more than five months. In the north, where the mean annual rainfall is under 13", the effective period is also less than five months. Stephens *et al* (15) give the analysis of weather data for the adjacent County Victoria. There it is shown that a portion of the county has a period of five months of effective rainfall.

Extent of the Wet Season—In areas where there is at least five months of effective rainfall, wet and dry seasons are characteristic of the climate. Typical areas having wet seasons are those in the rain shadows of uplands, when July is the average wettest month, and March the driest. In the north, where there is no rain shadow, the rainfall of 13" or less is equally distributed in each month, and so there is no obvious wet season.

Fogs and Snow—Fogs occur occasionally each winter, but snow rarely, falls being separated by years.

TEMPERATURE

On the smaller subject area there is a hot summer when temperatures over 100° F. are frequent, followed by a cold winter with frosts. Frosts do not occur to any extent on the coastal plain. Mean monthly temperatures are less in the eastern vicinity of the coastal spur where elevations are considerable, than on the eastern hillocks or eastern plain.

In the hot season severe scorching dust storms are frequent and sear the crowns of trees, while strong winds in the wet season cause some windthrow of trees. The drought resistance of plants is tested during these periods, in which the transpiration rate must be greatly increased. Both Pidgeon (10, 11) and Cockayne (5) have observed that exposure to wind can be limiting when other factors favour the development of a forest.

SOILS

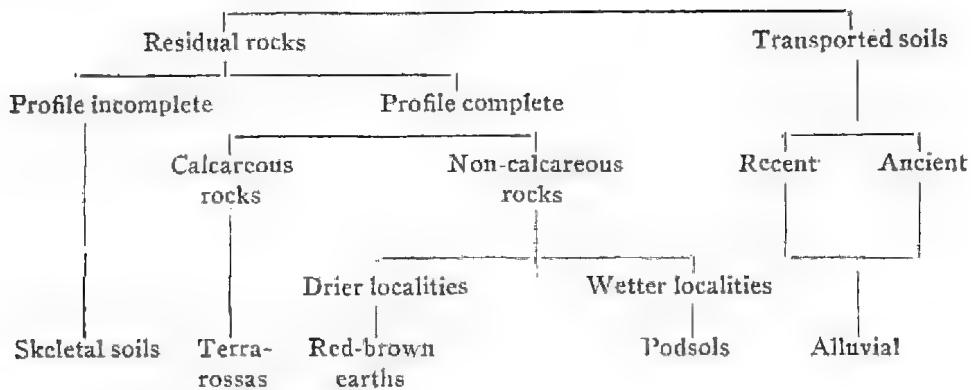
To show the relations between vegetation and soil types a soil map is required. As time did not permit the gathering of sufficient data to map the soil types, it is possible to make only general observations.

In the smaller subject areas the soils are classed as either residual or transported. In the case of residual soils, the skeletal soils are shallow and have an incomplete profile. They are typical of the upland areas and comprise at least one-third of the area of soils on the smaller subject area. Deeper soils result on areas of more favourable topography and may be classed according to whether they were derived from calcareous or non-calcareous rocks. The development of the profile of transported soils generally depends on the age of the soil, as recently transported soils show immature profiles, whilst those of ancient water-courses show more complete profiles. Stephens, *et al* (15), give a detailed description of the soils in part of the adjacent County Victoria, and relations are evident between these soils and those of County Frome.

The soils of the smaller subject area are derived from Pre-Cambrian rocks, and Table I shows the general relations between rocks and soil groups.

TABLE I

PRE-CAMBRIAN SERIES



Observations in the smaller subject area show that the two extremes of soil tolerance occur. The *E. transcontinentalis* association, a mallee association, is restricted to the terra-rossa soils derived from calcareous rocks of the middle Pre-Cambrian. But the *E. leucoxylon* association occurs on most of the soil types, from skeletal to alluvial. Other vegetation associations show a soil tolerance to a lesser degree, *viz.*, the *E. cladocalyx* association is typically found on skeletal soils of the quartzite uplands, but in the Hundred of Howe it is found on terra-rossas derived from calcareous rocks.

The soil groups may be further related to other natural features (Table II).

TABLE II

| Formation | Association | Locality | Soil Type | Mean Annual Rainfall |
|------------------------|---|---------------|-----------------|----------------------|
| Dry Sclerophyll Forest | <i>E. claeophora</i> | Uplands | Skeletal | 27" plus |
| | " | " | Podsol | 26" " |
| | <i>E. cladocalyx</i> | " | Skeletal | 25" " |
| | " | " | Podsol | 24" " |
| | <i>E. leucoxylon</i> | " | Podsol | 26" " |
| Savannah Woodland | <i>E. cladocalyx</i> | " | Terra-rossa | 18" " |
| | <i>E. leucoxylon</i> | Various | Podsol | 21" " |
| | " | " | Red-brown | 17" " |
| | " | Water-courses | Alluvial | 16" " |
| | <i>E. micracarpa</i> | Foothills | Podsol | 18" " |
| | " | " | Red-brown | 17" " |
| | " | Valleys | Alluvial | 17" " |
| | <i>E. odorata</i> var. <i>erythrandra</i> | Hillocks | Red-brown | 17" " |
| | " | Plains | Solonized brown | 14" " |
| | <i>E. calcicultrix</i> | Hillocks | Terra-rossa | 15" " |
| Mallee | " | Valleys | Alluvial | 14" " |
| | <i>E. camaldulensis</i> | Valleys | Alluvial | 13" " |
| | " | Valley slopes | Red-brown | 18" " |
| | <i>E. transcontinentalis</i> | Plains | Solonized-brown | 12"-17" plus |
| | | Ridges | Terra-rossa | 17"-24" plus |

As in other parts of South Australia, there is a clear-cut division between sclerophyll communities on the nutrient-poor skeletal soils and podsols, and savannah woodlands on relatively nutrient-rich soils. The above associations are widespread and typical, but changes occur under the influence of compensating factors, especially water relations, e.g., *E. elaeophora* and *E. cladocalyx* associations may approach savannah woodland and *E. microcarpa* and *E. leucoxylon* approach sclerophyll forest in formation.

The same association tends to recur in similar environments, but precise evaluation of an environment extending over thousands of acres depends upon climatic records, physiographic and soil surveys, all of which are fragmentary. Consequently, a detailed study correlating environment and association is not possible. However, when the vegetation map is superimposed upon the isolhyet map the main trends are apparent. The trend is from mallee associations (*E. transcontinentalis*) on limestone ridges to *E. odorata* var. *crythrandra* (peppermint) association on the hillocks; then to *E. microcarpa* (grey-box) on the red-brown soils of the foothills; then to *E. leucoxylon* (blue gum) association on soils of varied origin; to *E. cladocalyx* (sugar gum) and *E. elaeophora* (long-leaved box) associations on the podsols derived from quartzites of the uplands. This trend coincides with increasing annual rainfall and increasing altitude and is summarised in Table II. The occurrence of the associations are shown on the vegetation map.

To a large degree changes in any factor of the environment are reflected by changes in the association. Soil water content is a major factor.

In some instances aspect produces marked effects, e.g., the extension of the *E. camaldulensis* association up the southern aspect of protected valleys. On the exposed rough north-west aspects in the range country, the hardy *Callitris gracilis* colonises and successfully excludes other tree species. The *Banksia marginata* society is limited to a few acres on the protected southerly aspect of deep fertile gorges in the range country. Constant exposure to winds produces a defective growth form and a stunted forest type may be observed on the western scarp of the Flinders Range in the *E. cladocalyx* association, and on the upper slopes of the quartzite series in Section 19, Hundred of Darling, in the *E. leucoxylon* association. That the soil moisture relationship is dominant is shown by the occurrence of an island of *E. camaldulensis* on a skeletal soil on the upper slopes of a quartzite ridge at the site of a permanent spring.

The natural changes of an association are frequent and involve three main alterations—1. Changes in formation. 2. Alterations in the frequency of dominant species. 3. Alterations in the growth habit of the dominant species.

In addition, extensive alterations have taken place in forest associations through man's opening up of the country, involving clearing, burning and grazing, together with the subsequent introduction of exotic species and soil erosion. In changes of formation to type an association reflects a change in the environment which may mean that either the dominant species is sufficiently exclusive and tolerant to grow in the changed environment, or the change is not of sufficient degree to enable the development of another association. The *E. cladocalyx* dry sclerophyll formation is frequently observed on areas of less than 19" annual rainfall as a savannah woodland formation, while the *E. leucoxylon* savannah woodland formation on areas of more than 24" annual rainfall frequently adopts a dry sclerophyll formation. More often an association adapts itself to minor changes in the environment by alteration in the frequency of the dominant species, or alterations in the understory, thus forming a forest type or a society respectively. When the change in the environment is sufficiently great other tree species may become associated with the dominant, resulting in a grading forest type between two associations; e.g., *E. camaldulensis* association in the watercourses, changes

through *E. camaldulensis* -- *E. leucoxylon* grading forest type of the lower valley slopes to *E. leucoxylon* association of the middle slopes.

The major forest types recognised, together with factors chiefly responsible for their maintenance, are set out in Table III. The factor chiefly responsible is the soil water content, which is only partially expressed in terms of annual rainfall. The occurrence of types is indicated on the vegetation map of the smaller area of 15,000 acres, and to a large extent on the balance of the area.

TABLE III
Associations and Forest Types

| | Associations | | Types |
|---|--------------|---|---|
| LOWLANDS— | | | |
| <i>E. oleosa</i> | | | |
| <i>E. transcontinentalis</i> | | | |
| <i>E. gracilis</i> | | | |
| <i>E. leptophylla</i> | | | |
| <i>E. fruticetorum</i> | | | |
| <i>E. dumosa</i> | | | |
| <i>E. viridis</i> | | | |
| <i>E. calycogona</i> | | | |
| <i>E. calcicultrix</i> | - | - | - |
| | | | <i>E. calcicultrix</i> - <i>E. camaldulensis</i> |
| | | | <i>E. calcicultrix</i> - <i>E. leucoxylon</i> |
| | | | <i>E. calcicultrix</i> - <i>E. transcontinentalis</i> |
| <i>E. odorata</i> var. <i>erythrandra</i> | | | <i>E. odorata</i> var. <i>erythrandra</i> - <i>E. microcarpa</i> |
| | | | <i>E. odorata</i> var. <i>erythrandra</i> - <i>E. microcarpa</i> - <i>E. leucoxylon</i> |
| | | | <i>E. odorata</i> var. <i>erythrandra</i> - <i>E. leucoxylon</i> - <i>E. microcarpa</i> |
| | | | — <i>E. camaldulensis</i> |
| <i>E. microcarpa</i> | - | - | - |
| | | | <i>E. microcarpa</i> - <i>E. odorata</i> var. <i>erythrandra</i> |
| | | | <i>E. microcarpa</i> - <i>E. leucoxylon</i> |
| | | | <i>E. microcarpa</i> - <i>E. leucoxylon</i> - <i>E. camaldulensis</i> |
| | | | <i>E. microcarpa</i> - <i>E. cladocalyx</i> |
| FOOTHILLS— | | | |
| <i>E. leucoxylon</i> | - | - | - |
| | | | <i>E. leucoxylon</i> - <i>E. transcontinentalis</i> |
| | | | <i>E. leucoxylon</i> - <i>E. microcarpa</i> |
| | | | <i>E. leucoxylon</i> - <i>E. elaeophora</i> |
| | | | <i>E. leucoxylon</i> - <i>E. cladocalyx</i> |
| | | | <i>E. leucoxylon</i> - <i>E. camaldulensis</i> |
| | | | <i>E. leucoxylon</i> - <i>E. calcicultrix</i> |
| | | | <i>E. leucoxylon</i> - <i>E. microcarpa</i> - <i>E. odorata</i> var. <i>erythrandra</i> |
| | | | — <i>E. camaldulensis</i> |
| UPPLANDS— | | | |
| <i>E. cladocalyx</i> | - | - | - |
| | | | <i>E. cladocalyx</i> - <i>E. microcarpa</i> |
| | | | <i>E. cladocalyx</i> - <i>E. leucoxylon</i> |
| | | | <i>E. cladocalyx</i> - <i>E. elaeophora</i> |
| <i>E. elaeophora</i> | - | * | - |
| | | | <i>E. elaeophora</i> - <i>E. leucoxylon</i> |
| | | | <i>E. elaeophora</i> - <i>E. cladocalyx</i> |
| | | | <i>E. elaeophora</i> - <i>E. camaldulensis</i> - <i>E. leucoxylon</i> |
| | | | <i>E. elaeophora</i> - Stunted <i>E. leucoxylon</i> |
| VALLEYS— | | | |
| <i>E. camaldulensis</i> | - | - | - |
| | | | <i>E. camaldulensis</i> - <i>E. leucoxylon</i> |
| | | | <i>E. camaldulensis</i> - <i>E. leucoxylon</i> - <i>E. microcarpa</i> |
| | | | <i>E. camaldulensis</i> - <i>E. cladocalyx</i> - <i>E. elaeophora</i> |
| | | | <i>E. camaldulensis</i> - <i>E. calcicultrix</i> |
| | | | <i>E. camaldulensis</i> - <i>Callitris propinqua</i> |

VEGETATION

NOMENCLATURE

Wood (19) summarised the terms and meanings and pointed out the confusion that exists, and then defined an *association* as a constant group of dominant species recurring in similar habitats, where the dominant species refer both to tree and undergrowth species which give the characteristic look or facies of the community. This definition of an association is adopted in this paper.

Associations may vary in floristic content and vegetative habit. When the variation takes place amongst the dominant tree species, then the variant community is a forest type, but when the dominant tree species are constant, but changes occur in the undergrowth, then the changed community comprises a society.

The development of closer subdivisions is the obvious step in the mapping of forests. This is brought about by the use of the concept of *forest types*.

Because this term has only recently been used in Australian ecological publications, a brief history of its origin will be given. Grisebach, in Germany in 1838, classified the plant communities and used the term "plant association." His usage of the term "plant association" is identical with the present usage of "forest type." Graves (8) in 1899 stated that, "If nature is left undisturbed, the same type of forest will tend to be produced on similar classes of situation and soil in a specified region. There will be variations within the type, but the characteristic features of the forest will remain constant, that is the predominant species, density, habit of tree, reproduction and character of undergrowth. 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, it will revert to the original form."

Ecological workers from 1920 onwards were active in Europe and often very detailed communities were described, but application of similar principles to Australian communities is unsatisfactory. Pidgeon (10), in 1937, was aware of the problems created by the frequent dominance of the genus *Eucalyptus* and grouped the communities for the coastal area of New South Wales as mixed *Eucalyptus* forest. She added detailed forest types in 1941 (11).

Foresters in vegetation surveys of Australia have, for a long time, probably since 1917, used a subdivisional system involving forest types, where a type is defined as a variation in the dominant stratum of the association. In this case there is no recognition of succession, associations, or smaller units, as the forest type is the only unit used.

The botanical mapping of forest types is carried out according to the floristic content of the dominant stratum, together with characters of habit and form, so that with field experience ocular estimates are all that are necessary in fixing the boundaries of any two adjacent types. For example, *E. camaldulensis* type, which is found along the watercourses, may give way to *E. leucoxylon* type on the middle slopes of the valley. There is, however, a zone of gradation (see Table IV) of varying width in which *E. camaldulensis* is more frequent than *E. leucoxylon*; climbing further up the slope, the two species intermingle and form the *E. leucoxylon* type. If the zone where the species are approximately equal in frequency is five chains wide, then it was mapped as the *E. leucoxylon - E. camaldulensis* type. If less than five chains wide, then notes were made on the map of the presence of other species, during the gradation from one community to another. It is not proposed to map the types of a further subdivision used in forest surveys, where the trees are classified as growing stock and the area is divided into open areas, regenerating areas with seedlings or coppice, saplings, poles, piles and finally stags or over-mature trees.

TABLE IV
Valley bottom to upper slopes

| Topographical position | Forest type: |
|-------------------------|--|
| Valley bottom | - - - - - <i>E. camaldulensis</i> |
| Lower slopes of valley | - - - - - <i>E. camaldulensis-E. leucoxylon</i> |
| Middle slopes of valley | - - - - - <i>E. leucoxylon</i> |
| Ridge tops | - - - - - <i>E. cladocalyx</i> or <i>E. cloeophora</i> |

It is evident that the boundaries of the types are not constant, as man in a short space of time has considerably altered them by burning, clearing, and by extensive exploitation of the trees. These alterations are shown by areas of regeneration with large stumps. The composition of an altered type may have been due to selective exploitation, and this change can be examined by identification of the stumps through the use of wood technology. In addition the environment slowly alters over a long period of time, and so growth adjustments are made by the residual types, either by changes in habit or composition.

To a large extent residual soil series are correlated with the nature of bedrock (see Table 1), as well as the effective rainfall. Inter-related correlations are frequent between soil types and plant types on a given area of 10,000 acres approximately. Some correlations are particularly stable, e.g., *E. transcontinentalis*, a mallee in this district, is always found on calcareous soils.

The factors determining the distribution of vegetation involve interrelations between soil fertility, rainfall and water-retaining capacity of the soil. A few vegetation societies and types are widely distributed over a variety of sites, so that the compensating factors are difficult to evaluate in the absence of further data, such as rainfall gaugings, soil surveys, frost incidence, and the effect of drought. An example is *Cullitris propinqua*, a widely occurring tree on soils with a quartzite bedrock, which may occur as a restricted forest type in the range country of Section 19, Hundred of Darling, or may form a forest type with *E. camaldulensis* bordering Mambray Creek, or occur as a member of the under-story in the *E. leucoxylon*, *E. microcarpa* and *E. calciculrix* associations.

FLORISTICS

Quick identification of the species, frequently from a distance up to 300 feet, is necessary to make the best use of the time available for mapping. The most convenient method in mapping the occurrence of species is to use a key based on field characters, as one based on the various organs would impede the rate of mapping.

It frequently happens that the usual heterogonic variations of a species are significantly different from the published description, which is often limited by incomplete examination of a species. Even so, the genus *Eucalyptus*, besides its numerous identified species and varieties, still seems capable of producing new forms. It is common knowledge that specific identification generally requires a comprehensive collection of correctly named specimens for comparison, for example, certain species like *E. hemiphloia*, have been recorded and denied by different botanists for South Australia. The following floristic difficulties were encountered: *E. jugalis*, a previously imperfectly known species in this State, is recorded in Blakely, but described by Maiden as a synonym of *E. leucoxylon* var. *pauperita*, which is definitely a different tree from *E. jugalis*. *E. leucoxylon* var. *pauperita*, if justified, is irregular in its occurrence, and is merely a depauperate

form of *E. leucoxylon* involving little constant botanical difference. The field characters of habit and form were insufficient to separate *E. microcarpa*, *E. albens* and *E. hemiphloia* from one another. The separation of a number of mallee species is difficult both in the field and the laboratory, for example, the difference between conical and rostrate-shaped opercula used to separate *E. oleosa* and *E. transcontinentalis*, between which gradations are found. *E. calcicultrix*, black mallee-box, was identified and is recorded in Blakely (2), but is omitted by Black (1). However, the two varieties recorded by Blakely were not located, and it is doubtful whether they occur in this area. The narrow-leaved peppermint is best named *E. odorata* var. *erythrandra*,⁽¹⁾ despite the rareness of red-flowering trees.

It seems certain that a detailed use of field ecology would strengthen and facilitate identification of the genus *Eucalyptus*. Throughout this paper the nomenclature of the genus *Eucalyptus* conforms to that of Blakely, and the other species to that of Black.

THE PLANT ASSOCIATIONS

Eight associations have been defined in the area. These are named from their dominants, formation, topography, soil type and rainfall characteristics, as set out in Table III.

E. calcicultrix Association

The description of *E. calcicultrix* is facilitated by the study of a large pure stand near Yatina in County Dalhousie. There it may be a small tree up to 25' high or a mallee with several stems arising from a common rootstock. The bark is greyish, somewhat flaky, and often with brownish stains caused by dust. The stem is generally less than 12" in diameter at 4' from the ground, but trees up to 20" in diameter with a height up to 30' occur along the Booleroo Creek near Booleroo. The crown is compact, rounded, pleasantly fresh-green and is often a shining green on a sunny day. The leaves have an obvious venation, the intra-marginal veins being very distinct, and when dried, the veins may stand out as ridges. The shape is ovate, acute and usually under 4" long, but a wide variation in shape and size has been observed. The buds mature in October, and early flowers are observed in October, whilst late ones may continue to February. The buds are typically stellate in arrangement, pedicellate, and are somewhat similar to those of *E. odorata* var. *erythrandra*. The matured capsules are held for at least one year, and the proportion of length to breadth is reasonably constant.

E. calcicultrix occurs as a pure stand in a few restricted areas near Quorn, but near Yatina there are at least 500 crowns per acre forming a thin canopy to the exclusion of any other tree except for a sporadic dryland ti-tree, *Acacia pubescens*. *Acacia Victoriae*, *Dodonaea attenuata*, and *Bursaria spinosa*, are the shrubs occasionally seen; *Zygophyllum crenatum*, *Zygophyllum* spp. are common herbs, while *Danthonia* spp. and *Stipa* spp. are the commonest grasses forming the partial ground cover.

E. calcicultrix is found in three vegetation types. One is a semi-arid mallee type, dominated by *E. transcontinentalis* - *E. calcicultrix*. This type has numerous shrubs, herbs and mat-like plants in the understory. This type is generally found on solonized brown soils and terra-roosas.

The *E. calcicultrix* - *E. leucoxylon* type is a savannah woodland in facies, although it contains numerous shrubs, herbs and ground cover plants in its under-

⁽¹⁾ Personal communication—N. T. Burbidge.

story. Here *E. leucoxylon* is at its limits of occurrence and has a dwarfed and defective form due to twists in the stem, and an unbalanced, wind-blown crown. Along the fertile banks of watercourses, in semi-arid country, *E. calcicultrix* is found associated with *E. camaldulensis* as a narrow fringing community. In general it occurs on areas with less rainfall than *E. odorata* var. *erythrandra* and the soils are predominantly solonized.

E. odorata var. *erythrandra* Association

This association is typical of the eastern limits of the lowlands, being found on the eastern hillocks and to the west of the eastern plain. To the east it grades into the mallee-box and mallee associations, and to the west into the *E. microcarpa* association through the *E. microcarpa*-*E. odorata* var. *erythrandra* forest type. This association occupies a similar ecological position to that of the *E. odorata* association in the foothills of the Mount Lofty Ranges. The tree is rather similar from a distance, having dark-grey, twisted, rough bark, often stained by exudations of kino. In height it may reach 45', with a bole up to 25' long, and is often 20" in diameter at 4' from ground level. The crown is thin, being composed of narrow lanceolate leaves up to 5" long, which are often pendant when the tree is growing on more favourable sites. The leaves are never a shining green but are usually dull or subglaucous, and so the crown has a similar dull appearance to that of *E. odorata*, but is thinner in density. Occasional saplings have erect leaves which gradually become depressed as the tree matures. Buds mature in autumn, early flowers may be seen in April, and late flowers in August. The buds have a wide range of shapes and lengths of pedicels, but the inflorescence is typically stellate with 6-7 buds. There is also a wide range of capsule sizes, but the proportion of length to width is reasonably constant. The matured capsules are held for less than one year.

In describing the appearance of the association, considerable difficulty exists in locating a compact area that has not been altered biotically. Just north of Melrose, and also near Yandiah, are two areas in which occur several hundred trees per acre. No doubt there are other isolated patches, but it is thought that the original density was much less, for at least half of the trees are of small diameter. It is therefore presumed that the association was a typical savannah woodland and had a similar facies to that of the *E. odorata* association. Geographically, it is believed that this association is the northern counterpart of the *E. odorata* association. It occurs on the Bundaleer Ranges far to the west of the area mapped, therefore no attempt has been made to define the limits of its occurrence. This association now consists of isolated patches along a few uncleared roads, and single trees left standing as the remnants of a once widespread association.

There is a widely spaced dominant with a few scattered shrubs, such as *Bursaria spinosa*, *Acacia armata*, *Acacia Victoriae* and *Acacia pycnantha*. Grasses form the bulk of the ground cover, and are mostly *Danthonia* spp. and *Themeda triandra*. Some annual species of *Stipa* are also found, together with many exotic grasses and annuals such as *Echium plantagineum* which covers thousands of acres.

This association contains two forest types, the *E. odorata* var. *erythrandra*-*E. microcarpa*, and the *E. odorata* var. *erythrandra*-*E. calcicultrix*. The former is found along the western boundary of the eastern plain, and the latter along the western margin of the coastal spur as well as on the northern and southern limits of the area mapped. It is also occasionally found with *E. camaldulensis*-*E. leucoxylon*, and *E. microcarpa*-*E. leucoxylon* types.

E. microcarpa Association

Grey-box is the common name given to *E. microcarpa*, and also to the very similar trees, *E. hemiphloia* and *E. albens*. While *E. microcarpa* forms an exclusive association and occurs as a pure stand over a large area, both the other species occur scattered with *E. microcarpa*. A small area of *E. hemiphloia* occurs due west of Murraytown, but *E. albens* occurs only as a mixed stand.

E. microcarpa is a tree often growing up to 70' in height, and useful trees may have a diameter of 36" four feet from ground level, although larger trees have been measured. The crown is not dense as the leaves are generally over 3" long, cockled and are dull green, sub-glaucous to glaucous. Much variation is therefore encountered in the colour of the leaves. The bark is characteristically grey to light-grey in colour, tightly plaited, and continuous even up to limbs only 4" in diameter. An occasional tree has smooth white upper bark. The buds and capsules are generally shortly pedicellate. The buds mature in February and early flowers appear in late February to March. Although cream-coloured flowers are general, two trees with pink flowers were recorded. *E. hemiphloia* has a capsule nearly twice the volume of *E. microcarpa* and *E. albens* has a capsule about twice the volume of *E. hemiphloia*. Buds of both the latter species mature earlier than those of *E. microcarpa*. In each species the timber is dense, hard, durable and nutty-brown in colour.

The association is a savannah woodland, but it is doubtful if any virgin areas are now in existence, as pit sawing, sleeper cutting, and clearing has taken place for a period of 80 years in this reasonably accessible forest. It seems certain that there were once 10-20 trees per acre over a grassy ground cover. On two occasions this association was found with a thin, incomplete canopy which was successful in crowding out all shrubs and the ground cover. This can be seen on the lower western slopes of Richman's Valley, and a limited area in the north-east of Section 9 in the Hundred of Darling. Occasional occurrences of shrubs such as *Bursaria spinosa*, *Acacia pycnantha*, *Acacia Victoriae*, *Acacia Wattiana*, and *Dodonaea attenuata* are to be observed. The grasses are numerous and are chiefly *Danthonia* spp. and *Stipa* spp. *Casuarina stricta* occurs on the more rocky sites with sporadic occurrences of *Callitris propinqua*.

On the western margin of its occurrence where it grades into the eucalypt associations of moister areas it forms forest types with *E. leucoxylon*, *E. camaldulensis*, *E. cladocalyx* or *E. elaeophora*. The number of trees per acre is generally over 400, and the understory is often shrubby when it occurs with *E. cladocalyx* or *E. elaeophora*.

On the drier margins near Yandiah it occurs with *E. odorata* var. *erythrandra*, and on other areas with *Casuarina stricta*. The former type has a similar understory to the pure *E. microcarpa* type, but the latter contains several societies. The most frequently occurring are the soft grasses, replaced by porcupine grass, *Triodia irritans*, which in turn is replaced by *Xanthorrhoea quadrangularis* and *Calythrix tetragona*.

Although the geographical occurrence of the box association has been mapped, considerable areas have been cleared which may amount to one-third of the original areas dominated by this tree. The northern limit of the association is in the vicinity of Mount Brown, and the southern limit near Wirrabara. This distance is about 50 miles with a width of 10 miles near Wirrabara, but the association does not extend over the crest of the coastal spur as has been reported by Robertson (13).

E. leucoxylon Association

Because *E. leucoxylon* is such an adaptable species, generalities are too broad

to convey precise information. In the larger subject area, it is the dominant of a degraded savannah woodland near Saltia where the mean annual rainfall is approximately 12". On the southern ridges of the Beetaloo Valley, where the mean annual rainfall is approximately 15", it forms a scrubby type with affinities to a mallee association on the one hand, and a savannah woodland on the other. *E. calciculrix* is present in equal numbers.

This association is at its best on the red-brown earths, with a moist climate, and on alluvial soils or terra-rossas with an even moister climate. There it may reach a height in excess of 80', with a clean straight bole of 40' to 8" top diameter and 30" diameter at 4' from the ground. This class of tree is generally free of dry rough bark, but as the climate becomes drier there is a tendency for dry rough bark to persist as a basal "stocking" of 6' in height, and may even clothe half the length of the bole. The smooth bark has a grey-white base with olive-green and slaty-blue streaks.

In the Range sections 4, 10, 11 and 19, Hundred of Darling, this species varies from a stunted tree of 25' in height to a tree of 65' in height, according to the suitability of the site. Here the bark markings are yellowish-green and sometimes almost orange in colour. Generally the leaves are dark shining green on both sides, the venation is obvious, and the length is 3"-8" with a corresponding range in width from .5-.8 of an inch. The buds are more uniform in size and shape than those collected from the Mount Lofty Ranges but agree in being restricted to the maximum of three per peduncle. The operculum is typically conical, but sometimes sub-rostrate. Buds mature in April and early flowers may be seen in April, but the flowering period is indefinite, being annually May to December. The fruit shows great variations in volume and shape and the valves are deeply enclosed in the larger fruits, but are shallow in the smaller fruits.

The association is typically a savannah woodland and exhibits an adaptability to environmental changes. It may have a dense sclerophyllous under-story in the high rainfall range areas, or a shrubby xerophytic under-story in the *E. leucoxylon*-*E. calciculrix* type on the outlying southern ridges of the Beetaloo Valley. Typically, the under-story consists of a ground cover of grasses with a few scattered shrubs such as *Bursaria spinosa*, *Acacia pycnantha*, and *Acacia Wattsiana*. Societies of *Acacia continua*-*Calythrix tetragona* occur in the ranges; *Acacia rupicola* in the *E. leucoxylon*-*E. microcarpa* forest type, and *Acacia brachybotrys* in the pure *E. leucoxylon* type on a terra-rossa in Section 1 B, Hundred of Howe.

The frequency of the dominants is much greater than in the original virgin areas. This is due to the stimulation of regeneration from the timber operations of 1870 to the present day. It is now common to see stands with 200 stems per acre, but it is thought that the original stands had only 20-30 trees per acre.

In the smaller subject area *E. leucoxylon* forms at least six types, one of which includes a mallee, *E. transcontinentalis*. The mallee association occupies limestone and calcareous ridges in the higher rainfall areas, and the areas are small and are usually islands or inliers in a savannah woodland formation. The under-story consists of numerous sclerophyllous shrubs and herbs, such as *Hibbertia sericea*, *Hibbertia acicularis*, *Hakea rugosa*, *Grevillea lavandulacea* and *Acrotriche* spp.

The *E. leucoxylon*-*E. microcarpa* type is a grading type between the *E. microcarpa* and the *E. leucoxylon* association. The under-story may be grasses on the more favourable sites nearer the *E. leucoxylon* association, or shrubs such as *Bursaria spinosa*, *Xanthorrhoea quadrangulata*, *Casuarina stricta* and *Triodia irritans* prominent on the less favourable sites.

The *E. leucoxylon* - *E. cladocalyx* and *E. leucoxylon* - *E. elaeophora* types may reach the status of a dry sclerophyll forest where a thin canopy partially shades the forest floor and the understory is a dense assemblage of sclerophyllous shrubs and herbs. These types are best seen on the coastal spur on areas receiving at least 24" mean annual rainfall. The understories are composed of *Calythrix* - *Xanthorrhoea* - *Cassinia complanata* society; the *Hakea ulicina* - *Hibbertia stricta* society and the *Acacia Wattsiana* society. There *Calythrix tetragona* and *Hibbertia stricta* may reach 8' and 6' in height respectively.

E. leucoxylon forms a forest type with *E. camaldulensis* on the broad valleys containing fertile red-brown earths, or alluvial soils receiving a rainfall of 20" plus. The understory is usually a grassy ground cover with scattered shrubs of *Bursaria spinosa* and *Acacia Wattsiana*. Some fine large trees occur in this forest type.

In semi-arid areas, *E. leucoxylon* manages to obtrude into the mallee areas. It may form a relatively pure type on red-brown soils as in the elevated Beautiful Valley, where the trees are several hundred to the acre, stunted and small with twisted defective stems. The understory is grassy, with a few herbs. On terra-rossas of the southern ridges of Beetaloo Valley, *E. leucoxylon* forms a type with *E. calcicultrix* over an understory of *Cassinia lacris*, *Bursaria spinosa*, *Xanthorrhoea quadrangularis*, *Pittosporum phyllyreoides* and *Lepidosperma* spp. The habit of *E. leucoxylon* shows gradual changes from the extreme of dwarfness in the above drought resistant type to the fine trees of the normal savannah woodland type. The understories also show changes in size of the species, floristic content and frequency.

The northern geographical range of the *E. leucoxylon* association is only partly shown on the vegetation map, as there are small islands north of Quorn in the vicinity of the Dutchman's Keel, and far on the eastern plain scattered remnants of islands are now marked by an occasional stump, or a scraggy windblown tree on the roadside. Generally it is not found on the coastal plain, but is found in valleys on the western side of the Beetaloo Valley throughout the coastal spur, as islands in the higher rainfall areas, and typically occupies the area between the *E. cladocalyx* association and the *E. microcarpa* association.

E. cladocalyx Association

Few large pure areas exist and the association extends from four miles north of the Hughes Gap road to Port Pirie to as far north as the Dutchman's Keel, just a few miles north-west of Quorn. It is typical of the uplands, rarely descending below the 1,000' contour, and is generally found on the exposed quartzite ridge-tops, but occasionally occurs on limestone ridgetops in the Beetaloo Catchment area.

At its best *E. cladocalyx* is a handsome tree, having a clean, yellowish-brown, smooth barked bole with a striking, small, dark-green compact crown perched on the ends of the branches. The bole reaches 70' in length to the first branch with a total height of 120' and diameters of 72" have been recorded four feet from ground level. Botanically, it is well figured in the "Forest Flora of South Australia" by J. E. Brown (3).

On areas near the limit of its occurrence which receive approximately 18" mean annual rainfall, the association is savannah woodland in formation. This formation grades into the complex dry sclerophyll formation as the rainfall increases.

E. microcarpa or *E. leucoxylon* are frequently found associated with *E. cladocalyx* in the savannah woodland formation. In these types the dominants are widely spaced, usually less than 60 trees per acre, but the regeneration may increase the number of stems to over 100 per acre.

As is to be expected in an association with this range of environment, a number of societies are found in the understory. The sub-humid *E. cladocalyx*–*E. microcarpa* type has an understory of grass cover with occasional shrubs.

The *E. cladocalyx*–*E. leucoxylon* type has a similar understory, but in moister localities the understory may contain numerous shrubs to form societies of *Acacia Wattsiiana* or *Cassinia complanata* and grass, or *Triodia* spp., *Lomandra* spp. and grasses on podsols.

In cooler, moister localities islands of pure *E. cladocalyx* may occur, and these may extend over an area of up to 300 acres of adjacent uplands and valleys. The understory grades into a dense assemblage of shrubs in which three common societies are seen. The *Acacia Wattsiiana* society forms a dense, bushy, exclusive society which may be difficult to penetrate. *Calythrix tetragona*–*Xanthorrhoea quadrangulata*–*Cassinia complanata* also form a dense society which may be difficult to penetrate. *Hakea ulicina*–*Hibbertia stricta*–*Casuarina Muellerina* comprise a society on extremely infertile exposed skeletal soils of the range sections 4, 8, 10 and 19 in the Hundred of Darling. Small areas of *Triodia* spp. were also seen. These understories are also found in the *E. elaeophora* association.

Associated plants are trees, *Callitris propinqua*, *Casuarina stricta*, *Exocarpus sparteo*, and *Exocarpus cupressiformis*. Shrubs are *Acacia continua*, *Acacia rupicola*, *Acacia pycnantha*, and in watercourses, *Acacia iteaphylla*, *Acacia calanafolia* and *Callistemon rugulosus*. Other common shrubs are *Daviesia ulicina*, *Daviesia corymbosa*, *Hakea rugosa*, *Grevillea lavandulacea*, *Callistemon teretifolius* and *Euxtaenia microphylla*. The commonest herbs are *Hibbertia sericea*, *Hibbertia acicularis*, *Astrolobium humifusum*, *Acrotriche* spp. and *Goodenia pinnatifida*. The rush, *Lepidosperma semiteres*, may sometimes form small exclusive societies on exposed skeletal soils.

On the coastal spur *Casuarina stricta* is often the dominant tree on southern aspects, and *Callitris propinqua* on the northern aspects. Water plants, geophytes and grasses are scarce, and only occasional *Danthonia* spp. and orchids were seen.

The pure *E. cladocalyx* association grades into the pure *E. elaeophora* association through the *E. cladocalyx*–*E. elaeophora* type.

E. elaeophora Association

This association occupies a greater area of the highlands than the *E. cladocalyx* association, and occurs as a pure association, exceeding 4,000 acres in area. It tends to replace *E. cladocalyx* on the wetter sites, and may continue along the banks of watercourses to intrude into the *E. camaldulensis* savannah woodland formation in Section 9, Hundred of Darling, and Section 3, Hundred of Howe.

E. elaeophora has a rough, persistent, scaly bark which is continuous to the smaller branches. The tree is not impressive in habit, top height being generally under 40'. The stem is frequently forked and the branches twisted, bowed and bearing a thin crown. This tree habit is typical of the frosty, wet highlands with infertile skeletal soils. In the protected fertile valleys it may reach a top height of 50' and be 40" in diameter at four feet from the ground. Botanically, it agrees with the description in Blakely (2).

All the eucalypt species found on the uplands form forest types with *E. elaeophora* and are associated with shrubby understories similar in composition to those found in the *E. cladocalyx* association as previously described. The understory at its most complex development closely resembles some of the understories of the dry sclerophyll formation dominated by *E. obliqua* in the Mount

Lofty Ranges. Notable differences are the absences of *Pultenaea* spp., *Leptospermum* spp., *Banksia* spp., *Pteridium aquilinum*, and *Ixodia achilleoides*. The nearest *E. obliqua* association is distant, being near Clare, where there are several thousand acres.

Geographically, *E. elaeophora* does not extend north of Mount Brown, while its southerly limit is 6-7 miles north of the Hughes Gap Road to Port Pirie. Typically, it is found on the highlands and may reach an altitude of over 3,000'.

E. camaldulensis Association

As is usual, this association is found on fertile soils with an adequate water supply. Such areas are the banks of watercourses, and the nearby plains which are subject to periodical flooding. In semi-arid to arid areas *E. camaldulensis* grows in the watercourses, and as it stretches for many miles across otherwise treeless country, it forms unique ribbon-like communities. This feature is vividly shown on the vegetation map.

The tree has a smooth bark with a dull grey-white to light grey base colour, relieved by patches of light-grey, white, light-yellowish-orange colours. Sometimes there are only a few markings, but generally they are more numerous after the spring and summer rains when decortication takes place. The crown is dense and luxuriant, being dull green and occasionally bronze in colour. Heights up to 120' have been recorded with diameters of 13' at four feet from ground level. Botanically, it agrees with the description in Blakely (2). Generally the buds have a rostrate operculum, but some with a conical-shaped operculum were found along the watercourses in arid areas. Robertson (13) makes some pertinent remarks on the variation of bud shapes in relation to geographical occurrence. In this area the buds mature in late autumn to spring, early flowers appear in October, and late flowers in February and March. The capsules are usually in the lower size range as given in Blakely.

The association in its pure state is a savannah woodland having a few widely spaced trees over a ground cover of grasses with an occasional shrub and herb, but when exploitation of the mature trees has been carried out, regeneration may be so dense that the crowns may form a thin canopy. The shrubs are *Acacia Victoriae*, *Acacia rupicola*, *Acacia Wuttsiana* and *Bursaria spinosa*. On the mallee plains limited areas of *Callitris praeingua* mixed with *E. camaldulensis* are found, as at Mambray Creek on the coastal plain. In watercourses in the highlands *Casuarina stricta* may be found associated with *E. camaldulensis*, and along the deep gorge bottoms societies of *Acacia iteaphylla*, *Acacia calamifolia*, or *Callistemon rugulosus* are found.

E. leucoxylon is frequently found with *E. camaldulensis*, and this type occupies similar sites as the *E. leucoxylon*-*E. camaldulensis* type. It also has a similar understory. Dense societies of *Acacia Wuttsiana* or *Acacia rupicola* may be found in the understory over a ground cover of grasses.

Along the valleys of the Ippinitchie and White Park Creeks limited areas are seen where *E. microcarpu* has become associated with *E. camaldulensis*-*E. leucoxylon* type. In the frosty, wetter valleys of the eastern slopes of the coastal spur, both *E. cladocalyx* and *E. elaeophora* are found associated with *E. camaldulensis*. Here the understory is usually denser, and is typically composed of thickets of *Acacia Wuttsiana*. A small area of *Banksia marginata* in tree form is found in this type in Section 4, Hundred of Darling. Thickets of *Casuarina stricta* frequently occur on either aspect of the steep rocky slopes of skeletal soils. Geographically, its occurrence is unique in being closely correlated with the presence of watercourses.

SUMMARY

This paper contains a description of the environment of County Frome, an area of 650,000 acres. The main topographical feature is the coastal spur of the Flinders Ranges with its associated foothills. The spur has a marked influence on the climate, as the high rainfall areas are closely associated with it and the rainfall decreases on areas a few miles distant from it. The six soil series are derived from Pre-Cambrian rocks. Those of the higher rainfall areas are mainly podsols and skeletal soils, supporting sclerophyll forests, while several soil series are represented on areas with an intermediate rainfall which generally support a savannah woodland, and on the drier areas are redearths and solonized brown soils supporting mallee formations.

Eight vegetation associations were mapped, representing three vegetation formations. Each association contains several types, where a type is defined as a community which varies from the pure association in floristic content or in habit. The types were mapped on an area of 15,000 acres in the Hundred of Darling.

ACKNOWLEDGMENTS

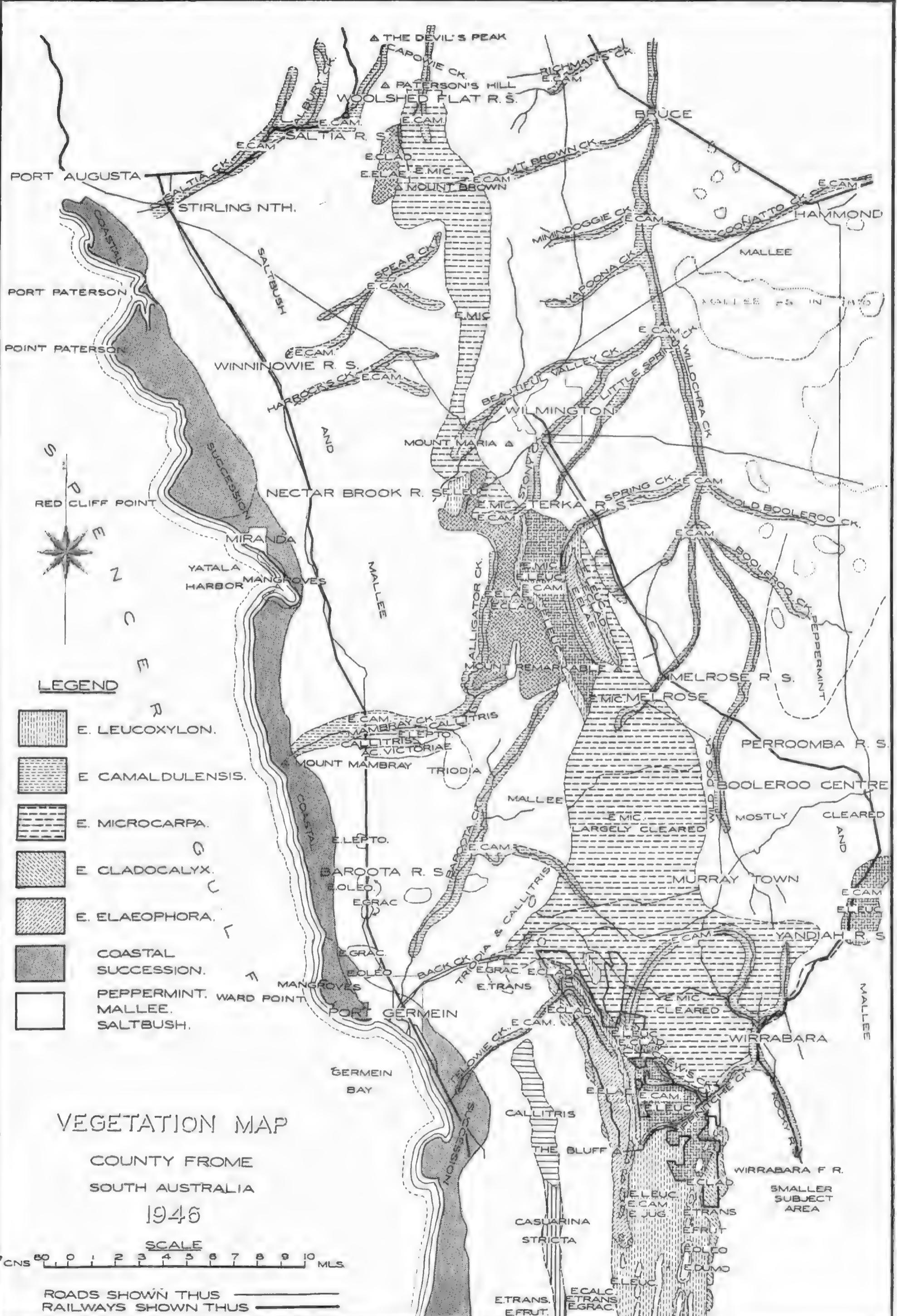
My thanks are due to Prof. J. G. Wood, Messrs. R. W. Segnit, V. M. Healy, C. B. Kay, C. G. Stephens and P. B. Casson for constructive criticism and suggestions. To many of the stations owners, my thanks are due for permission to use their rainfall gaugings, and it is with gratitude that I thank Miss N. T. Burbidge of the C.S.I.R. for help in the complicated task of identification of species, and Mr. C. Scarfe, apiarist, for his co-operation by carrying out the transport in this vast relatively unmapped area. The Librarian of the Commonwealth Forestry Bureau kindly supplied references to term "forest type."

The map draughting was carried out by W. J. Tedmanson.

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Eucalyptus hemiphloia, savannah woodland association, Melrose



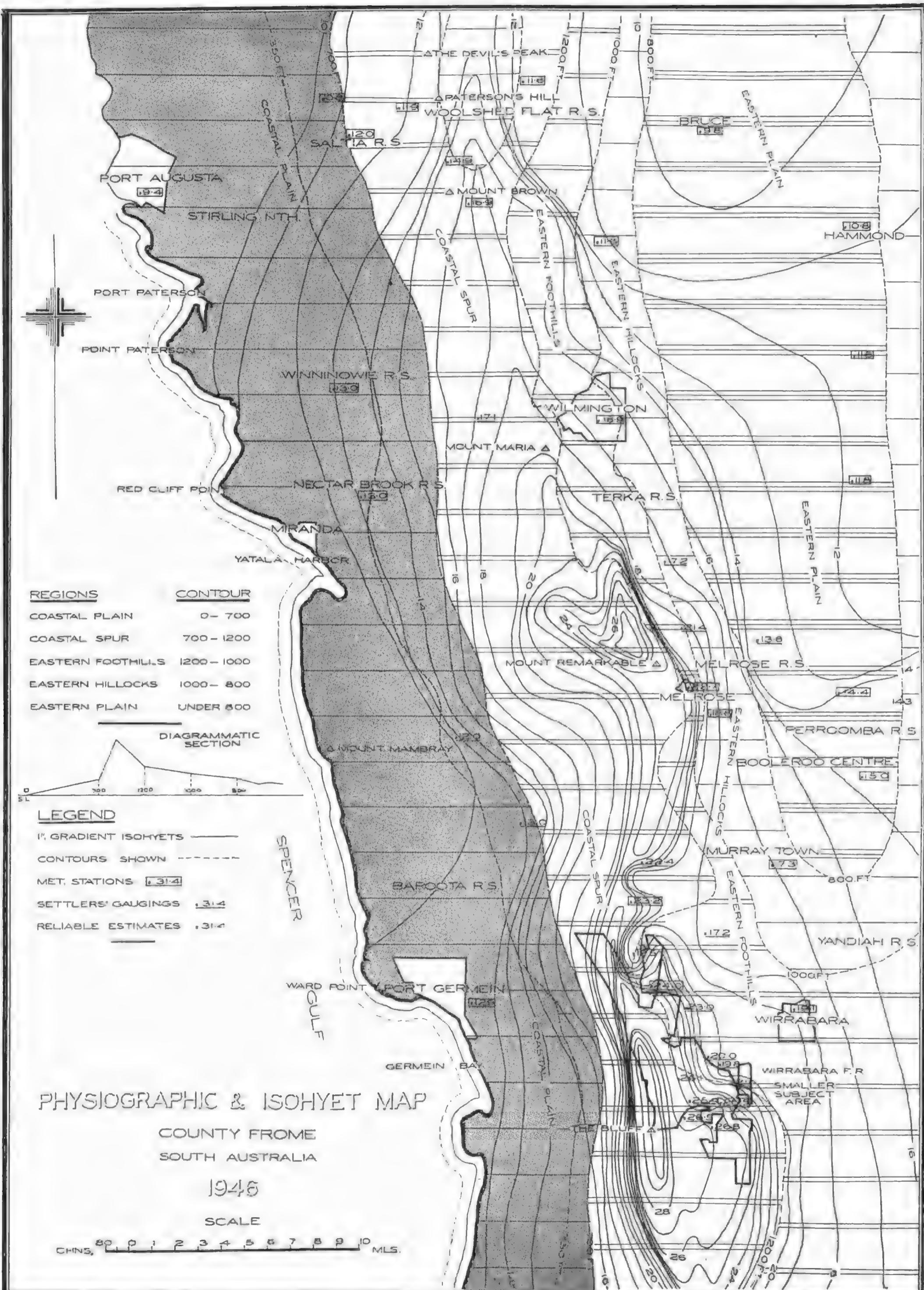
E. clivicola, dry sclerophyll forest, Flinders Range



Eucalyptus cladocalyx, savannah woodland association, Melrose



Eucalyptus camaldulensis association, showing mature trees in the foreground, poles in the background with *Callitris prepinqua*.



BARIUM-RICH APLITIC GNEISSES OF BROKEN HILL

BY D. MAWSON AND E. R. SEGNOT

Summary

Herein is described in some detail the unique occurrence of barium-rich, aplitic schliers in the early Precambrian, granitic, flaser-gneisses in the neighbourhood of Broken Hill. Their occurrence was first recorded some 24 years ago by E. C. Andrews in his memoir on the Geology of the Broken Hill District. In an appendix to that volume W. R. Browne makes special reference to these barytic gneisses. He states on page 337: "A remarkable rock type was found in a few places in the vicinity of Broken Hill, which appears to be unique in petrology. It was first observed as a dyke-like intrusion into the Hanging Wall Augen Gneiss some distance south of the Municipal Abattoirs, in fact at the most southerly extremity of the Augen Gneiss. Later on a precisely similar rock (B222) was found near the western margin of the Platy Gneiss just north of the De Bavay shear zone, and what appear to be allied types occur elsewhere in the Platy Gneiss, as on top of the hill in M.L.75."

BARIUM-RICH APLITIC GNEISSES OF BROKEN HILL

By D. MAWSON and E. R. SEGNIK

[Read 8 August 1946]

CONTENTS

INTRODUCTORY REMARKS

Herein is described in some detail the unique occurrence of barium-rich, aplitic schliers in the early Precambrian, granitic, flaser-gneisses in the neighbourhood of Broken Hill. Their occurrence was first recorded some 24 years ago by E. C. Andrews in his memoir on the Geology of the Broken Hill District. In an appendix to that volume W. R. Browne makes special reference to these barytic gneisses. He states on page 337: "A remarkable rock type was found in a few places in the vicinity of Broken Hill, which appears to be unique in petrology. It was first observed as a dyke-like intrusion into the Hanging Wall Augen Gneiss some distance south of the Municipal Abattoirs, in fact at the most southerly extremity of the Augen Gneiss. Later on a precisely similar rock [B222] was found near the western margin of the Platy Gneiss just north of the De Bavay shear zone, and what appear to be allied types occur elsewhere in the Platy Gneiss, as on top of the hill in M.L. 75."

An analysis by H. P. White (Mines Department) of this type of rock from the De Bavay shear zone is given. This is quoted in our table on pp. 280-281. Browne concludes his account by stating:

"This rock appears, in its barium content, to be quite unique among silicate rocks. It seems most reasonable to suppose that the barium is contained in the feldspar, but a calculation shows that there is not enough alumina present in the rock to satisfy the feldspar formula, assuming all the barium and lime to be present in this mineral. The latter must remain unexplained for the present.

"As regards the affinities of the rock little can be said with certainty. The dykes are apparently intrusive into the gneiss and are sometimes pretty closely associated with gabbros. It was thought from the field occurrence, together with the microscope characteristics, that the feldspar rock might be of the nature of an anorthosite derived from the gabbro magma, but there is no certain proof that this is so."

Some years later S. R. Nockolds and E. G. Zies petrologically examined a specimen catalogued as [B222] and believed it to be the same as that collected from the De Bavay shear zone locality, which had been analysed by H. P. White, as quoted in Browne's petrological report.

The contribution of these authors to the problem is of a very high order of merit. They concluded that the barium is included in the plagioclase—a new barium plagioclase which they refer to as "a barium anenousite or, more appropriately, a barium anorthite."

They state, however, that "the barium content in our analyses of the feldspar shows a large discrepancy when compared with that found for the rock as a whole in the analyses made by H. P. White. On the other hand, there does not seem to be a sufficient quantity of any other mineral in the rock to bring the total up, even if we assume the mineral in the rock to be rich in barium."

Nockolds and Zies went further with the enquiry, and then stated: "Finally, our analysis shows an amount of BaO comparable with the hypothesis that it is all in the feldspar, whereas White's analysis demands the presence of another barium-bearing mineral which, if it carries the same percentage as feldspar, should be almost as abundant. It is thus possible that the rock varies in composition and that another barium-bearing mineral such as sanbornite was present in the sample analysed by White."

During a visit to Broken Hill, eight years ago, one of us examined the areas remarked upon by Browne. The occurrence south of the old Municipal Abattoirs site appeared to be of special interest. Of specimens collected, one was kindly examined for BaO content by R. G. Thomas (University of Adelaide; now C.S.I.R. Geochemical Laboratory) and found to contain 13.7% BaO. From this rock, by a bromiform separation, Mr. Thomas then isolated the feldspars. The mixed feldspars thus separated were found to contain 19.50% BaO.

At this stage the problem had become a very interesting one, consequently it was decided to prosecute it further. It was obvious that there was no uniformity in the mineral composition of the various outcrops of these aplitic barytic gneisses; more especially it was clear that the rock analysed by White was not identical with that examined by Nockolds and Zies.

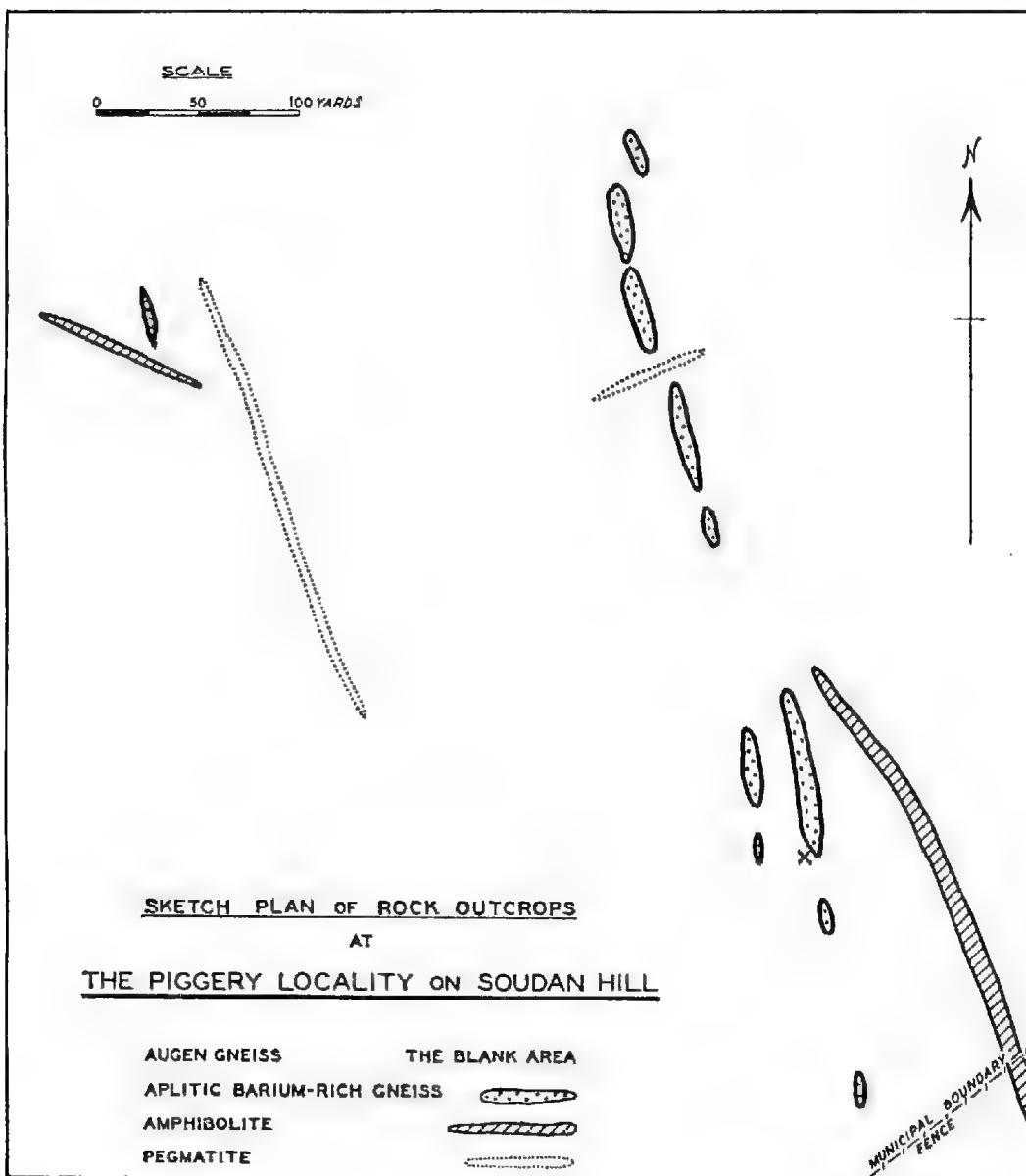
In the prosecution of this investigation the nature of the barium feldspars proved so interesting that one of us has already published (Segnit, 1946) a separate report on them.

THE PIGGERY LOCALITY

The area mentioned by Browne as south of the old Municipal Abattoirs was found to be by far the most interesting and important. The general locality is known as Soudan Hill; this is indicated on Andrews' map where he shows a large area of Augen and Platy Gneiss near the southern boundary of which are, on the southern slopes of the hill, two patches marked "barium," roughly indicating the whereabouts of the barytic aplite; outcrops of amphibolite are also shown.

We include herewith, below, a more detailed sketch map of the immediate area, including the barytic aplitic schliers. A location where specimens especially rich in BaO were obtained is marked with a cross on the plan.

The barium-rich schliers are irregular in width, ranging from a few inches to a few feet in thickness. The broken nature of the outcrop, as shown in the



plan, is due partly to sand and soil covering sections of the outcrop, and partly to the irregular distribution of the rock itself.

The aplitic gneiss being distinctly lighter in colour than the general gneiss of the locality readily catches the eye, and can be traced following along in general accord with the schistosity of the flaser-gneiss.

Light-coloured phases of the gneiss are not always notably barytic. When they are barytic, however, the nature of the weathered surface is usually a very good indication of the probable richness in BaO of the rock. The feldspars rich in barium are more easily eroded, mainly by corrosion, than normal feldspars. Their presence is indicated, therefore, when the exposed surface of the rock shows pitting or smooth corrosion features. When present embedded in a mass of the feldspathic material, quartz and usually also amphibole stand up in positive relief. This is the one helpful criterion in the field in attempting to locate barium-rich schliers in the gneiss.

The barytic aplitic phase of the gneiss appears to be distributed, in part at least, along special shear zones in the flaser-gneiss. In some places it passes rather abruptly into the normal flaser-gneiss with very low BaO content. In other cases examined there is a progressive transition both in general physical appearance and in BaO content from the richly-barytic, aplitic variety to the normal flaser-gneiss.

THE NATURE OF THE GNEISS IN WHICH THE BARYTIC SCHLIERs OCCUR

W. R. Browne, who has dealt petrographically with the rock formations surrounding Broken Hill, refers to extensive occurrences of rather similar gneisses extending with the trend of the country and outcropping both to the east and to the west of the great Broken Hill ore body. He distinguishes in the field three variations of this type of rock referred to respectively as the Hanging-Wall-Gneiss, the Platy Gneiss and the Augen Gneiss. These three forms he regards as nothing more nor less than phases in the crystallization of an original igneous magma. He further states "that the augen gneiss and the platy gneiss are igneous is beyond question."

Our own observations suggest that in some areas these gneisses may be sheared migmatites; they are traversed occasionally by fine-grained granitic rocks which exhibit comparatively little evidence of structural orientation.

Brown quotes chemical analyses of these granitic gneisses. The mean of three examples typical of the foot-wall and Potosi-Gneiss is given in column IV of the table on pp. 280-281. The mean of the Augen-Gneiss and the Platy-Gneiss is stated in column V of the same table. Both of the above types are potash granites, the former with a leaning towards granodiorite. Variations of these gneisses, collected adjacent to the Broken Hill ore body were reported upon by F. L. Stillwell; these are more granodioritic, as will be seen by reference to column VI of the table of analyses, where a mean of four such examples is given.

In dealing with this class of Gneiss as the host of the aplitic schliers, we refer to it herein as a sheared or flaser-gneiss.

| | I | II | III | IV | V | VI | VII | VIII |
|--------------------------------|-------|-------|-------|-------|-------|-------|------|------|
| SiO ₂ | 49.10 | 55.12 | 68.97 | 66.04 | 72.04 | 69.29 | 35.1 | 42.0 |
| Al ₂ O ₃ | 25.43 | 20.72 | 16.45 | 14.37 | 13.47 | 15.73 | 26.8 | 25.8 |
| Fe ₂ O ₃ | 0.04 | 0.75 | 0.36 | 1.28 | 1.00 | 1.64 | — | — |
| FeO | 0.19 | 0.36 | 3.38 | 5.59 | 2.61 | 3.80 | — | — |
| MgO | — | — | 1.00 | 0.85 | 0.75 | 1.42 | — | — |
| CaO | 7.65 | 10.08 | 4.32 | 2.71 | 1.30 | 3.21 | — | 4.0 |
| Na ₂ O | 1.68 | 1.13 | 3.14 | 1.79 | 2.46 | 1.56 | — | 0.3 |
| K ₂ O | 0.73 | 0.39 | 1.28 | 4.85 | 4.92 | 2.03 | 2.3 | 1.4 |
| H ₂ O+ | 0.35 | 1.36 | 0.40 | 1.06 | 0.84 | 0.12 | — | — |
| H ₂ O- | 0.08 | 0.22 | 0.20 | 0.14 | 0.18 | 0.48 | — | — |

| | I | II | III | IV | V | VI | VII | VIII |
|-------------------------------|---------------|----------------|--------|--------|---------|--------|-------|------|
| CO ₂ | — | — | tr | — | 0·01 | 0·01 | 0·08 | — |
| TiO ₂ | 0·17 | 0·65 | 0·10 | 0·65 | 0·36 | 0·64 | — | — |
| ZrO ₂ | — | a | — | a | a | — | — | — |
| P ₂ O ₅ | 0·06 | 0·25 | 0·26 | 0·19 | 0·11 | — | — | — |
| SO ₃ | — | a | — | a | a | — | — | — |
| Cl | 0·04 | a | 0·06 | tr | tr | — | — | — |
| S | 0·04 | a | 0·01 | a | a | — | — | — |
| MnO | 0·005 | tr | 0·03 | 0·28 | 0·03 | 0·20 | — | — |
| BaO | 14·72 | 9·23 | 0·09 | 0·10 | 0·03 | — | 35·8 | 25·8 |
| SrO | — | tr | — | tr | tr | — | — | — |
| Less O for S & Cl | 100·28 ·02 | 100·26* ·02 | 100·05 | 99·91† | 100·11‡ | 100·20 | 100·0 | 99·3 |
| Total | 100·26 | 100·26 | 100·03 | 99·91 | 100·11 | 100·20 | 100·0 | 99·3 |
| Sp. Gr. | — | 2·887 | — | 2·806 | 2·694 | — | — | — |

* F, Cr₂O₃, NiO, Li₂O, V₂O₅ and CuO absent. † Cr₂O₃, NiO, Li₂O, and V₂O₅ absent

‡ Cr₂O₃, NiO, and V₂O₅ absent; Li₂O trace.

- I. Barium-rich gneiss [5081] from The Piggery, Broken Hill (N.S.W.). Analysed by E. R. Segnit.
- II. Barium-rich gneiss [B 222] from the western margin of the platy-gneiss just north of the De Bavay shear zone, Broken Hill (N.S.W.). Analysed by H. P. White; quoted by Dr. W. R. Browne.
- III. The Haser-gneiss [5083] adjacent to the aplitic barium-rich schliers, at The Piggery, Broken Hill. Analysed by E. R. Segnit.
- IV. The foot-wall- and potosi-gneiss, Broken Hill; the mean of three analyses, numbers 1, 3 and 4, of the table quoted by W. R. Browne.
- V. The augen-gneiss and platy-gneiss, Broken Hill; the mean of two analyses, numbers 2 and 3 of the table quoted by W. R. Browne.
- VI. The augen- and platy-gneiss adjacent to the Broken Hill lode; the mean of four analyses quoted by Dr. F. L. Stillwell.
- VII. Celsian of rock [5081 A] calculated to 100% after eliminating contaminating plagioclase. Analysed by E. R. Segnit (1946).
- VIII. Calciocelsian mechanically separated from rock [5081]. Analysed by E. R. Segnit (1946).

PETROGRAPHY OF THE FLASER-GNEISS OF THE PIGGERY LOCALITY

Quartz-feldspar-biotite flaser-gneiss [5083] is a good example of the general type of gneiss enclosing the aplitic barytic schliers at the Piggery locality. The specimen was collected about six feet from a barytic schlier. The schistosity is strongly defined by the orientation of biotite-rich tracts and intervening quartz-feldspathic streaks and lenticular patches. In some portions of the outcrop typical augen are developed. Its chemical character is illustrated by an analysis made by one of us as stated in the table on pp. 280-281.

In the microscope slide the quartz is seen to be in irregular grains up to 5 mm. in length, elongated parallel to the direction of foliation of the rock. The larger individuals usually exhibit undulose extinction. Solid, liquid and gaseous inclusions are plentiful.

The feldspar is almost entirely plagioclase. It has a tendency to appear in lens-shaped masses, one or two centimetres in length, composed of smaller equi-

granular individuals averaging about 1 mm. diameter. These plagioclase grains exhibit albite, and occasionally pericline and Carlsbad twinning. In a small degree, sericitization is evidenced in some instances. The optical characters of this plagioclase are: $2V = 89^\circ$; sign, negative; $X' \wedge 1010$ max.) = 18° . Thus it is an andesine of composition $An_{36}Ab_{64}$.

Biotite is abundantly represented in the slides of this rock, appearing usually as lens-shaped aggregates parallel to the foliation. The small flakes of biotite tend to accord with the foliation but may lie in any direction. In size individual flakes rarely exceed 1 mm. x 0·5 mm. It is a dark variety with strong pleochroism. X = pale yellow-brown, Y = Z = deep red-brown.

A little black iron-ore, apatite and zircon are present as accessories. The latter is usually included in the biotite and exhibits pleochroic haloes.

The granodioritic character of this gneiss is borne out by the analysis which shows it to be related more nearly to the augen- and platy-gneisses recorded by Stillwell from locations adjacent to the Broken Hill Lode than to those recorded by Browne from elsewhere in the district (see table, pp. 280-281). It is probable that the relative abundance of orthoclase and plagioclase in these gneisses varies considerably even in neighbouring areas. However, we have established that the gneiss at the Piggery adjacent to the barium-rich rocks is granodioritic in character. It will be observed that the barium content, namely $BaO = 0\cdot09\%$, is notable, but probably not much greater than is normal in such rocks.

Another example of the flaser-gneiss, rock [5930], collected some 20 yards from [5083], exhibits marked augen-structure. It occasionally encloses streaks, mainly composed of garnet and biotite.

A further example is rock [5932], resembling [5083]. It was collected within 4 feet of a barytic schlier. This is found to contain 0·29% BaO, which is a notable increase on that of [5083].

PETROGRAPHY OF THE BARIUM-RICH AFLITIC GNEISSES

A petrological study of specimens from the various outcrops indicates that, when considering the barium minerals contained therein, the barytic-gneisses of the locality naturally fall into the following three groups:

- I. Those containing 8% to 15% of BaO. In these the barium minerals are chiefly celsian and calciocelsian. In exceptional cases rocks containing celsian or calciocelsian from this locality may contain a yet lower BaO content.
- II. Those containing 4% to 7% BaO. The barium mineral in these is chiefly hyalophane.
- III. Those with lower amounts of BaO. In these the barium is taken up in the structure of the plagioclase.

GROUP I

Herein comprised are light-coloured gneisses, bearing only a small amount of dark ferromagnesian constituents, which may be either hornblende or biotite. The BaO content in these ranges from 8·04% in [5948] to 14·72% in [5081].

Rocks [5080] and [5081] were collected from the same spot marked A on the plan (p. 279) and differ only in that [5080] contains even less ferromagnesian constituent than [5081]. There are occasional streaks of black biotite along the shear planes of the gneiss. Elsewhere the rock presents a white alabaster-like appearance. The former, [5080], was found to contain 12·65% BaO, while the

latter, [5081], carries the record amount of 14.72% BaO. The feldspars of the weathered surface of these rocks exhibit corrosion effects, indicating that they weather more readily than normal feldspars. A petrological description of [5081] will suffice to illustrate the character of both specimens.

Calciocelsian-bytownite-quartz-biotite-gneisses

Rock [5081] is mainly an equigranular mass of feldspar with subordinate quartz and a small but variable amount of biotite which is directed in conformity with the foliation of the adjacent gneisses.

The feldspars which constitute about 85% of the rock are of two distinct varieties. These two feldspars govern the structure of the rock, forming an equigranular mass, the individual crystal grains having rough irregular boundaries. The average grain size is of the order of 0.5 mm.

The more abundant of these feldspars is a variety of celsian, containing about 4% CaO. The composition and optical properties of this variety distinguished as calciocelsian have been described elsewhere by one of us (Segnit). It now suffices to mention only that in thin section, it is quite clear and untwinned, rarely showing cleavages and determined only with difficulty by subjecting to both chemical and optical investigations, a heavy-mineral fraction separated from a crushed sample of the rock.

The second variety of feldspar is a plagioclase, frequently twinned on one or both of the albite or pericline laws. Examples of other twin laws were sought, but not found. Except when twinned this feldspar cannot be distinguished at sight from the calciocelsian. Its ascertained characters are $2V = 80^\circ$; sign, negative; extinction angle $X' \wedge 010$ in section normal to $001 = 45^\circ$; these are the characters of a bytownite of composition $Ab_{18}An_{81}$.

Quartz occurs in rather smaller grains than the feldspar; these are frequently rounded. The norm indicates its presence to the extent of about 10%.

The biotite is the common red-brown variety; strongly pleochroic $X =$ pale straw colour, $Y = Z =$ dark red-brown. It most commonly forms clusters of small flakes, with which are associated the bulk of the accessory minerals. These comprise sphene, ilmenite, zircon, apatite and a little muscovite and orthite. Some of the ilmenite is replaced by fine granular sphene, and in these cases expansion resulting therefrom has developed a system of radial cracks in the surrounding feldspar. Similar radial cracks mantle the grains of orthite.

The chemical analysis of silicate rocks with so high a barium content presents features requiring special attention and method, otherwise the barium recorded may be grossly in error. Irregularities arising during the analysis of these barium-rich rocks and minerals caused one of us (Segnit, 1946) to publish a short note on methods to be adopted to ensure accuracy in such determinations.

A chemical analysis of [5081] is given in the table on pp. 280-281, which is approximately equivalent to the following percentage (weight) composition: Celsian 35.6, orthoclase 3.9, albite 13.8, anorthite 37.0, quartz 9.0, apatite 0.3, black iron ores (ilmenite and magnetite) 0.4. No pyrite is visible in the rock. It is likely that the sulphur and the excess chlorine are present as adventitious traces of chloride and sulphate from the seepage of surface water into the rock outcrop.

Rock [5939] contains 9.39% BaO. It is a light-coloured gneiss streaked with only a very little coloured mineral, biotite. The weathered surface is corroded, rendering obvious a small amount of quartz raised in positive relief.

In microscope slide, calciocelsian is observed to be the principal mineral, with which is associated some quartz irregularly distributed. Red-brown biotite is fairly plentiful, and in places is seen to be changing its character with the liberation of colourless dust-like sphene. In view of the fact that so much of the barium is not acid soluble, it is probable that hyalophane is also present.

Of the accessory minerals clove-brown sphene is abundant; in some cases the sphene has a core of black iron-ore, probably ilmenite. Colourless apatite is not an uncommon constituent.

Calciocelsian-bytownite-quartz-hornblende-gneisses

Other rocks of this group, but containing hornblende as the ferromagnesian mineral, are [5944], [5941], [5942], and [5948]. These are generally similar to the foregoing but carry hornblende which stands in relief on the weathered surface in streaks and lenticles up to 3 cm. long, parallel to the foliation. Tiny pink garnets also may be present.

Rock [5944], which is representative of the others, will be considered at some length. The face of the hand-specimen is corroded by weathering and exhibits a streaked gneissic appearance.

A microscopic examination reveals that feldspar, the chief mineral, forms granular aggregates of interlocking individuals of very irregular outline. The BaO content of this rock was found to be 10.88% and it is almost completely acid soluble, as in rock [5081]. This suggests the presence of a barium feldspar like that of the latter rock, but no distinction can be made by optical means between any of the feldspars of the slide except that a few show fine multiple twinning. Most of the untwinned feldspar, like the calcicelsian of [5081], shows little or no cleavage. On this evidence the feldspars present are considered to be similar to those in rock [5081], namely calcicelsian and plagioclase.

Further investigation by chemical means is limited by the interlocking granular and sieve structure of the rock being such that effective separation of the constituent minerals by mechanical means is almost impossible. Very little twinning of the feldspars is observable in the slide. Sections showing one or two good cleavages were examined on the Universal-Stage. These proved to be plagioclase of negative sign and $2V = 85^\circ$, indicating $Ab_{20}An_{80}$ bytownite. This finding was verified by the position of the 001 cleavage pole when superimposed on Emmon's graphs.

The quartz occurs in large irregular crystal grains included in the feldspar.

The hornblende is strongly pleochroic. Its characters are: $2V = 79^\circ$, sign, negative; $Z \wedge c = 18^\circ$; pleochroism, X = very pale green, Y = green, Z = blue-green. The hornblende individuals lie athwart the foliae of the rock. They often contain patches of dark inclusions, which appear to be the relics of original biotite from which the hornblende has been formed. Dark brown haloes are developed around small included crystals of zircon and orthite. The apatite also gives rise to less pronounced haloes.

Of accessory minerals, brown pleochroic sphene is the most notable constituent. Orthite is common; it is always altered, expansion during the process causing radial cracks in the enveloping feldspar and hornblende. Apatite and zircon are less common.

Zoisite, secondarily developed, occurs as small crystal grains scattered irregularly through the rock. Garnet appears occasionally as larger subhedral crystals.

Rock [5491] contains 11.21% BaO. It is rich in calcicelsian. Quite rarely scraps of primary white mica appear. Grains of brown sphene are plentiful. Secondary zoisite is fairly abundant and there is some clinzozoisite.

Ruck [5942] contains 11.18% BaO. Calciocelesian and plagioclase are the principal constituents, but quartz grains are in notable quantity. Brown sphene and a little garnet are the most obvious accessories, while apatite and zircon are also present.

Rock [5943] has a mineral constitution similar to [5944], though containing somewhat less celsian. In it, however, there is a well-developed augen structure as in the general gneiss of the locality.

Rock [5948] contains 8.04% BaO. It is very light-coloured with occasional faint streaks of dark amphibole. Microscopic investigation shows that the abundant calciocelesian and plagioclase have undergone mechanical shattering and are presented as fine granules. The amphibole, present in the slide as individuals up to 1.75 mm. in length, has rather unusual pleochroic colours, namely yellow, yellowish-green and yellowish-blue. Sphene in fragments up to 1.5 mm. long is plentiful. Odd apatites up to 1.5 mm. in length and occasional crystals of faintly pink garnet up to 0.5 mm. diameter are to be observed.

Celsian-bytownite-quartz-hornblende-gneisses

Rock [5081A] exhibits flat gneissic banding in the hand-specimen and contains 11.79% BaO. Though generally similar in outward appearance to the foregoing, it differs therefrom in that it contains ordinary celsian.

Viewed under the microscope it is seen to be an even-grained rock, of grain-size about 0.2 mm. Feldspar constitutes 85 to 90% of the rock, the other 10 to 15% being chiefly quartz and hornblende. The two feldspars present, plagioclase and celsian, are both quite unaltered and practically indistinguishable in a cursory microscopical examination.

The plagioclase, though rarely twinned, is found conforming to the albite and pericline laws. The optic axial angle ($2V$) is 82° and the sign is negative; this, together with the high extinction angles of the albite twins, indicates a bytownite of composition $\text{Ab}_{18}\text{An}_{82}$.

The celsian is perfectly clear and untwinned. It commonly exhibits two perfect cleavages at 90° . The optical properties are: $2V = 88^\circ$; sign, negative; R.I. $a = 1.579$, $b = 1.583$; $c = 1.588$; $Z \wedge a = 28^\circ$; $Y = b$. During the examination of the slide on the universal-stage, about one crystal in three was found to be celsian. This amount would account for the total BaO content of the rock.

The hornblende, which is concentrated along gneissic bands in the rock, is a green variety with strong pleochroism; X = pale greenish-yellow, Y = dark green, Z = blue-green.

Accessory minerals are plentiful. They include epidote, sphene, garnet, apatite, zircon, orthite, chlorite, biotite and muscovite.

Rock [5937] contains 4.54% of BaO, practically all of which is acid soluble; it is therefore present as celsian or calciocelesian. The barium content is lower than usual for rock of this locality bearing such minerals. This is to be explained by the greater abundance of quartz and amphibole with reduction in the feldspar content. The ferro-magnesian mineral is hornblende, the presence of which renders more obvious the gneissic character of the rock.

Rock [5933] is a granular mass mainly of small equigranular particles but includes some larger straggling grains of quartz. Sieve structure is well evidenced, especially in the case of the garnet.

The minerals present are chiefly feldspars of which celsian is much in evidence, and there is very little ordinary plagioclase. Hyalophane appears also to

be present. Quartz is the next most abundant constituent but is mainly in large irregular masses, though small grains are infrequently met with among the granular feldspars. Bluish-green amphibole is the principal coloured constituent, though scraps of biotite are in evidence.

Light pink garnet is a rather abundant accessory and apatite is present in quite notable amount. Original ilmenite has changed to granular sphene and some magnetite. Orthite occurs sparingly in very tiny grains.

GROUP II

The barium-rich gneisses of this group contain from 4 to 7% BaO. In these, hyalophane is the chief barium-containing mineral. Rocks [5945] and [5938] fall into this group.

Aplitic hyalophane-bytownite-mica-gneiss

Rock [5945] contains 7.06% BaO. It is a grey, fine and even-grained rock traversed by occasional white veins 3 or 4 mm. wide. The weathered surface exhibits smooth areas, the result of corrosion. It is composed almost entirely of feldspar of which there are two varieties, namely plagioclase and hyalophane, present in about equal amounts.

In microscopic examination, the plagioclase is observed to form comparatively large irregular individuals (up to 1.5 mm. in length) in which are abundant inclusions. Some degree of secondary change is evidenced which has resulted in the development of an opaque white alteration product. Twinning is not common nor is it clearly shown; but a high extinction angle in albite twins is indicated. This, combined with a $2V$ of -87° , indicates that the composition is about $\text{Ab}_{30}\text{An}_{70}$.

The hyalophane forms a much finer equigranular aggregate among the larger plagioclase. The average grain-size is about 0.2 mm. It is clear, rarely twinned or cleaved and presents an appearance very like that of quartz. The D.R. is low, $2V = -76^\circ$, and the R.I. is about 1.54. Most of the crystals exhibit minor zoning phenomena. Early in its investigation, the fact that the barium in this rock is not present in the form of celsian was demonstrated by the fact that it cannot be extracted by acid.

The rest of the rock is made up of small flakes of muscovite and biotite, together with occasional crystals of apatite, sphene, zircon and black iron-ore.

The white veins obvious in the hand-specimen appear to be the channels along which alteration has taken place. The material of these veins is characterised by a relative abundance of the white opaque alteration product of the plagioclase.

Aplitic hyalophane-labradorite-quartz-gneiss

Rock [5938] contains 4.64% BaO. It is rather different from the preceding in that it is porcelain-white in colour and contains dark specks and grains of black iron-ore. However, the bulk of the rock is constituted of plagioclase, quartz and hyalophane.

Microscopic observations show the plagioclase to be well twinned on the albite law, the maximum symmetrical extinction angle ($X' \wedge O10$) being 45° , indicating a composition $\text{Ab}_{75}\text{An}_{25}$; this is closely in accord with that indicated by the optic axial angle determined as -88° .

The hyalophane is untwinned and can be distinguished from the quartz by a slight difference in relief and by the fact that perthitic intergrowths are not uncommonly to be seen growing into the edges of the crystals, which are up to 1 mm. in diameter. The optic axial angle $2V$ is -77° , which, according to

Winchell, indicates a composition of about $\text{Or}_{75}\text{An}_{25}$. Quartz, containing abundant inclusions, is plentiful, while the only other accessory constituents are ilmenite and sphene.

Group III

Rocks of this group have a BaO content of less than 3% and generally less than 2%. Here the quantity of barium present is so small that it has been taken into the plagioclase framework, thus presenting barium-plagioclases. Rocks [5936], [5080A], [5934] and [5935] are of this group.

Barium-plagioclase-quartz-hornblende-gneisses

Rock [5936] contains 2.22% BaO, and is light grey streaked with a moderate amount of dark amphibole.

Under the microscope the average grain-size is observed to be about 0.75 mm. Feldspar and quartz, the former predominating, are the main constituents. Brown sphene is abundant, as well as smaller amounts of ilmenite, hornblende, biotite, chlorite and epidote.

The plagioclase is well twinned on both the albite and pericline laws. It has the following optical characters: $2V = 89^\circ$; sign, negative; $X' \wedge 010$ (max.) $= 45^\circ$. The composition thus indicated, respectively by the $2V$ value and by the extinction angle, is $\text{Ab}_{25}\text{An}_{75}$ and $\text{Ab}_{10}\text{An}_{71}$. This variation is probably due to instrumental error, rather than the effect of the barium content: ([5080A] shows no such variation). The plagioclase is quite unaltered, occurring in anhedral crystals which show a tendency to elongation parallel to the gneissic foliation of the rock.

The quartz contains an abundance of minute inclusions, imparting to it a cloudy appearance. It frequently appears as large individuals, markedly elongated in the direction of foliation. One such crystal observed measures 5.5 mm. by 1.5 mm. It also appears as small rounded grains distributed through the feldspar.

Rock [5080A], which contains 1.44% BaO, is similar to the foregoing but differs in several respects. The feldspar is cloudy, due, partly to alteration products, partly to inclusions. Its optical characters are: $2V = 86^\circ$; sign, negative; $X' \wedge 010$ (max.) $= 45^\circ$. In the case of normal plagioclase these figures would indicate a composition $\text{Ab}_{25}\text{An}_{75}$.

Quartz is a little more abundant than in rock [5936], but the chief difference is in the accessories. Of these latter sphene, biotite and hornblende are rare; muscovite and black iron-ore are more common.

Rock [5934] is somewhat similar in appearance to [5938] but contains only 0.80% BaO. In microscope section it differs only in a relative paucity of quartz and in the nature of the accessory minerals. Of the latter the most important is ilmenite, which appears in small grains surrounded by light-coloured granular sphene. Rutile occurs in the centre of some of the larger grains of ilmenite. Other accessory minerals present include zircon, muscovite, clinozoisite, orthite and apatite.

The feldspar is generally twinned but albite and pericline types only are present. The optical character are: $2V = 85\frac{1}{2}^\circ$; sign, negative, $X' \wedge 010$ (normal to 001) $= 41^\circ$. Thus it is a bytownite containing 2 or 3% of the celsian molecule. Referred to the plagioclase series it approximates to $\text{Ab}_{26}\text{An}_{80}$.

Barytic bytownite-quartz-biotite-gneiss

Containing 0.62% BaO, rock [5935] differs from the three preceding rocks in being of finer grain (average about 0.3 mm.). It is a light grey, even, fine-

grained rock. The weathered surface is fairly smooth but the feldspars are not so depressed by corrosion as is usual in the high-barium rocks of the locality.

It is made up chiefly of feldspar, which appears as irregular grains with sutured boundaries. Twinning is mainly a fine albite type, but is rare. The value of $2V$ is -80° , indicating a bytownite (containing, of course, a little BaO) of composition about $\text{Ab}_{12}\text{An}_{68}$. There is a patchy distribution of fine, irregular, sieve-like intergrowths of quartz and feldspar.

Quartz is not very abundant. Of the minor constituents sphene is again notable; biotite is present in small amount, but hornblende is absent; a little apatite, orthite, zircon and black iron-ore are present.

PETROGRAPHY OF THE AMPHIBOLITES OF THE PIGGERY LOCALITY

Amphibolite [5082] is a rather typical example of the outcrop just east of the main barytic belt. It is an even, medium-grained, very dark grey to black, foliated rock found to contain 0·04% BaO. In the hand-specimen there is a strongly marked schistose arrangement of the amphibole.

About half the area of the slide is feldspar; the rest is chiefly amphibole and pyroxene, the former predominating. Just a little quartz is also present.

Plagioclase is in compact grains mostly under 0·5 mm. diameter. It is usually twinned rather coarsely on the albite law; also ala A and ala B twinning are to be observed. No example of pericline twinning is observable in the slide. Optical determinations gave $2V = 85^\circ$; sign, negative; $X' \wedge 010$ (normal to 001) $= 40^\circ$. The feldspar is thus a bytownite of composition $\text{Ab}_{18}\text{An}_{22}$.

The amphibole and pyroxene form somewhat larger and more irregular crystals than the plagioclase. They are evenly distributed throughout the rock. The amphibole is a light brown variety with the following optical characters: $2V = 85^\circ$; sign, negative; D.R. $= 0\cdot022$; $Z \wedge c = 17\frac{1}{2}^\circ$. Pleochroism X = nearly colourless, Y = Z = light brown. Small zircons are sometimes included and these have developed dark green pleochroic haloes.

The pyroxene is colourless or cloudy in section; it has a high R.L., giving it a marked relief. Optical characters determined are $2V = 56^\circ$; sign, positive; D.R. $= 0\cdot022$; $Z \wedge c = 40^\circ$. There is evidence that in part at least this pyroxene has been made over to the amphibole.

There is present accessory black iron-ore, probably ilmenite, surrounded by colourless granular sphene.

Rock [5946] appears, in the hand-specimen, to be a variant of [5082]. It contains a small proportion only of plagioclase whose composition is $\text{Ab}_{15}\text{An}_{55}$. It is constituted of about 75% of amphibole. In this rock the breakdown of the brown hornblende to actinolitic amphibole has proceeded very far, so that only cores of the original mineral are to be observed.

Amphibolite [5079] is another modification of [5082] and is much finer in grain. Colour, dark grey. The BaO content is 0·09. There is no obvious schistosity in the hand-specimen. Relict structure discernible suggests that it is the metamorphic equivalent of an original basic gabbro. Microscopic examination reveals that the plagioclase is very similar to that of rock [5082]. Its optical properties were found to be $2V = 80^\circ$; sign, negative; $X' \wedge 010$ (normal 001) $= 42^\circ$; thus it is a bytownite of composition $\text{Ab}_{14}\text{An}_{56}$. Twinning is chiefly on the albite law, rarely on pericline and ala laws.

The amphibole is in large connected aggregates of very small individuals. It appears to have originated from the breaking down of the brown amphibole

which is to be seen in process of alteration in rocks [5946] and [5947]. This secondary amphibole is a pale green actinolite with the following characters: $2V = 82^\circ$; sign, negative; $Z \wedge c = 20^\circ$ (approx.). Pleochroism: $X =$ colourless; $Y = Z =$ pale green.

Garnet is present in very abundant small rounded crystals, scattered chiefly through the amphibole. Magnetite, chlorite and a little apatite are also present.

Rock [5947], collected 50 yards east of the main barytic schlier, is a type intermediate between [5079] and [5082]. It is similar in appearance to the latter but contains no pyroxene. The amphibole is present in two forms, of which the brown variety represented in [5082] is most abundant. In places the margins of the latter are seen to be changing over to a colourless to pale amphibole of the nature of tremolite or light-coloured actinolite comparable to that in rock [5079]. Plagioclase is less abundant than in the earlier described amphibolites.

Rock [5951] is a very fine-grained black variety occurring to the north-west of the barytic area. In the microscope slide it is seen to have a relic dolerite structure but original pyroxene has been entirely converted to actinolitic amphibole with pleochroism: yellow, yellow-green and blue-green. Original ilmenite has been converted to sphene and magnetite.

THE DE BAVAY FAULT ZONE LOCALITY

Though not exhaustively examined we succeeded in locating in this neighbourhood only limited outcrops of barytic gneiss, none of which proved to be as rich in BaO as some of those from the Piggery. Further, it is to be noted that none of our samples from this area was found to contain as much barium as that collected by the N.S.W. Mines Department and analysed by H. P. White.

There is here a wide outcrop of flaser-gneiss with occasional aplitic schliers, one at least of which carries a notable barium content. Amphibolites cutting the gneiss are again met with; also towards the eastern side of the area there are local narrow outcrops of an epidote, clinozoisite rock. The latter appear to have been derived from an original basic igneous rock. Petrological notes on these various types are as follows.

Quartz-Feldspathic Rocks containing Barium

Included here are [5957], [5959], [5956] and [5958] collected in the southern section of Mineral Lease 134.

Rock [5957], which contains 0·68% BaO, is a light to medium grey and moderately coarse-grained flaser type of gneiss consisting largely of quartz and feldspar with a notable development of biotite. The latter appears mainly along definite foliae, and the rock itself has a tendency to split along these planes.

It is variable in grain-size but chiefly constituted of equigranular feldspar and quartz of about 0·4 mm. diameter; exceptional grains both of quartz and of feldspar may reach to 6 or 7 mm. in length. The feldspar is frequently twinned on both the albite and pericline laws. It has an optic axial angle of 80° and negative sign; thus it is an $Ab_{13}An_{47}$ bytownite containing a little barium.

The biotite is strongly pleochroic with $X =$ light yellow-brown, $Y = Z =$ dark brown. Accessories are rather plentiful. Small grains of an epidote mineral are most common, but there are present also a little apatite, chlorite, muscovite and black iron-ore.

Rock [5959], containing 0·64% BaO, is very fine-grained and darker coloured than the preceding. It exhibits schistose structure and, like the fore-

going, is composed of quartz, feldspar and biotite, with the feldspar rather less plentiful than in the case of rock [5957]. The grains are roughly equidimensional with an average size of about 0.22 mm. While the quartz is clear and free from inclusions, the feldspar encloses abundant particles of biotite, apatite and epidote. The feldspar is a barium-containing $\text{Ab}_{26}\text{An}_{14}$ bytownite ($2V = 87^\circ$). The biotite is similar to that in rock [5957] but is more abundant, often in clusters of small flakes.

Rock [5956] contains 2.24% BaO. This is a light-coloured gneiss, studded with dark spots of actinolitic amphibole and specks of brown sphene, often strung out in the direction of schistosity.

In microscope slide the rock is seen to be mainly constituted of basic plagioclase, evidently carrying some celsian molecule and quartz. There is also a little yellow to yellow-green actinolitic amphibole which usually exhibits sieve structure and is associated with clinozoisite. Small grains of brown sphene are abundant, but biotite, garnet, apatite and ilmenite are present in very small amount.

Rock [5958] is akin to [5957]. The weathered surface exhibits corrosion pitting. It is mainly composed of quartz and basic plagioclase (probably barytic), the latter predominating. Yellowish-brown biotite is not uncommon. Amphibole in bluish-green laths is quite rare. Apatite and minute zircons are present. Tiny granules of zoisite riddle some areas of the slide and grains of epidote are widely distributed.

Amphibolites

There are in this locality also some amphibolite intrusions. Examples were collected near the south-west corner of Mineral Lease 134. Of these rock [5953] is a coarse-grained variety with a marked schistose structure. Some 75% of its bulk is hornblende. X = light brownish-yellow, Y = Z = olive-green. The plagioclase is an $\text{Ab}_{25}\text{An}_{75}$ bytownite. Accessories are biotite, apatite and black iron-ore all in very small amount.

Rock [5954] is a dark, very fine and even-grained variety penetrated by a mining shaft on the western side of the area. In addition to basic plagioclase there is much red-brown biotite. Magnetite and sphene are abundant, while apatite and faintly pink garnet are a minor feature. This rock appears to be a meta-basalt.

Epidote-Clinospisite Rocks

These were collected in Mineral Lease 109 and occur in narrow formations and local patches in the eastern portion of the area examined.

Rock [5964] is light grey and of high specific gravity for normal silicate rocks. It was found to contain 0.16% BaO.

Microscopically examined it is an even and fine-grained (0.3 mm.) rock, composed of mineral grains exhibiting little tendency to develop crystal outlines. There is present, but in subordinate amount only, a finely twinned basic plagioclase which, however, in some areas has undergone considerable alteration with the development of coarse sericite.

Epidote minerals are very abundant and are present in two forms which are indistinguishable in ordinary light. Optic axial angle measurements were made on a number of these, with the result that both epidote of $2V = (-) 82^\circ$ and clinozoisite of $2V = (+) 82\frac{1}{2}^\circ$ were found to be present, each in relatively large amounts. This is further indicated by the fact that many crystals show a high D.R. and others show anomalous blue tints.

Rounded grains of light brown sphene are quite common. Also black iron-ore and chlorite are present.

Rock [5961] is very light grey and fine-grained. In microscope slide it is found to be composed almost entirely of zoisite. Very small amounts of quartz, sericite and chlorite are present.

Rock [5963] is an even, fine-grained, zoisite-clinozoisite-hornblende-plagioclase variety. It bleaches to a very light grey colour in the more highly zoisitised areas, contrasting strongly with the darker colour of the original rock.

SUMMARY OF DISTRIBUTION OF BARIUM IN THE ROCKS

The average barium content of the Earth's crust is given (Clark) as 0·05%. An overall average in the case of first-class analyses listed by Washington recording BaO is approximately 0·10%. In the case of normal basic rocks the BaO content averages about 0·03%, but some groups of basic composition average as high as 0·06%. Average granites contain about 0·08% BaO, but an aplitic granite group listed by Washington contains an average of 0·12%. Washington records aplites containing as much as 0·30% and quotes an alaskite porphyry as containing 0·60%. Furthermore, magmas of some localities may be exceptionally rich in barium; for instance a group of alaskites from Yellowstone average 0·28%.

Of the rhyolites and granitic rocks of South Australia that have been analysed for BaO, the average is low, only about 0·05%. A surprising case is an albitite from Miltalie (see Jack, 1914), which is stated to contain 2·04% BaO. The aplitic granites of the Giant's Head locality, Umberatana, South Australia, recently analysed have no appreciable BaO content. In the case of melaphyres and amphibolites, several examples from South Australia average 0·05%.

In relation to the above it is interesting to make a comparison with the barium content of rocks from the Piggery and De Bavay Shear Zone localities of Broken Hill and of rocks associated therewith.

The average BaO content, based on published analyses (see p. 280-281) of the associated Broken Hill rocks works out at 0·10% in the case of the Foot-Wall and Potosi Gneiss and 0·03% in the case of the Augen- and Platy-Gneiss.

The table on p. 292 summarises the barium content of rocks collected by us from the barium-rich outcrops and in their immediate vicinity. The exact localities of all the rocks specified by numbers were entered upon a sketch plan which, unfortunately, was subsequently lost. However, it can be stated that those from the Piggery locality, except representatives of the general flaser-gneiss, the amphibolites and the pegmatite were taken at regular intervals throughout the full extent of the outcrops of the aplitic barytic gneiss, and therefore give a good general idea of the degree of variation both in barium content and petrological character of the entire formation.

It will be observed that whereas very high barium values were obtained in the case of aplitic phases of the flaser-gneiss, a normal flaser-gneiss collected near the barytic aplitic bodies at the Piggery was found to contain only 0·09% BaO, and even less where further away; a sample collected nearer to the barytic aplite contains 0·29% BaO. The amphibolites of the Piggery locality have a BaO content ranging from 0·04% to 0·09%.

The feldspar of a coarse granitic pegmatite which intersects both the barium-rich aplitic gneiss and the general flaser-gneiss, was found to contain 0·28% BaO.

BARIUM CONTENT OF ROCKS FROM THE PIGGERY AND DE BAVAY
FAULT ZONE

| Rock Number | BaO content: | | Type of Rock |
|----------------|---------------------|----------------------------|---|
| | percentage Total | percentage Acid Soluble | |
| 5079 | 0.09 | 0.08 | Amphibolite |
| 5080 | 12.65 | 11.9 | Aplitic calciocelsian-bytownite-quartz-gneiss |
| 5080A | 1.44 | 0.66 | Barium-plagioclase-quartz-hornblende-gneiss |
| 5081 | 14.72 | 12.9 | Calciocelsian-quartz-biotite-gneiss |
| 5081A | 11.79 | 11.1 | Celsian-bytownite-quartz-hornblende-gneiss |
| 5082 | 0.04 | — | Amphiholite |
| 5083 | 0.09 | — | Flaser-gneiss |
| 5930 | 0.04 | — | Augen-gneiss |
| 5932 | 0.29 | — | Flaser-gneiss |
| 5933 | 10.03 | 5.1 | Celsian-plagioclase-quartz-hornblende-garnet-gneiss |
| 5934 | 0.80 | 0.32 | Barium-plagioclase-quartz-hornblende-gneiss |
| 5935 | 0.62 | 0.53 | Barytic bytownite-quartz-biotite-gneiss |
| 5936 | 2.22 | 1.8 | Barium-plagioclase-quartz-hornblende-gneiss |
| 5937 | 4.00 | — | Celsian-bytownite-quartz-hornblende-gneiss |
| 5938 | 4.64 | 1.4 | Aplitic hyalophane-labradorite-quartz-gneiss |
| 5939 | 9.39 | 4.9 | Calciocelsian-bytownite-quartz-biotite-gneiss |
| 5941 | 11.21 | 10.5 | Calciocelsian-bytownite-quartz-biotite-gneiss |
| 5942 | 11.18 | 9.4 | Calciocelsian-bytownite-quartz-biotite-garnet-gneiss |
| 5944 | 10.88 | 10.8 | Calciocelsian-bytownite-quartz-hornblende-gneiss |
| 5945 | 7.06 | 0.96 | Aplitic hyalophane-bytownite-mica-gneiss |
| 5948 | 8.04 | 7.00 | Calciocelsian-bytownite-quartz-hornblende-gneiss |
| 5950 | 0.16 | — | Aplitic labradorite-quartz-gneiss |
| 5952 | 4.08 | — | Calciocelsian-bytownite-quartz-mica-schist |
| 5956 | 2.24 | 0.60 | Barium plagioclase-hornblende-quartz-clinzoisite-gneiss |
| 5957 | 0.68 | 0.59 | Barytic flaser-gneiss |
| 5959 | 0.64 | — | Bytownite-quartz-biotite-gneiss |
| 5964 | 0.16 | — | Epidote-clinozoisite rock |
| | 0.28 | — | Feldspar of pegmatite cutting the flaser-gneiss |

The barium-rich aplitic rocks of Broken Hill, in part at least, appear to occupy minor shear zones and were probably introduced as late crystallising fraction of the granodioritic magma of the area.

Both the aplitic schliers and the general body of the gneiss appear to have undergone an equal amount of shearing, though in the case of the aplitic rock evidence of foliation shows up less in the hand-specimen owing to the comparative absence of directed particles of coloured constituents.

Amphibolites at the Piggery locality cut across the direction of foliation of the acid gneisses. They contain only a normal quantity of barium. Thus we have no evidence that the barium-rich schliers bear any genetic relationship to the amphibolites.

On the other hand, analyses of the granitic gneisses of the neighbourhood of Broken Hill show, in almost all cases, an appreciable amount of barium. A segregation vein in the Foot-Wall-Gneiss of the Zinc Corporation Mine is reported (Browne) to contain 0.17% BaO.

We found that while the normal augen-gneiss [5930] of the Piggery locality collected some distance from the barytic schliers contains only 0.04% BaO, the corresponding flaser-gneiss [5083] collected 6 feet away contained 0.09% BaO, while at 4 feet away [5932] it contained 0.29% BaO.

Specimens [5952] and [5937], recorded in the field as transitions in type between the enclosing gneiss and the aplitic gneiss of the barytic schliers, were found to contain respectively 4·08% and 4·00% BaO thus supporting the contention that they are, chemically as well as physically, transition types. The margins of the schliers were found to be lower in barium than the central areas.

Usually the more aplitic phases of the gneiss contain a higher barium content, but this is not always the case, for [5080] (12·65% BaO) and [5080A] (1·44% BaO) are both markedly wanting in ferro-magnesium minerals.

The evidence obtained is strongly in favour of the schliers originating as a derivative of the granitic magma rather than genetically connected with the amphibolites.

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A FOSSIL SOIL FROM KANGAROO ISLAND, SOUTH AUSTRALIA

BY K. H. NORTHCOTE

Summary

In the course of the field operations of the Division of Soils, C.S.I.R., on Kangaroo Island, South Australia, during 1945, a soil belonging to a monotype series, named the Eleanor Sand, proved to be of special interest both because of the morphology of its profile and because of its relationship to the other soils of the Island. It is of interest not only to the pedologist and geologist but also to the agriculturist in considering soil fertility problems.

A FOSSIL SOIL FROM KANGAROO ISLAND, SOUTH AUSTRALIA

By K. H. NORTHCOTE⁽¹⁾ (Communicated by J. A. Prescott)

[Read 8 August 1946]

In the course of the field operations of the Division of Soils, C.S.I.R., on Kangaroo Island, South Australia, during 1945, a soil belonging to a monotype series, named the *Eleanor Sand*, proved to be of special interest both because of the morphology of its profile and because of its relationship to the other soils of the Island. It is of interest not only to the pedologist and geologist but also to the agriculturist in considering soil fertility problems.

In this paper the topographical and vegetational associations, the morphology of the profile and the origin of the *Eleanor Sand* are discussed.

The *Eleanor Sand*, typically, occurs on small, slightly elevated portions of the lateritic plateau country of Kangaroo Island. These slightly elevated portions of the plateau have suffered only a minimum of the natural erosion endured by the plateau as a whole. From evidence brought forward it will be seen that these areas represent remnants of the original plateau country.

The vegetation association typical of this sand is dominated by a dwarfed form of *Eucalyptus Baxteri* (stringybark). This association, because of the open spacing of *E. Baxteri*, presents a peculiar physiognomy which is in striking contrast to the taller, closely grouped stringybark, *E. Baxteri-E. obliqua* associations of the main plateau soils. *Leptospermum myrsinoides* (tea-tree), *Adenanthes sericea* and *Platylobium obtusangulum* commonly occur, but are only rarely found on the main areas of the plateau soils.

Table I gives the detailed morphology of a typical profile of the sand.

TABLE I
Detailed Morphology of the *Eleanor Sand* Profile

| | | |
|--------|--|---|
| 0-3" | A 0-1 | Grey fine sand with some organic matter. |
| 3-7" | A2 | Light grey fine sand, main root zone. |
| 7-14" | A2 | Light grey to white fine sand. |
| 14-31" | Laterite horizon (pseudo-B horizon) | Laterite boulders or conglomerate laterite containing about 10% of brown or yellow-brown fine sand in small channels. The laterite is sandy and concretionary in form. It may be stained dark brown by organic material on the surface. |
| 31-44" | B2 | Yellow-brown clay with bands of concretionary lateritic gravel. |
| 44-54" | B2 | Yellow-brown clay with red and light grey inclusions. Sometimes with bands of concretionary lateritic gravel. |
| 54-60" | B-C | Mottled red and light grey sandy clay. |
| 60-72" | C | Light grey sandy clay with some yellow and light red mottlings. Structure of underlying rock may be preserved. |
| 72" | — | Decomposing Precambrian sedimentaries. |

(1) An officer of the Division of Soils, C.S.I.R.

The sand exhibits the main features suggested by Prescott (1931) as occurring in a lateritic profile, and he considers that the laterite formations of Australia are fossil in character. Further, it conforms to the profiles described by Stephens (1946) for the "normal lateritic profile" of southern Australia. It is essentially a podsol with an accessory laterite horizon. The laterite horizon is located on top of the clayey B₂ horizons, but does not invariably occur in this position in related soils. Other bands of lateritic gravel occur at irregular intervals in the B₂ horizons. These bands suggest that there were variations in the level of the watertable during the period of laterisation. The clays of the B₂ horizon have a typically sub-kaolinitic feel or texture, and the C horizon clays have a typically kaolinitic texture. The structure of the underlying rock is frequently preserved in the C horizon.

TABLE II
Laboratory Analyses of the Eleanor Sand⁽²⁾

| Location of sample site | South-western portion Hundred of Seddon, Kangaroo Island. | | | | | | | |
|--|--|-------|-------|-------|-------|-------|-------|-------|
| Soil type | Eleanor sand | | | | | | | |
| Soil No. | 10139 | 10140 | 10141 | 10142 | 10143 | 10144 | 10145 | 10146 |
| Depth in inches | 0-3 | 3-7 | 7-14 | 14-31 | 31-44 | 44-54 | 54-60 | 60-72 |
| Texture | S | S | S | S | C | C | SC | SC |
| Gravel % > 2 mm. | — | — | — | 90 | 61 | 50 | 24 | — |
| Mechanical analysis of fine earth % < 2 mm.— | | | | | | | | |
| Coarse sand | 24.8 | 25.0 | 23.0 | 22.1 | 16.1 | 13.9 | 12.5 | 14.6 |
| Fine sand | 69.9 | 71.1 | 74.4 | 75.2 | 45.6 | 40.4 | 38.3 | 52.1 |
| Silt | 1.3 | 1.4 | 1.2 | 1.8 | 3.6 | 3.2 | 2.0 | 0.8 |
| Clay | 1.8 | 1.5 | 1.2 | 6.2 | 34.7 | 43.1 | 46.1 | 33.3 |
| Proportion coarse to fine sand | 26.74 | 26.74 | 24.76 | 25.75 | 26.74 | 26.74 | 25.75 | 22.78 |
| Loss on acid treatment % | 0.3 | 0.2 | 0.1 | 3.5 | 0.7 | 0.2 | 0.3 | 0.1 |
| Moisture % | 0.4 | 0.3 | 0.1 | 1.9 | 1.9 | 2.1 | 2.1 | 1.4 |
| Total soluble salts % | 0.008 | 0.013 | 0.008 | 0.013 | 0.023 | 0.020 | 0.023 | 0.035 |
| Chlorides, % Cl | 0.002 | 0.002 | 0.002 | 0.003 | 0.007 | 0.005 | 0.007 | 0.013 |
| Reaction (pH) | 5.8 | 5.2 | 6.1 | 6.1 | 6.3 | 6.3 | 6.1 | 6.0 |

Table II shows the results of the laboratory examination of one profile of Eleanor Sand. These analyses were carried out by methods described by Piper (1942). The mechanical analysis shows that the fine sand is the dominant fraction in all horizons. Both fine and coarse sand decrease in amount from the surface to the deep subsoil. Further, it will be seen that the proportion of coarse to fine sand (see Table II) remains practically constant throughout the profile. The silt content is negligible. Clay is the controlling factor texturally, in the B and C horizons, although the fine sand is important.

Reaction shows it to be an acid soil, with pH rising slightly in the B horizons.

The analyses for the exchangeable cations (see Table III) show that this soil is low in fertility. The figures for the number of milligram equivalents per gram of clay are very low in relation to clay content and pH values; they are about half the value over a similar pH range obtained by Piper (1938) for the red-brown earths. Magnesium is the dominant metal ion and calcium is second in order of importance.

⁽²⁾ All analyses were carried out by the Chemistry Section of the Division of Soils under the direction of Dr. C. S. Piper.

TABLE III
Exchangeable Cations in the B and C Horizons

| Soil No. | | 10143 | 10144 | 10145 | 10146 |
|---|--|-------|-------|-------|-------|
| Reaction pH | | 6.3 | 6.3 | 6.1 | 6.0 |
| Total metal ions mg. equiv. per 100 grm. soil | | 5.48 | 5.26 | 5.44 | 4.13 |
| No. mg. equiv. exch. cations per grm. clay | | 0.16 | 0.12 | 0.12 | 0.12 |
| Percentage of total metal ions— | | | | | |
| Ca | | 22 | 22 | 22 | 23 |
| Mg | | 60 | 63 | 64 | 65 |
| K | | 13 | 10 | 9 | 8 |
| Na | | .5 | .5 | 4 | 5 |

The origin of the Eleanor Sand is of special interest. The profile characteristics and the topographical situation definitely suggest that it is a relic of a former period of laterisation. In recent years evidence has been accumulating which suggests a Pliocene age for the pedogenesis of Australian laterites (*vide* Whitehouse 1940). It is highly feasible that the Eleanor Sand is the remnant of a "fossil" Pliocene soil, although some of the original surface horizon material may have been removed. Therefore, it could be classified as a "*lateritic residual*" which now appears in podsolic or pseudo-podsolic form.

Crocker (1946) records that in the vicinity of Mount Taylor and Mount Stockdale, Kangaroo Island, the lateritic residuals are overlain by a covering of grey and white siliceous sands. He considers that the sands are the re-sorted, leached A horizons of Pleistocene calcareous sand dunes. This suggests the possibility that much of the plateau received accessions of blown siliceous sand during the Pleistocene; since the laterite would undoubtedly guard the subsoil against any contamination by wind-blown sands, accumulation would have occurred in the surface (A) horizons. However, evidence brought forward in this paper, notably the constant proportion of coarse and fine sands throughout the profile, shows that all horizons are definitely related and that the surface (A) horizons did not receive accessions of blown sand. Thus, it appears that the Eleanor Sand is a relatively undisturbed fossil soil containing a laterite horizon *in situ*.

It is quite clear in the field that the Eleanor Sand is the immediate *precursor* of the main group of plateau soils, the Seddon series. This relationship will be discussed in a forthcoming Bulletin of the Division of Soils, C.S.I.R.

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**FORAMINIFERA AND OTHER MICRO-FOSSILS FROM SOME OF THE
TERTIARY DEPOSITS IN THE VICINITY OF ALDINGA BAY, SOUTH
AUSTRALIA**

BY I. CRESPIN

Summary

This report gives the result of a microscopic examination of a small collection of fossiliferous rocks made by the writer in 1936 from the glauconite deposits at Maslin Beach, Blanche Point, and of material collected by Sir Douglas Mawson from the vicinity of Aldinga Bay. Only the micro-fauna has been investigated as the mega-fossils have been described by many palaeontologists.

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By I. CRESPIN

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This report gives the result of a microscopic examination of a small collection of fossiliferous rocks made by the writer in 1936 from the glauconite deposits at Maslin Beach, Blanche Point, and of material collected by Sir Douglas Mawson from the vicinity of Aldinga Bay. Only the micro-fauna has been investigated as the mega-fossils have been described by many palaeontologists.

There is little doubt that the sediments examined are of Middle Miocene age and are referable to the basal part of the Balcombian Stage of the Victorian Tertiaries. The presence, in some abundance, of certain foraminiferal species in some samples suggests a correlation with the Longford Substage of the Balcombian (Crespin 1943).

The samples examined are as follows:

1. Whitish bryozoal sandstone from a small Headland, just north of Aldinga Creek.
2. Yellowish marl from the same locality as No. 1, but stratigraphically higher than that sample.
3. Yellowish marl from Cliffs immediately south of Aldinga Creek, about 200 yards north of the jetty, and stratigraphically higher than No. 2.
4. Yellowish marl from Cliffs 12 feet above beach level, several hundred yards south of jetty, and stratigraphically higher than No. 3.
5. Greenish glauconitic marl, Maslin Beach, Blanche Point.

The micro-faunal content of these rocks and the distribution of species is given below:

| | Species | Localities | | | | |
|---|---------|------------|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| FORAMINIFERA— | | | | | | |
| <i>Anomalina ammonoides</i> Reuss | - | - | - | - | f | - |
| <i>A. glabrata</i> Cushman | - | - | + | + | - | r |
| <i>A. nonionoides</i> Parr | - | - | - | - | f | - |
| <i>Astrononion australe</i> Cushman | - | - | - | - | r | r |
| <i>Baggina</i> sp. | - | - | - | - | - | c |
| <i>Bolivina limbata</i> Brady | - | - | - | - | r | - |
| <i>R. victoriana</i> Cushman | - | - | - | - | f | - |
| <i>Cassidulina subglobosa</i> d'Orb. | - | - | - | - | r | r |
| <i>Carpenteria rotaliformis</i> Chapm. & Cresp. | - | - | - | - | r | - |
| <i>Cibicides lobatulus</i> (W. & J.) | - | - | - | r | c | r |
| <i>C. refulgens</i> (Montf.) | - | - | - | - | f | - |
| <i>C. ungerianus</i> (d'Orb.) | - | - | - | r | r | c |
| <i>C. victoriensis</i> Chapm., Parr & Collins | - | - | - | r | - | - |
| <i>C. sp. 2</i> | - | - | - | r | r | f |
| <i>C. sp.</i> | - | - | - | - | - | f |
| <i>Dentalina filiformis</i> (d'Orb.) | - | - | - | - | r | - |
| <i>D. fissicostata</i> (Gumbel) | - | - | - | - | r | - |
| <i>D. obliqua</i> (Linnè) | - | - | - | - | r | - |

⁽¹⁾ Report No. 1946/27 Bureau of Mineral Resources, Department of Supply and Shipping, Commonwealth of Australia.

| Species | Localities | | | | |
|---|------------|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| <i>D. soluta</i> Reuss | - | - | - | - | f |
| <i>D.</i> sp. | - | - | r | - | - |
| <i>Discorbis orbicularis</i> (Terq.) | - | - | - | r | - |
| <i>D.</i> sp | - | - | - | r | - |
| <i>Dorothia parri</i> Cushman | - | - | f | f | - |
| <i>Eponides concentricum</i> (P. & J.) | - | - | - | r | - |
| <i>E. repandus</i> (F. & M.) | - | - | f | r | f |
| <i>E. cf. scabriculus</i> (Chapman) | - | - | r | - | - |
| <i>Frondicularia</i> sp. nov. | - | - | - | r | - |
| <i>Gaudryina (Pseudogaudryina) cespinae</i> Cushman | - | - | - | f | r |
| <i>Glandulina laevigata</i> Reuss | - | - | - | r | r |
| <i>Globigerinoides trilobus</i> (Reuss) | - | - | - | - | f |
| <i>Guttulina irregularis</i> (d'Orb.) | - | - | r | - | - |
| <i>G. lactea</i> (W. & J.) | - | - | - | - | r |
| <i>G. problema</i> (d'Orb.) | - | - | - | - | r |
| <i>G. (Sigmoidina) silvestri</i> CUSH. & Ozawa | - | - | f | - | r |
| <i>Gyridina soldanii</i> (d'Orb.) | - | - | r | - | - |
| <i>Heronallenia lingulata</i> (B. & H.) | - | - | f | - | - |
| <i>H. wilsoni</i> (H. A. & E.) | - | - | f | r | r |
| cf. <i>Karreriella barbata</i> Cushman | - | - | - | r | - |
| <i>Lagena hexagona</i> Williamson | - | - | r | f | - |
| <i>L. laevis</i> (Montf.) | - | - | r | - | - |
| <i>L. marginata</i> (W. & B.) | - | - | r | - | - |
| <i>L. sulcata</i> (W. & B.) | - | - | r | - | r |
| <i>Lenticulina articulata</i> (Reuss) | - | - | - | - | r |
| <i>L. gibba</i> (d'Orb.) | - | - | - | r | - |
| <i>L. rotulata</i> (Lam.) | - | - | - | r | - |
| <i>L.</i> sp. | - | - | r | - | r |
| cf. <i>Massilina torquayensis</i> (Chapm.) | - | - | - | r | - |
| <i>Planorbulina mediterraneus</i> d'Orb. | - | - | r | r | - |
| cf. <i>Planulina wuellerstorfi</i> (Schw.) | - | - | - | r | - |
| <i>Discorbinella biconvava</i> (P. & J.) | - | - | - | r | - |
| <i>Polystomellina miocenica</i> Cushman | - | - | r | f | - |
| <i>Pseudopolymorphina</i> sp. | - | - | - | r | - |
| <i>Pyrulina fusiformis</i> (Roemer) | - | - | - | r | - |
| <i>Pyrulina</i> sp. | - | - | r | - | - |
| <i>Pullenia bulloides</i> (d'Orb.) | - | - | r | - | r |
| <i>Quinqueloculina lamarckiana</i> (d'Orb.) | - | - | - | r | - |
| <i>Reussella spinulosa</i> (Reuss) | - | - | r | - | - |
| <i>Sherbornina atkinsoni</i> Chapman | - | - | c | c | r |
| <i>Sigmidiella elegantissima</i> (P. & J.) | - | - | - | r | r |
| <i>Sigmomorphina</i> cf. <i>batesfordensis</i> Parr & Collins | - | - | - | r | - |
| <i>S. chapmani</i> (H. A. & E.) | - | - | - | - | r |
| <i>Sphaeroidina bulloides</i> d'Orb. | - | - | r | - | - |
| <i>Spirillina inaequalis</i> Brady | - | - | - | c | r |
| <i>Textularia carinata</i> d'Orb. | - | - | r | - | r |
| T. cf. <i>flintii</i> Cushman | - | - | - | - | r |
| <i>T. sagittula</i> Defr. | - | - | - | r | r |
| <i>Trifarina bradyi</i> Cushman | - | - | c | r | c |
| <i>Uvigerinella</i> sp. | - | - | - | - | f |
| <i>Vaginulina legumen</i> (Linnè) | - | - | r | - | - |
| <i>Verneuilina triquetra</i> (Munster) | - | - | r | r | r |

| | Species | | | | | | Localities |
|---|---------|---|---|---|---|-----------|------------|
| | | | | | | | 1 2 3 4 5 |
| SPONGIDA— | | | | | | | |
| <i>Ecionema newberryi</i> (McCoy) | - | - | - | - | - | - | f f - |
| ANTHOZOA— | | | | | | | |
| <i>Mopsea tenisoni</i> Chapman | - | - | - | - | - | r r r r - | |
| BRYOZOA— | | | | | | | |
| <i>Acanthodesia simplex</i> (McG.) | - | - | - | - | - | - | r - r r |
| <i>Adeonellopsis clavata</i> (Stol.) | - | - | - | - | - | f - - - | |
| <i>A. obliqua</i> (McG.) | - | - | - | - | - | f - - - | |
| <i>A. symmetrica</i> (McG.) | - | - | - | - | - | f - - - | |
| <i>Cellaria contigua</i> McG. | - | - | - | - | - | f - f f | - |
| <i>C. depressa</i> Maplestone | - | - | - | - | - | - f - - | |
| <i>C. gracilis</i> Busk | - | - | - | - | - | - - - | f r |
| <i>C. rigidia</i> var. <i>perampla</i> Waters | - | - | - | - | - | r f - - | r |
| <i>Cellepora coronopus</i> M. Edws. | - | - | - | - | - | - - | r - |
| <i>Chiastosella daedala</i> (McG.) | - | - | - | - | - | - - | r - |
| <i>Crisia acropora</i> Busk | - | - | - | - | - | r - - | f r |
| <i>Ellisinidra profunda</i> (McG.) | - | r | - | - | - | r - - | - |
| <i>Escharoides erectus</i> Canu & Bassler | - | - | - | - | - | - - | f - |
| <i>Entalophora australis</i> Busk | - | - | - | - | - | - - | r r r |
| <i>E. longipora</i> McG. | - | - | - | - | - | - - | r r r |
| <i>Filisparsa orakeiensis</i> Stol. | - | - | - | - | - | - - | r r |
| <i>Hincksina geminata</i> (Waters) | - | - | - | - | - | - - | f r |
| <i>Hippomonella abdita</i> (McG.) | - | - | - | - | - | - - | r r - |
| <i>Horniera frondiculata</i> McG. | - | - | - | - | - | r - r - | r |
| <i>H. striata</i> Stache | - | - | - | - | - | r - - | - |
| <i>H. sulcata</i> McG. | - | - | - | - | - | - - | f r |
| <i>Idmidronea</i> sp. | - | - | - | - | - | - - | r - |
| <i>Idmonea bifrons</i> Waters | - | - | - | - | - | r - - | - |
| <i>I. contorta</i> Busk | - | - | - | - | - | f - - | r - |
| <i>I. geminata</i> McG. | - | - | - | - | - | f - - | - |
| <i>I. milneana</i> d'Orb. | - | - | - | - | - | f - - | - |
| <i>I. trigona</i> McG. | - | - | - | - | - | f - - | - |
| <i>I. venusta</i> McG. | - | - | - | - | - | r - - | f r |
| <i>Lichenopora australis</i> McG. | - | - | - | - | - | r - - | - |
| <i>Macropora clarkei</i> (T. Woods) | - | - | - | - | - | r r - | - |
| <i>M. crassatina</i> (Waters) | - | - | - | - | - | - - | r - |
| <i>Mecynoecia proboscidea</i> (M. Edws.) | - | - | - | - | - | r - - | f - |
| <i>Membranipora concamerata</i> Waters | - | - | - | - | - | - - | r - |
| <i>M. macrostoma</i> (Reuss) | - | - | - | - | - | - - | r - |
| <i>Mesonea hochstetteriana</i> (Stol.) | - | - | - | - | - | r - - | - |
| <i>Omoiosia elongata</i> Canu & Bassler | - | - | - | - | - | r - - | r |
| <i>Palmicellaria magna</i> Canu & Bassler | - | - | - | - | - | - - | r |
| <i>Porina gracilis</i> (McG.) | - | - | - | - | - | r r f f | r |
| <i>P. vertebralis</i> Stol. | - | - | - | - | - | r - - | r r |
| <i>Retepora aciculifera</i> McG. | - | - | - | - | - | r - f | - |
| <i>R. porcellana</i> McG. | - | - | - | - | - | - - | r |
| <i>R. rimata</i> Waters | - | - | - | - | - | f - - | f - |
| <i>Schizolavella phymatopora</i> (Reuss) | - | - | - | - | - | - - | f - |
| <i>Smittina ordinata</i> McG. | - | - | - | - | - | - - | r - |
| <i>Smittinella tatei</i> (T. Woods) | - | - | - | - | - | - - | f - |
| <i>Trigonopora vermicularis</i> Maplestone | - | - | - | - | - | r - - | - |

| Species | Localities | | | | |
|--------------------------------------|------------|---|---|---|-------|
| | 1 | 2 | 3 | 4 | 5 |
| OSTRACODA— | | | | | |
| <i>Bairdia amygdaloides</i> G. S. B. | - | - | - | - | f |
| <i>B. subdeltaidea</i> G. S. B. | - | - | - | r | c r r |
| <i>Bythocypris tumefacta</i> Chapman | - | - | - | - | r |
| <i>Cythere demissa</i> G. S. B. | - | - | - | - | f r |
| <i>C. dictyon</i> G. S. B. | - | - | - | - | r |
| <i>C. lactea</i> G. S. B. | - | - | - | - | r |
| <i>C. cf. lauta</i> G. S. B. | - | - | - | - | r f |
| <i>C. rastromarginata</i> G. S. B. | - | - | - | - | f |
| <i>C. scabrocuneata</i> G. S. B. | - | - | - | - | r c r |
| <i>Cytherella lata</i> G. S. B. | - | - | - | - | r e |
| <i>C. pulchra</i> G. S. B. | - | - | - | - | r |
| <i>C. punctata</i> G. S. B. | - | - | - | - | r r |
| <i>C. subtruncata</i> Chapman | - | - | - | - | c r |
| <i>Loxoconcha australis</i> G. S. B. | - | - | - | - | r |
| <i>Macrocypris decora</i> G. S. B. | - | - | - | - | f |

NOTES ON THE MICRO-FAUNA⁽²⁾

The assemblage of species of foraminifera, sponge spicules, *Mopseut*, bryozoa and ostracoda in samples 1 to 5, is typical of that found in the Balcombian Stage of the Middle Miocene in the Victorian Tertiary deposits, certain species of the foraminifera indicating that the beds may be referred to the Longford substage of the Balcombian as developed in Gippsland.

Sir Douglas Mawson has intimated the stratigraphic sequence of samples 1 to 4 from Aldinga Bay, sample 1 being the lowest in the sequence. It would appear that sample 5, from Maslin Beach, Blanche Point, with its glauconitic lithology, forms the base of the section. It is impossible to distinguish any stratigraphic difference in age of the faunas between samples 1 to 4 and 5, and it must be concluded that, based on the micro-faunas, the five samples should be referred to the same age, i.e., to the Longford substage of the Balcombian.

(a) FORAMINIFERA—The foraminiferal assemblage is distinctly Balcombian, although many of the species range throughout the Middle Miocene up to Recent. Amongst the species of zonal value is an undescribed *Cibicides*, referred to as *Cibicides* sp. 2, a form which is very common in the sediments at Dowd's Quarry near Longford, Gippsland, the type locality for Longford substage, and which is present in all the Aldinga samples. An associated form is *Polystomellina miocenica*, described by Cushman from Batesford, Victoria. It is typically Balcombian in Eastern Victoria.

One of the most distinctive foraminiferal species is *Sherbornina atkinsoni*, which is well represented in samples 1, 2, 3 and 4. This form was described by Chapman from Table Cape, Tasmania. It is rare in the Victorian Tertiaries, one record being from the sample at 856 feet in No. 11 Bore, Ph. Colquhoun near Lakes Entrance, in beds referable to the Longford substage. It has also been found in South Australia in Culley's Bore, Hundred of Willunga, between the depths of 80 and 125 feet, and in a bore at Sellick's Hill at 260-265 feet.

Other species characteristic of the Balcombian include *Gaudryina (Pseudogaudryina) cespinae*, *Bolivina victoriana*, *Sigmamorphina chapmani*, *Guttulina (Sigmoidina) silvestri*, *Carpenteria rotaliformis*, *Cibicides victoriensis*, *Heronalenia lingulata* and *Spirillina inaequalis*. All these forms, except *H. lingulata* and *S. inaequalis*, were originally described from Balcombian deposits.

⁽²⁾ Notes for Nos. 1 to 4 supplied by Sir Douglas Mawson.

(b) *Ecionema newberryi* and *Mopsea tenisoni* are typical Balcombian fossils. At Dowd's Quarry, near Longford, spicules of the sponge *E. newberryi* are very abundant.

(c) BRYOZOA—The bryozoa are fragmentary and not well preserved, but many species can be determined. They are typical of the Balcombian deposits in Victoria. The only species which was not recorded in Gippsland above the underlying Janjukian is *Trigonopora vermicularis*, which is present in sample 3.

(d) OSTRACODA—Although the majority of species of ostracoda are long ranging, the assemblage is typically Balcombian. *Bythocypris tumefacta* and *Cytherella subtruncata* are the only Miocene species recorded, both being described by Chapman from the Balcombian deposits in the Mallee Bores.

REFERENCE

CRESPIN, I. 1942 The Stratigraphy of the Tertiary Marine Rocks in Gippsland, Victoria. Min. Res. Surv. Bull. 9 (Pal. Ser. 4). Mimeographed.

COMPOSITION AND GENESIS OF LUNETTES

By C. G. STEPHENS and R. L. CROCKER

[Read 8 August 1946]

INTRODUCTION

Attention was drawn to special land forms associated with lakes in the Echuca district and in the Parish of Benjeroop, Victoria, by Harris and Hills in 1939. Hills proposed a theory for their genesis, and subsequently amplified this, at the same time giving them the name of lunettes (Hills 1940).

Of recent years the authors have seen these land forms in all States except Queensland. They are a feature in southern Australia and are always associated with depressions variously termed lakes, lagoons, swamps or pans which are periodically wet and dry. The present paper deals with the general distribution of the lunette land form, its characteristics and composition, and introduces new evidence to indicate that an alternative theory of genesis is possible. The probable age of the lunettes is also discussed.

CHARACTERISTICS OF LUNETTES. ORIGINAL THEORY OF ORIGIN

Lunettes are essentially low crescentic ridges with smooth even contours that occur on the south-eastern to north-eastern sides of depressions which are frequently drainage terminals. They decrease in elevation towards the north and south ends. It was because of their crescentic outline that the ridges were very appropriately called lunettes.

There can be little doubt that the ridges have been built up by the dominant westerly winds, which have played a major role in sand movement in southern Australia generally (Hills 1939, Crocker 1946). The foreslope of the lunette is generally steeper than the back slope, and usually provides a smooth clean sweep for the eastern shore of the lake or depression. This frequently contrasts very markedly to the irregular western edge. (see pl. xlvi, fig. 1).

Hills (1939) quotes a mechanical analysis of "loam" from one of the ridges described by him as typical and in which the sand fraction (0·5 mm. and over) was only 6·4%, the "silt" fraction 78·3% and the material soluble in hydrochloric acid (chiefly calcium carbonate) 15·3%.

In suggesting the mode of genesis of lunettes, Hills (*loc. cit.*) considered that the regular form of the ridges made it improbable that they were products of aeolian surface drift and saltation. The fact that they were fixed was believed sufficient to differentiate them from regular sand accumulations like barchans, and other drift accumulations are usually irregular and hummocky. Further, Hills says that during the periods when the depression was dry, "The material of the lake floor is so fine-grained that much of it would undoubtedly be lifted into the air by strong winds and it is unlikely it would be redeposited on the lake shore." In view of the above, and the mechanical analysis of the typical ridge, he suggested that lunettes were built up when the lakes and depressions contained water. He considered they were composed of atmospheric dust "captured by spray droplets derived from the lake," and that "the essential feature in all is the

deposition and retention of atmospheric dust." The possibility of drift accumulations from the floor of depression during periods when the lake was dry was discounted.

Before discussing the above theory further, some observations on lunettes in various parts of southern Australia will be briefly recorded.

OBSERVATIONS IN VARIOUS STATES

TASMANIA

A study of the soils of the Cressy-Longford district (Stephens, Baldwin and Hosking 1942) revealed a distribution of lunettes of quite typical form on the eastern side of a number of lagoons near Little Hampton and Wilmore's Lane. These lunettes are coarser textured than those described by Hills, being composed predominantly of fine sand. Mechanical analyses⁽¹⁾ of the Wilmore sandy loam, the soil developed on the lunettes, are given in Table I.

TABLE I
Mechanical analysis of the Wilmore sandy loam

| Soil number | - | - | 6613 | 6614 | 6615 |
|------------------------|---|---|------|------|-------|
| Depth in inches. | - | - | 0-6 | 6-11 | 13-27 |
| Horizon | - | - | A1 | A2 | B |
| | | | % | % | % |
| Coarse sand | - | - | 12.6 | 14.7 | 14.7 |
| Fine sand | - | - | 55.9 | 56.8 | 52.8 |
| Silt | - | - | 10.0 | 9.0 | 5.0 |
| Clay | - | - | 15.7 | 16.9 | 26.6 |
| Loss on acid treatment | - | - | 1.0 | 0.8 | 0.5 |
| Moisture | - | - | 1.8 | 1.3 | 1.3 |
| Loss on ignition | - | - | 6.2 | 4.0 | 4.0 |
| Reaction (pH) | - | - | 6.1 | 6.4 | 7.2 |

The Little Hampton and Wilmore's Lane lunettes are associated with remnants of a low lateritic tableland, formerly the floor of the Launceston Tertiary basin—a lower Pliocene formation (Singleton 1941).

Another lunette which has not been closely studied occurs on the eastern side of Lake Tiberias in the midlands of the State. It is of a sandy nature.

VICTORIA

In addition to the extensive lunettes described by Hills (1939, 1940) and Harris (1939), others occur. Some of these have been given close attention in soil surveys. Baldwin, Burvill and Freedman (1939) mapped a number of lunettes as Soil Type 4, in their survey of part of the Kerang Irrigation District. These are undoubtedly almost identical with those described by Hills and Harris for the nearby Swan Hill and Echuca districts. At Kerang Baldwin *et al* point out that "the rises have been stable for a long time and the soil profiles have reached an advanced stage of maturity."

Mechanical analysis of a profile of Soil Type 4 is shown in Table II, and shows that the clay and fine sand fraction predominates.

⁽¹⁾ On the International System—coarse sand 2.0–·2 mm., fine sand ·2–·02 mm., silt ·02–·002 mm. and clay <·002 mm.

TABLE II
Mechanical analysis of Soil Type 4. Kerang

| Soil number | - | - | 8026 | 8027 | 8028 | 8029 | 8030 | 8031 | 8032 | 8033 |
|------------------------|---|---|------|------|-------|-------|-------|-------|-------|-------|
| Depth in inches | - | - | 0-5 | 5-10 | 10-13 | 13-22 | 22-36 | 36-48 | 48-66 | 66-84 |
| Texture | - | - | - | SL | MC | LC | LC | CL | CL | SCL |
| | | | % | % | % | % | % | % | % | % |
| Rubble and gravel | - | - | 0 | 0 | 0.7 | 4.6 | 1.9 | 1.9 | 1.7 | 0.3 |
| Coarse sand | - | - | 22.9 | 15.3 | 11.7 | 12.3 | 13.2 | 12.2 | 10.4 | 11.6 |
| Fine sand | - | - | 55.0 | 33.8 | 25.9 | 25.7 | 24.9 | 24.0 | 21.3 | 35.1 |
| Silt | - | - | 6.9 | 4.0 | 3.6 | 1.9 | 3.0 | 2.7 | 4.3 | 4.5 |
| Clay | - | - | 13.8 | 44.1 | 53.9 | 52.6 | 51.2 | 53.8 | 53.8 | 43.0 |
| Moisture | - | - | 1.2 | 2.7 | 4.9 | 5.2 | 5.4 | 5.3 | 5.3 | 4.1 |
| Loss on acid treatment | - | - | 0.7 | 1.3 | 1.9 | 4.0 | 3.8 | 4.5 | 6.5 | 4.1 |
| Loss on ignition | - | - | 2.9 | 4.7 | 5.3 | 5.9 | 5.1 | 5.6 | 6.4 | 4.3 |
| Calcium carbonate | - | - | 0.01 | 0.01 | 0.06 | 1.41 | 1.07 | 2.32 | 3.82 | 1.91 |
| Total soluble salts | - | - | 0.04 | 0.08 | 0.38 | 0.65 | 0.79 | 0.92 | 0.92 | 0.81 |
| Reaction (pH) | - | - | 6.9 | 7.7 | 8.3 | 8.6 | 8.6 | 8.6 | 8.6 | 8.6 |

NEW SOUTH WALES

Smith, Herriot and Johnston (1943) have mapped and recognised lunette formations in the Wakool Irrigation Area. The soil type found on them was called the Warobyan sandy loam, and the mechanical analysis of a profile from an eroded site (Table III), reveals that it is largely composed of fine-textured material, the sandy loam surface soils being due to normal profile development. The old lunette formations "occur in close association with the mallee riscs, and appear to be contemporaneous" (Smith *et al.*)

TABLE III
Mechanical analysis of an eroded profile of the Warobyan sandy loam

| Soil No. | - | - | - | - | 7311 | 7312 | 7313 |
|------------------------|---|---|---|---|------|-------|-------|
| Depth in inches | - | - | - | - | 0-2½ | 2½-30 | 30-53 |
| Texture | - | - | - | - | CL | MC | MC |
| | | | | | % | % | % |
| Coarse sand | - | - | - | - | 8.0 | 5.2 | 3.1 |
| Fine sand | - | - | - | - | 29.9 | 18.9 | 16.8 |
| Silt | - | - | - | - | 7.9 | 7.5 | 3.0 |
| Clay | - | - | - | - | 50.0 | 58.3 | 65.5 |
| Loss on acid treatment | - | - | - | - | 5.1 | 11.2 | 12.6 |
| Moisture | - | - | - | - | 5.7 | 7.7 | 8.3 |
| Loss on ignition | - | - | - | - | 8.1 | 10.1 | 10.0 |
| Reaction (pH) | - | - | - | - | 8.3 | 8.5 | 8.4 |

SOUTH AUSTRALIA

Lunettes occur in quite a number of localities in South Australia. The Bool Lagoon region near Naracoorte, the terminal of the Mosquito Creek, consists of a complex of alternating swamp and lunette. A soil profile examined on one of the ridges consisted of a deep coherent sandy loam, almost black in colour. There is thus evidence that the sand fraction can dominate the composition of these lunettes. Other lunettes in this region occur at Moyhall Swamp and Lake Roy. This latter carries a well-developed soil profile, the upper horizons being characterised by fine sand, and the subsoil by clay (Table IV).

TABLE IV
Mechanical analysis of soil from Lake Roy Lunette

| Soil No. | | 8518 | 8519 | 8520 | 8521 |
|------------------------|-------|------|------|-------|-------|
| Depth in inches | | 0-3 | 3-10 | 10-16 | 16-22 |
| Texture | | LS | S-SL | C | C |
| | % | % | % | % | % |
| Coarse sand | - - - | 9.1 | 8.3 | 3.7 | 2.9 |
| Fine sand | - - - | 71.1 | 74.8 | 26.6 | 17.1 |
| Silt | - - - | 8.2 | 7.2 | 1.9 | 1.0 |
| Clay | - - - | 8.2 | 7.7 | 57.2 | 67.2 |
| Moisture | - - - | 1.0 | 0.6 | 7.1 | 9.4 |
| Loss on acid treatment | - - | 0.7 | 0.3 | 1.6 | 2.0 |
| Loss on ignition | - - | 4.1 | 1.7 | 7.2 | 7.8 |
| Reaction (pH) | - - - | 6.9 | 7.0 | 6.9 | 7.6 |

Other lunettes occur in the South-East of South Australia, and some of the most conspicuous are those south of Kingston, as for example on Ashmore Station. They have not been closely examined but appear very similar to those on the Naracoorte-Penola plain, some of which were described in the last paragraph. An interesting feature of many of the swamps in the Kalangadoo district is the more loamy texture of the soils on the eastern bank. This is well known locally, and freely acknowledged and used when choosing sites for crops like potatoes. There is, however, no development of the true crescentic bank, which characterises the type lunettes.

Lunettes have been observed by Northcote (1946) and others associated with lagoons and swamps on Kangaroo Island. These vary considerably in texture, and some are associated with the lateritic tableland.

Two well-marked lunettes of a fine texture were recently investigated at Hutton's Lagoon and an adjacent depression, at Ucolta, near Peterborough. The lunette on Hutton's lagoon is badly eroded and the surface is littered with broken stone chips. Amongst these aboriginal implements are recognisable, and the presence of the stones is explained in this way. A soil sample from the eroded surface is a clay in texture, and its mechanical analysis is given in Table V.

TABLE V.
Mechanical analysis of soil from Hutton's Lagoon Lunette⁽²⁾

| Soil number | | | 10765 |
|----------------|---------|---------------|-------|
| Retained by | 1 mm. | sieve (1 mm.) | 0.2 |
| " " | ½ " | " (0.5 mm.) | 1.0 |
| " " | 40 mesh | " (0.38 mm.) | 0.4 |
| " " | 70 " | I.M.M. " | 4.0 |
| " " | 90 " | " (0.14 mm.) | 2.2 |
| " " | 120 " | " (0.10 mm.) | 3.8 |
| " " | 200 " | " (0.06 mm.) | 5.6 |
| Passed through | 200 " | " (0.06 mm.) | 8.0 |
| Silt | | | 23.0 |
| Clay | | | 36.0 |

Similar lunettes have also been seen at Willochra where the Willochra and Boolcunda Creeks meet on a plain subject to flooding, and also on the south-eastern shore of a small lagoon set deeply in a valley of the Flinders Ranges some six miles west of Hawker.

WESTERN AUSTRALIA

An inspection of the unpublished soil map of the Salmon Gums District survey (Teakle *et al* 1935), indicates that the soil mapped as the Red Lake sand has formed on lunettes. In addition the distribution of the Doust sand, eastward of, and partially in association with, the Red Lake sand, suggests a contribution of wind-borne material from the latter. The Red Lake sand is essentially deep and light-textured with some accumulation of clay in the B horizon, which is, nevertheless, dominated by the sand fractions.

At Lake Muir, which lies about midway between Mount Barker and Manjimup in the jarrah forest zone (rainfall about 30" per annum), there is an extensive development of a somewhat modified lunette of very coarse sandy material, much of the sand being in the vicinity of 2 mm. in diameter. Lake Muir is on the lateritic tableland.

On the western shores of Wagin Lake, and Lake Parkeyerring, near Wagin, there are two lunettes perfect in all topographic features (see pl. xlvi, fig. 2). They are composed of very coarse sandy material with only a slight development of a deep-seated B horizon. Mechanical analyses of material from the Wagin Lake lunette are shown in Table VI.

TABLE VI
Mechanical analyses of soils from the Wagin Lake Lunette⁽²⁾

| Soil number | Description | 10762 | | 10763 | | 10764 | |
|----------------------|---------------|---------|------------|---------|---------|---------|---------|
| | | Surface | Subsurface | Subsoil | Subsoil | Subsoil | Subsoil |
| Retained by 1 mm. | sieve (1 mm.) | 3.2 | % | 80.6 | % | 66.4 | % |
| " " ½ " | " (0.5 mm.) | 36.0 | coarse | 19.6 | coarse | 23.8 | coarse |
| " " 40 mesh | " (0.38 mm.) | 11.0 | sand | 10.2 | sand | 8.2 | sand |
| " " 70 " | I.M.M. " | 30.4 | | 34.6 | | 21.0 | |
| " " 90 " | " " | 3.4 | % | 11.2 | % | 29.8 | % |
| " " 120 " | " " | 3.2 | fine | 12.0 | fine | 5.8 | fine |
| " " 200 " | " " | 2.4 | sand | 8.0 | sand | 5.8 | sand |
| Passed through 200 " | " " | 2.2 | | 3.0 | | 6.0 | |
| Silt | | — | | — | | 9.5 | |
| Clay | | — | | — | | 12.7 | |

GENESIS OF LUNETTES — A REVIVED THEORY

In discussing the lunettes of the Echuca district Harris (1939) considered that "silt" blown from the adjacent depression was the probable source of the ridge material, but he considered the explanation inadequate. Hills (1939), as stated earlier, believed the material of the lake floors "so fine-grained that much of it would undoubtedly be lifted into the air by strong winds, and it is

⁽²⁾ Analyses under the direction of Dr. C. S. Piper, Waite Agricultural Research Institute, Adelaide.

unlikely that it would be redeposited on the lake shore, for there is no particular feature there that would cause the dust to be deposited," and so rejected this mode of origin.

Two important aspects seem to be worthy of further consideration. Firstly, clay dust is not usually, and certainly not entirely composed of ultimate particles but of aggregates. A certain size range of aggregates would behave like sand grains in being transported by saltation and surface drift—especially over a limited distance. In this way silt and clay particles from the lagoon or swamp bed could readily contribute towards the building of a lunette. The "clay pellets" he mentions as possible would be closely analogous (Hills 1940). Secondly, the vegetation that would occur at the edge of a lake depression, be it grass, samphire, shrubs or trees, could provide the type of surface required to cause deposition of wind-transported material (Bagnold 1940, Chepil 1945). Once this accumulation had attained even a slight elevation it would continue to grow, both under its own influence on the wind velocity and because of any vegetation on the incipient lunette.

There seems no reason, therefore, why the lunettes of finer material (the "loam ridges") should not have been the product of saltation and surface creep. Small quantities of fine particles being carried in true suspension could be expected to be trapped within the accumulation, and loessial accession normal to the region as a whole would also be contributed.

In putting forward his theory for spray-precipitated atmospheric dust as the lunette parent material, Hills was no doubt greatly influenced by the composition of lunettes in the Swan Hill district. These are predominantly "silty." Fineness of particle size of the lunette material is indeed essential to the atmospheric dust theory. The extensive occurrences of lunettes in southern Australia made up of material of widely differing grain-size, and listed in the foregoing section, indicate that the silt and loamy nature of those originally described is by no means general. Indeed, they exhibit a diversity apparently not suspected by Hills. In many localities, *e.g.*, Cressy-Longford (Tasmania), Lake Roy (South Australia), Wagin Lake (Western Australia), lunettes characterised by the sand fraction are by no means uncommon.

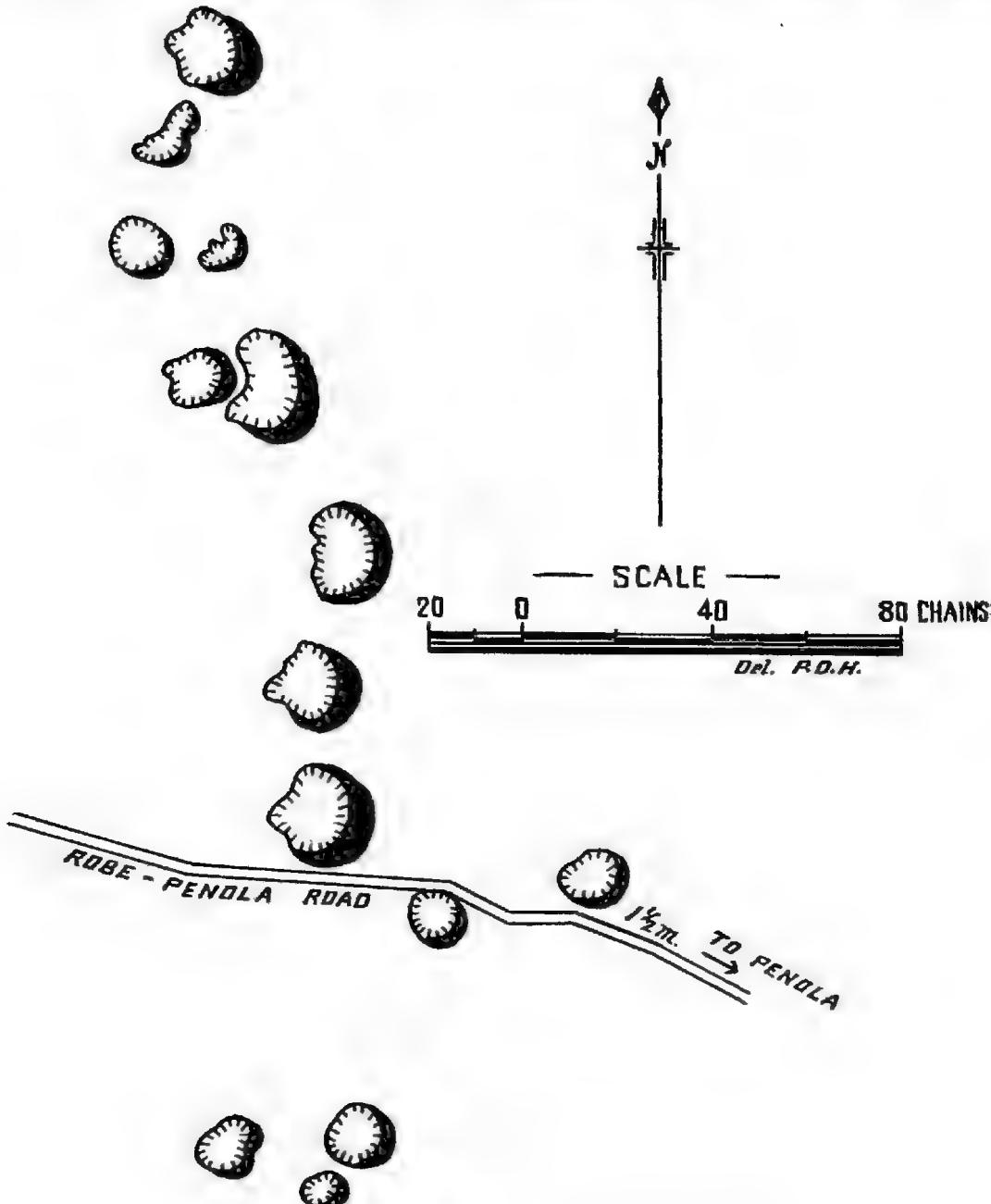
It is apparent that lunettes can be silt-clay dominant or sand dominant, and probably every gradation between the two occurs. Any adequate theory of their genesis must be able to explain the presence of both loam and sand lunettes.

The Wagin (Western Australia) lunette is ideal in essential features with its crescentic and regular contours and perfect cross-section, but is composed chiefly of very coarse sandy material (see Table VI). It provides a key to the origin of these land forms and a decisive counter to the spray precipitated atmospheric dust theory. The size of atmospheric dust is considered to range between .0001—.01 mm. (Bagnold 1940), and Beadle (1945) has recently given the predominant size of particles in New South Wales dust-storms of high turbulence as .03—.015 mm. The great bulk of the material in the Wagin Lake lunette is of greater size than this, and obviously could not have been transported entirely in atmospheric suspension. Some of it is too coarse to be transported by saltation and was probably moved by surface creep. Moreover the Wagin lunette, like all those of southern Australia, has been built up under the influence of predominant westerly winds. These in Western Australia, together with southerly winds, are the least dust-bearing, coming as they do at Wagin from the ocean and forest vegetated regions first.

This latter point is of even greater significance in relation to the lunettes of the South-East of South Australia. It is impossible to imagine the westerly and south-westerly winds as dust-bearing except under extreme aridity in those

regions. These latter conditions would conflict with the presence of water in the lakes and depressions so necessary for the provision of spray in the original theory.

The presence of multiple lunettes, as those at Benjeroop, was indicated as proof of the necessity of water. It is difficult to follow this argument. Recession of the old shore line could have been caused by numerous factors—suddenly improved vertical drainage, sinkhole development, increase in outlet size, deflec-



tion of drainage course, greater aridity, etc. Such a change would normally be followed by an encroachment of vegetation to the new shore line, which could act as a barrier causing discharge of wind-borne material (see pl. xlvi).

It is seen, therefore, from the foregoing that: (1) lunettes are not necessarily composed of essentially fine material (silt and clay)—that is, there are loamy lunettes and sandy lunettes, and lunettes of intermediate character; (2) that the loamy lunettes could have been built up by aggregates of silt and clay particles, which would behave more like sand grains than the ultimate particles of silt and clay; (3) the material in the sandy types is predominantly of too large diameter to be carried in suspension as atmospheric dust (loess); (4) that multiple lunettes are not proof that the depressions were full of water during the formation of the crescentic mounds. In view of these facts the initial theory of the genesis of the lunette land form is considered inadequate, and it is suggested that lunettes merely represent accumulation of wind transported material derived practically entirely from the floors of the adjacent associated depressions during a period in which they were dry. Their composition is governed by the nature of the material present on the surface of the dry floor, and immediately to the windward, during these periods, together with the minor loessial contributions as occur intermittently in the region as a whole.

The details of this theory are in full agreement with the qualified suggestions of Harris (*loc. cit.*), and they are supported by all the evidence and by the interpretation of Baldwin, Burvill and Freedman (1939). The latter describe the lunettes in the Kerang district as "accumulations on the leeward side of what are now depressions liable to inundation for varying periods. In one instance the rise was being added to at the present time with clay dust from the barren salty surface of such a dry swamp!"

The occurrence of lunettes in such humid environments as Lake Muir and in Tasmania also lends weight to the unlikelihood of atmospheric dust being the principal parent material. The possibility of a more arid climate in the past cannot, of course, be discounted, and there is ample evidence of such aridity (Crocker 1946) in southern Australia.

It is apparent from the regular curve and sweep of so many of the eastern lake and swamp shorelines, i.e., adjacent to the lunettes, especially by comparison with the western shoreline, that the accumulations making up the lunette can migrate small distances against the prevailing wind (see fig. 1, and pl. xlvi, fig. 1). The steep foreslope is an expression of the fact that the steepest gradient in surface roughness occurs at the shore, and the bulk of the windborne material is deposited there. Any vegetation on the lunette would prevent the re-initiation of particle movement necessary for the development of a steep back slope.

The recognition that lunettes can be either sandy or silty and clayey, or both, depending on the supply of material from in and across the depression during dry periods, places them merely as a special land form representative of a far more general expression. For example, the slightly higher and more loamy eastern sides of the swamps in the Kalangadoo sand regions of the Lower South-East is a minor expression of the same causative process (see fig. 2 (a)). In these swamps the supply of material for the formation of ridges was limited, as they are not part of any ancient or present drainage system or drainage by-way, being due to subsidence in the underlying limestone. The low loam mounds which occur along the eastern side of the Murray River and its anabranches (Hills 1939, p. 314) is a somewhat similar example, where the detrital material was limited. With a drainage system supplying ample sediments, or where the purely local supply is greater, the typical lunette land form develops. Depending on the source of the parent material these will be of either predominantly fine, predominantly coarse, or of fairly evenly mixed coarse and fine material.

It follows that one can expect in regions of finely fluviatile and lacustrine sediments, as in river terminals or flood plains, lunettes to be characterised by fine-textured material, and indeed they are, e.g., Kerang, Benjeroop, Boort, Swan Hill, etc. On the other hand, where a lunette occurs in a region in which erosion is more active, and the landscape less mature, unless the region is singularly free of sand, and coarse-grained rocks, it should be predominantly sandy. This is demonstrated at Wagin Lake which occurs in a valley of the dissected lateritic tableland. Where the supply of material is very large and conditions for the formation of wind-borne accumulations frequent or prolonged, the deposits may reach the status of littoral sand dunes, and lose the characteristic lunette regularity. They may at times tend to trail off as a small system of seif-like dunes, as with the Warobyan soil at Wakool, and partially the Doust sand at Salmon Gums.

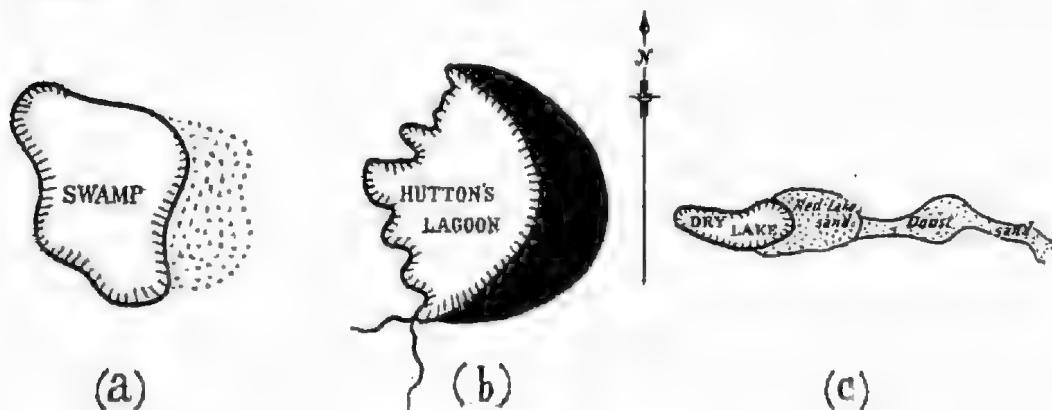


Fig. 2

Examples of three types of deposits which occur on the eastern side of depressions in southern Australia.

- (a) A "loam" accumulation near Kalangadoo, South Australia—supply of material capable of movement by wind limited.
- (b) Hutton's Lagoon, Ucolta, South Australia, with a typical lunette—supply of material moderate.
- (c) Relationship of Red Lake sand and Doust sand to a dry lake, Section 631, Salmon Gums, Western Australia (after Teakle *et al.*).—supply of material capable of wind transportation considerable.

The small series of dunes which frequently fringe the eastern sides of lakes and depressions in southern Australia have long been recognised as accumulations blown up from the dry lake bed. Such an explanation was put forward by Jack (1921) in illustrating the mode of formation of seed and flour gypsum deposits of the Murray Valley, Yorke Peninsula, etc. Hills (1929) recognises that the sand dunes east of Lake Hindmarsh are of this origin. It is of interest to note that in addition to the loam ridges occurring to the east of the Murray River and its anabanches, sand dunes also occur in a similar situation. An excellent example is afforded by the distribution of sand dunes along the Cochran-Yarrien Creeks—an old anabanch system associated with the Edward River—itself a Murray anabanch. (see soil map, Smith *et al.*).

Fig. 2 illustrates three types of resultant wind-piled accumulations that can occur with variation in the supply of detritus to a drainage depression which is alternately full and dry.

AGE OF THE LUNETTE LAND FORM

The age of the lunettes is uncertain. Hills considered (1940) that "lunettes belong essentially to the relatively wet late Recent epoch, although the view cannot be fully substantiated."

In the South-East of South Australia lunettes are plentiful on the flats in a region which is characterised by alternating strand dune ranges and swale flats, considered to have been elevated with intervening still-stands in late Pleistocene and Recent times. The lunettes south of Kingston in the same region are certainly Recent (Crocker and Cotton 1946). In Tasmania, the Little Hampton-Wilmore's Lane lunettes occur on a low lateritic tableland considered to be the floor of the Launceston Tertiary Basin, Pliocene in age (Singleton 1941). The dissection of this region was inaugurated in the Pleistocene, and is continuing today on a reduced scale. It is interesting that the dissection has left the most southerly of the lunettes without an associated lagoon. Smith *et al* (*loc. cit.*) consider the lunette formations in the Wakool region (N.S.W.) to be contemporaneous with the closely associated mallee rises. He believes the latter to be the oldest deposits and to have preceded the lacustrine and fluvial deposits of the Western Riverina, which are placed as late Pleistocene or early Recent. Hutton's Lagoon (S. Aust.) is on valley floor sediments, composed of mixed alluvial fan and colluvial apron material and undoubtedly Recent. Some of the lunettes on Kangaroo Island are associated with lateritic tableland, while those at Wagin Lake (W. Aust.) occur in a valley of a dissected lateritic tableland. As the major dissection of the lateritic peneplains is thought to have commenced in the late Pliocene or early Pleistocene, both these occurrences are post Pliocene.

It is apparent that the bulk of the lunettes belong to the late Pleistocene-Recent period, and that they have been forming for a considerable time, and are perhaps still being added to, as was suggested at Kerang by Baldwin *et al* (*loc. cit.*).

The fact that all the lunette soil types, e.g., Lake Roy, Kangaroo Island, Hutton's Lagoon (S. Aust.), Wagin Lake (W. Aust.), Kerang (Vict.), Warobyan sandy loam, Wakool (N.S.W.), etc., exhibit considerable differentiation and maturity of the profile is an indication of some age. The multiple lunettes are of especial interest. They have been seen in South Australia (South-East) and Victoria, and indicate either a migration westward or shrinking of the lake. In most cases the cause has probably been due to a sudden decrease in size of the lake, perhaps as a result of decrease in rainfall. In the South-East of South Australia the migration of the lake shore may have been influenced by tilting as suggested by Hills (1939). However, if this was so, there must have been shrinkage at the same time—in all cases of multiple lunettes observed, the present-day lake is much smaller in extent than the original one. The fact that the inner lunettes are very much smaller than the outer would indicate a shorter time for their formation, and/or a decrease in supply of suitable material (see pl. xlvi).

What influence the Recent arid conditions associated with a sudden decrease in rainfall, considered to have been responsible for the wholesale destruction of vegetation and loss of soil stability in southern Australia, has had in the formation of lunettes is difficult to assess. It is hardly likely to have had no influence, however, and may have been responsible for the initial drying up of lakes and lagoons, which have subsequently been alternatively wet and dry and are much shrunken in area.

SUMMARY

Notes on the distribution and composition of the lunette land form in southern Australia generally and analytical data on a number of soils from lunettes have been presented.

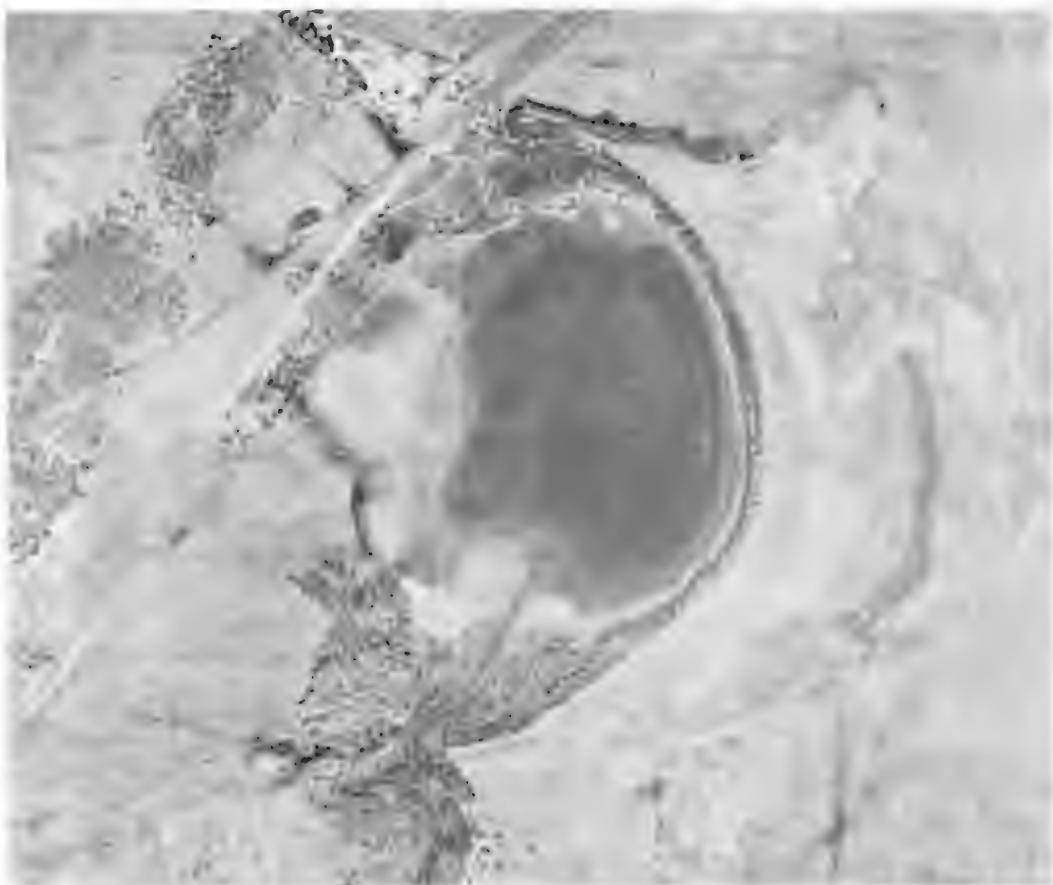
The initial hypothesis of their genesis put forward by Hills has been discussed and considered inadequate. As a more likely explanation than his spray-deposited atmospheric dust theory, it has been suggested that they represent accumulations of wind-transported material, largely derived from their associated depressions, called variously lakes, lagoons, swamps or pans.

It is demonstrated that lunettes can be dominated by the silt and clay or the sand fractions. That is that there can occur either silt-clay lunettes or sandy lunettes, or others in which the amount of silt or clay and sand is fairly evenly distributed.

Evidence for age of the deposits points to their being late Pleistocene-Recent, but all that can be said of some of them is that they are post-Pliocene, and this aspect requires further investigation. There seems little to indicate that they are associated with a relatively wet period of the Recent, as has been suggested.

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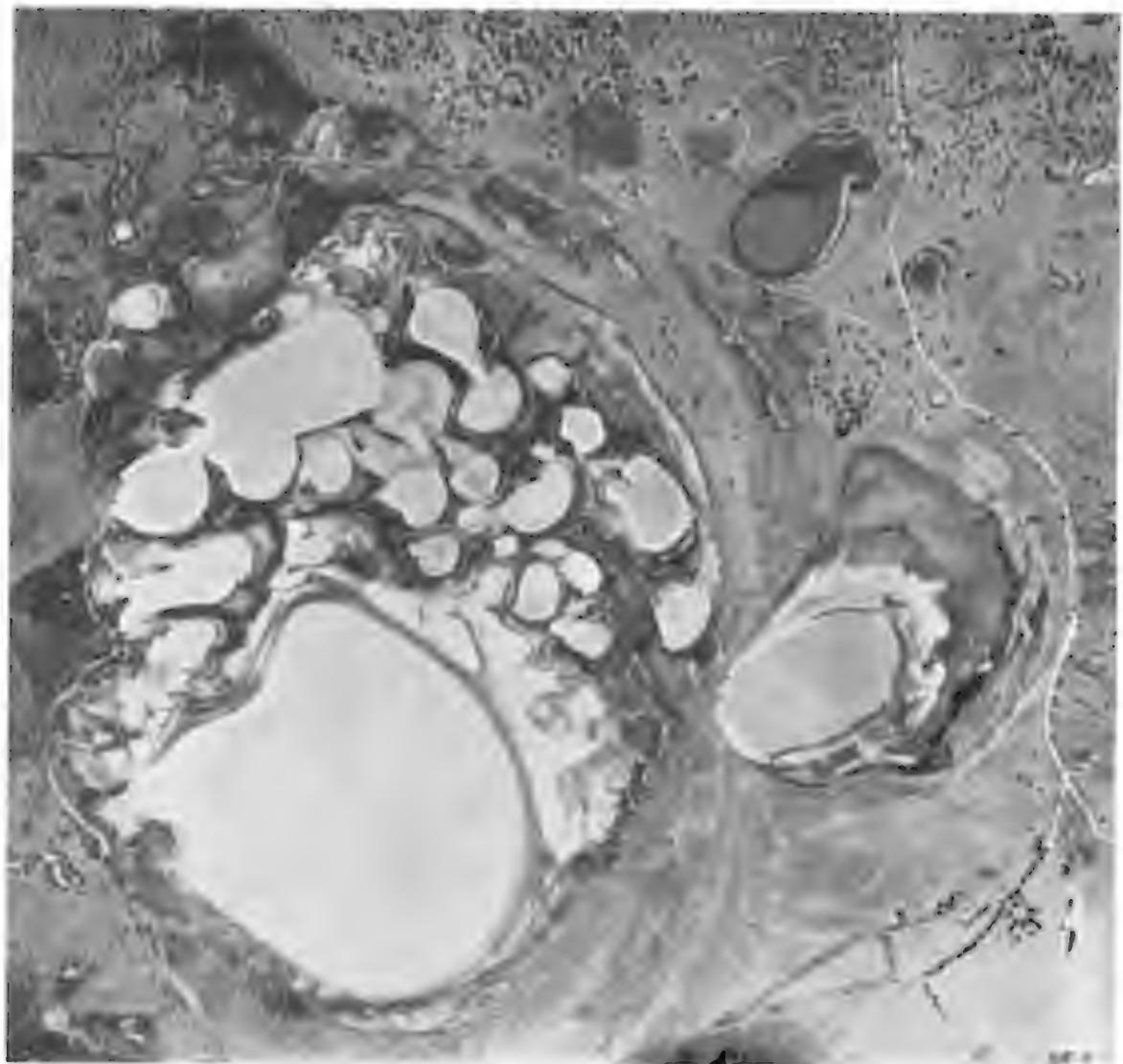


Hutton's Lagoon, Ucolta, Peterborough, S. Aust., showing the lunette on the eastern side and the smooth shoreline at the foot of its foreslope. (Vertical aerial view.)

N
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Typical cross-section revealed in the Wagin Lake, W. Aust. lunette by cutting of a track to the shore. Steeper foreslope to Lake and gentle backslope clearly seen.



A multiple lunette complex at Salt Lake, north-west of Naracoorte. (Vertical aerial view.)

RECONNAISSANCE GEOLOGICAL SURVEY OF PORTION OF THE WESTERN ESCARPMENT OF THE MOUNT LOFTY RANGES

BY REG. C. SPRIGG, M.Sc.

Summary

The remaining portion of W. Howchin's Type Area for the Adelaide Series (Upper Proterozoic and/or Eo-Cambrian) has been mapped and the geological history of the area with emphasis on orogeny is discussed. Howchin's broad findings on the Adelaide Series are confirmed, but his Pleistocene "dead river" theory in its local application is considered to be untenable.

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[Read 12 September 1946]

CONTENTS

ABSTRACT

The remaining portion of W. Howchin's Type Area for the Adelaide Series (Upper Proterozoic and/or Eo-Cambrian) has been mapped and the geological history of the area with emphasis on orogeny is discussed. Howchin's broad findings on the Adelaide Series are confirmed, but his Pleistocene "dead river" theory in its local application is considered to be untenable.

INTRODUCTION AND PREVIOUS INVESTIGATIONS

This contribution to the Geology of the Mount Lofty Ranges is the culmination of some two years private geological reconnaissance. The survey was undertaken to be presented as portion of a thesis for the degree of Master of Science. Since presentation the work has been expanded and slightly modified. The portion of the thesis dealing with Geomorphology has been published separately [Sprigg 1945 (2)].

The area surveyed includes portion of the main escarpment foothills east of the Adelaide Plains—St. Vincent Gulf senkungsfeld. To the north and south it is bounded by the Rivers Torrens and Sturt respectively. It includes, therefore, the northern extensions of the Eden-Moana and the Clarendon-Ochre Cove Tilt blocks. The Eden-Moana block has previously been mapped and discussed by the author (Sprigg 1942).

With the exception of two relatively small areas, geological mapping had been neglected in this region. Professor Howchin (1906), however, attempted to overcome this deficiency by a general description of the structure and stratigraphy of the younger basement rocks which he termed the Adelaide Series. These classical researches culminated in the preparation of a "type" sequence, which with slight modification is still accepted by most geologists. Mr. P. S. Hossfeld (1935), however, suggested radical modifications of the successional detail of the Adelaide Series as a result of his own broad-scale geological survey in the northern Mount Lofty Ranges.

In view of the close proximity of the area to Adelaide it is surprising that more mapping has not been undertaken in the past, but as Professor Mawson points out (1939), "the faulted and broken nature of these beds in the neighbourhood of Adelaide renders a more complete investigation difficult and unattractive." Furthermore, the series is practically unfossiliferous.

The areas which have been mapped include about five square miles in the Castambool vicinity by Howchin (1915) and approximately eight square miles by Messrs. T. A. Barnes and A. W. Kleeman (1934) covering the Waterfall Gully area. Howchin was attempting to elucidate the stratigraphical succession of the basal members of the Adelaide Series. Barnes and Kleeman set out to determine the thickness and stratigraphical relations of the Beaumont or Blue Metal Limestones and associated beds in one of Howchin's type localities. Howchin (1927) also published a geological sketch map of the limits of the Sturtian tillite near Eden.

There are a few very sketchy and incomplete records of mining operations published by the State Department of Mines. In 1928 Professor David announced that he had discovered in the Adelaide Series a "Lipalian Marine Fauna" of giant annelids and crustacea. He claimed that the fauna was distributed copiously throughout several horizons of the Adclaide Series within the type area.

GEOMORPHOLOGY

In a recent publication [Sprigg 1945, (2)] the author dealt at length with certain major features of the geomorphology and hydrology of the central Mount Lofty Ranges, which includes the area under discussion. In the development of the modern land forms within this area, Kosciusko block faulting has played a major role, and as this faulting is discussed later in this paper a very brief summary of the former work is given here.

In the early Tertiary Period much of South Australia had been reduced to a base surface, that is, a surface "old and fully dissected." This surface was then buried by Tertiary lacustrine and marine deposits (overmass sediments). Late in the Tertiary period block faulting commenced. Differential negative and positive movements of the various blocks, particularly those near Adelaide, resulted in warping and tilting. A new cycle of erosion thus initiated has led to the removal of much of the overmass sediments as well as much of the ancient erosion surface. The topography in the vicinity of the major fault escarpments is "young, well dissected."

In the author's paper the configuration of the major block fault pattern was outlined, using several recently developed methods of land form analysis. Polar analysis of stream flow directions provided data from which a new theory was developed embracing a wider interpretation of river capture as a dominant factor in the evolution of the Rivers Torrens and Onkaparinga, and certain smaller related streams. Finally, quantitative hydrological factors were calculated directly from Standard Military Survey Maps for the drainage basins and drainage nets of the Torrens and Onkaparinga. This data supported the author's contention that block faulting had controlled stream development very considerably.

GEOLOGY

Adelaide Series sedimentary rocks predominate throughout the surveyed area. The series includes all the horizons of Howchin's lower Adelaide Series from the Basal Ilmenitic Grits to the Sturtian Tillite. Two outliers of Barossian igneous and metamorphic rocks are exposed as the combined result of ancient fault movements and erosion.

The Adelaide Series sediments generally have not suffered severe folding except in the approaches to major fault zones. The presence of at least one major "competent" sedimentary formation, the Thick Quartzite, has inhibited such folding. Over the greater part of its outcrop the Thick Quartzite occupies a subhorizontal set or dips to the south and/or west at low angles.

At least three sets of faults disrupt the ancient rock series. Two of them date from the Palaeozoic era. These are respectively those associated with over-thrust movements, and a group of steeply dipping normal or reverse faults. The third group or high angle faults strike more or less meridionally and are approximately parallel in strike with regional cleavage, but this latter correspondence may be coincidental.

A protracted geological hiatus intervenes following the Palaeozoic deformation of these undermass rocks. The next record is of a nearly perfect fossil peneplain or base surface originally buried beneath sediments of late Oligocene or early Miocene Age. Evidence (Fenner 1931) favours the theory that such fluviatile sediments, and probably also Miocene Marine Sediments, originally covered the whole area.

With the advent of a third period of faulting (Kosciusko Epoch) the present Mount Lofty "Horst" Range took form. Contemporaneously deep dissection and the removal of the Tertiary sediments then began, exhuming the fossil peneplain and consequently exposing the undermass rocks. Today only scattered outliers of partly reworked oligocene sediments remain on this area, while the Miocene Marine Sediments tongue out on the "back" of the Eden-Moana Fault Block (Sprigg 1942).

ARCHAEozoic

In the present contribution the author uses the term Archaeozoic in C. K. Leith's sense. Leith (1933, 171) defines the "Archaeozoic as the underlying more or less indivisible, basement complex, containing igneous or sedimentary rocks or both, in which ordinary stratigraphic methods do not apply."

No detailed investigations were carried out on the metamorphosed sedimentary and igneous intrusives which are attributed to this period. The meta-sediments underlie the Adelaide Series with pronounced erosional unconformity, revealing a protracted geological hiatus—the ep-Archaean interval.

The original sediments have been metamorphosed to schists and gneisses. Within the areas mapped "normal" intrusion by igneous magma is not prominent. Igneous activity appears to have been restricted largely to lit-par-lit injection and to the formation of graphic quartz-tourmaline veins.

Mineralization of economic value has been very restricted in variety and extent. Occurrences of copper minerals, although not infrequent, are of poor grade and may have been formed in a much later period.

ADELAIDE SERIES (LATE PROTEROZOIC OR EO-CAMBRIAN)

Professor Howchin's classical researches into the stratigraphy of the Adelaide Series (1904, 1906, 1915, etc.) have formed the basis of a stratigraphical succession which has met with fairly general acceptance. Due partly to a lack of better exposures of the lowest members of the series elsewhere, Howchin made his most significant observations in an area on the Central Mount Lofty Horst near Adelaide. Unfortunately, as that author realised, this area was one of intense faulting, which rendered stratigraphical interpretations hazardous even after completion of systematic field mapping. The complete lack of fossils (with the possible exception of obscure problematica recognised by Professor T. W. E. David, 1922, 1928 and 1929) did not render the task easier.

More recently P. S. Hossfeld (1935) has disagreed fundamentally with Howchin's scheme and suggests radical modifications. Unfortunately, for reasons which will be dealt with in a later paper, the present author considers certain of Hossfeld's broader findings erroneous.

Mawson (1939 and etc.), who has been the principal worker in this field in succession to Howchin, has in general agreed with the latter's findings. Geological sections have been made across the Flinders Ranges in several places, and although as expected there is considerable variation in successional detail with Howchin's log, a broader correspondence is fair. Up to date, in the Flinders Ranges, Mawson has not succeeded in checking satisfactorily Howchin's findings on the basal members of the Series. He has attempted to overcome this deficiency in some measure by seeking out a section across these lower beds in a less disturbed though metamorphosed area nearer Adelaide, at Mount Magnificent [Mawson 1939, (1)]. Mawson writes that "the want of strict correspondence between the succession in the two areas (Howchin's Castambool area and Mount Magnificent area—R. C. S.), is perhaps partly explained by the fact that deposition in shallow waters at points 30 miles apart cannot be expected to be identical. It is especially remarked that whereas the marble horizons of the Torrens Gorge sections are highly magnesian, those met with in the Mount Magnificent area are notably deficient in magnesia."

Others who have carried out research on the series include Madigan (1925, 1927) and Barnes and Kleeman (1934), whose findings in general support

Howchin's scheme. Segnit's findings (1939, 1940), although extensive, are very confused, and it is now generally agreed (Mawson 1939; Sprigg 1942; Broadhurst 1943) that his geological survey results are practically valueless.

The present author has now mapped most of Howchin's type area, which includes the foothills region about Adelaide from Marino on the coast to the Torrens Gorge. In a previous publication (Sprigg 1942) beds of the Adelaide Series from the base of the *Archaeocyathinae* limestones down to the Sturtian tillite were discussed. In the text which follows sediments from the tillite down to the basal ilmenitic sandstones are considered, and the writer has subdivided formations of the Adelaide Series dealt with into two portions—the Lower and Middle divisions. The line of division is made at the base of the Glen Osmond Arkosic Quartzite.

LOWER ADELAIDE SERIES

The Lower Adelaide Series in this contribution is defined as including all sediments from and including the Basal Ilmenitic Sandstone or conglomerate up to the base of the Glen Osmond Quartzite.

Concerning the lowest horizons of this group, the writer considers that not all such beds are exposed within the "type area." However, the major sedimentary horizons as they occur in the area will be discussed, beginning with the Basal Ilmenitic Sandstone and the probable locations of gaps in the record noted.

Basal Ilmenitic Sandstone

This horizon has been located at two relatively widely separated situations in the area mapped, namely at the Torrens Gorge near Castambool, and adjacent the Prince's Highway between Crafers and Stirling. At neither locality are the outcrops good or extensive. Faulting in both cases has complicated the immediate stratigraphical succession to such an extent that it is impossible to say with any degree of certainty what is the nature of the immediate overlying sediments. However, the marked unconformable relations of the sandstone with the Archaeozoic complex are clear. No reliable estimate of the thickness of the unit is possible, but it is at least 100 feet thick, and possibly much more and variable.

In his map of the basal beds in the Castambool type area, Howchin (1915) indicates a south pitching major anticline with a core of Barossian igneous and metamorphic rocks. He records "on the western and southern side of the older rocks, the basal grits of the Cambrian Series (Adelaide Series—R. C. S.) outcrop at a low angle of dip. They closely resemble the ilmenitic grits of Aldgate, with an occasional pebble included."

The author has failed to locate the basal bed on the western side of the pitching anticline, but instead Howchin's Lower Torrens Limestone is faulted against the old core rocks, somewhat as can be interpreted on Howchin's map. On the eastern side another fault has brought a faintly ilmenitic bed of sandstone quartzite with overlying white marble against the old rocks. To the south the two faults unite and continue as the Stonyfell fault. Within the angle formed by these two south converging faults, the unconformable relations that the basal ilmenitic sandstone bears to the Barossian is readily apparent. Post-basal-sandstone sediments are not visible in the sector, and so the relations are obscure.

The author has been unable to decide for certain whether the "faintly ilmenitic bed of sandstone quartzite" mentioned above is the basal ilmenitic horizon, but apparently it is. However, this sandstone is overlain by slates and then a cream-coloured cryptocrystalline marble which is Howchin's Lower Torrens limestone.

Alternate Sandstones and Silty and Sandy Slates

This group of sediments, which will be treated as a unit, outcrops widely to the east of the area. Extensive exposures occur near Stirling, where the relations of the bed with the basal ilmenitic sandstone are not clear. It appears possible, however, that the unit may follow closely above the recognised basal sandstones, as it contains some ilmenite and its structural relations appear to tie it in with that horizon. It may even belong to a hitherto unrecognised series. Nevertheless, no positive statements can be made in this regard.

This formation of arenaceous and argillaceous sediments is at least 2,000 feet in thickness, is arkosic in part and contains laminations of heavy minerals not unlike some facies of the basal ilmenitic sandstone. Its relations with the Torrens limestones so far is unknown.

The Torrens Dolomites and the Lower Phyllites

Sediments of this association are dominantly fine-grained. They comprise dolomitic limestone, dolomite and magnesite interbedded with calcareous slates and phyllites, and minor sandstone quartzites occur frequently in the section.

On the area mapped the dolomites are practically limited to the Castambool and lower Sixth Creek vicinities. More restricted exposures occur in Fifth Creek and in Horsnells Gully. Howchin recorded the former occurrences, and upon completion of field mapping in this "type" locality arrived at a tentative sedimentary sequence for the limestones and the basal ilmenitic sandstone. He indicated a white and buff-coloured marble (Lower Torrens Dolomite) 150 feet thick, separated from 200 feet of blue limestones with interbedded slates (Upper Torrens Dolomites) by 1,000 feet of phyllites which include two bands of quartzite. The writer's investigations have indicated a similar succession but that there is greater development of the upper limestones. In Pinkerton Gully blue-grey dolomitic limestones occur through a stratigraphical thickness of about 500 feet, and in Pinkerton Gully and near the River Torrens lower weir a comparable thickness was also noted.

The Lower Torrens dolomite is a creamy-white or buff-coloured cryptocrystalline marble. Normally, it is massive throughout, although in some horizons there is a tendency to indistinct lamination. Not infrequently the marble is somewhat schistose with development of micaceous minerals. The Upper Torrens dolomites are much less homogeneous and range in colour from grey to dark blue-grey. Nodules of chert are not uncommon, and some bands are slaty and carbonaceous. Minor bluish and grey quartzites are interbedded with these upper dolomites.

It is suggested that the type section for the limestones be taken along the eastern side of Pinkerton Gully, as this appears to be the only section in the area not seriously affected by cross-faulting. It includes beds from the base of the Lower Torrens Dolomite to within a few hundred feet of the base of the Thick Quartzite. Major north-south faults occur on either side of the block, but do not appear to have disturbed the beds significantly. Compared with other local exposures of these beds there are several minor discrepancies which may be resolved when detailed mapping of the type area has been undertaken. For example, it is noticed that in Sixth Creek, above the Stonyfell Fault, beds of blue dolomitic limestones are overlain by a much greater thickness of phyllites and slates than in the Pinkerton Gully Section. The log of strata given is for the Pinkerton Section.

The successional detail of Pinkerton Gully Section is as follows:—

| Item No. | Feet | |
|----------|---------|---|
| 25. | 400+ | Phyllites with few very minor dark grey dolomites at intervals, and small sandstone bands. |
| 24. | 12 | Banded impure dolomites with chert. |
| 23. | 25 | Massive blue dolomite with suggestion of "Mawsonella" structure. |
| 22. | 3 | Irregularly banded quartzite. Bands weather in relief, suggesting calcareous cement in alternate bands. |
| 21. | 35 | Phyllites with a few thin quartzites. |
| 20. | 6 | Thin dolomites in phyllite. |
| 19. | 1 | Very cherty blue banded dolomite (Analysis No. 5). |
| 18. | 25 | Grey dolomites with bands of "Mawsonella" siliceous dolomite (Analyses No's. 4 and 3 respectively). |
| 17. | 10 | Massive light grey dolomite with magnesitic "Mawsonella" bands. |
| 16. | 12 | Phyllites. |
| 15. | 15 | Massive to slaty blue dolomite. |
| 14. | 15 | Phyllite. |
| 13. | 15 | Blue dolomite with plentiful chert inclusions. |
| 12. | 4 | Medium-grained sandstone quartzite; grains weather in relief. |
| 11. | 15 | Slaty blue dolomite. |
| 10. | 100 | Phyllites with very minor blue dolomites. |
| 9. | 15 | Medium-grained massive quartzite; grains weather in relief. |
| 8. | 70 | Calcareous phyllites and plentiful thin-bedded blue-grey dolomite. |
| 7. | 10 | Massive blue-grey dolomite. |
| 6. | 40+ | Quartzite. |
| 5. | 150-200 | Slaty-phyllites with minor blue limestones. |
| 4. | 30 | Massive quartzite. |
| 3. | 400+ | Phyllite with minor quartzites. |
| 2. | 50+ | Reddish medium-grained sandstone quartzite. |
| 1. | 150? | Lower Torrens light buff-coloured dolomite (Analyses 1 and 2). |

Items numbered 7 to 24, inclusive, constitute Howchin's Upper Torrens Dolomites. It is to be noted that a section across the Mawsonella magnesites in the Torrens Gorge, near the weir, indicates a greater development of these sediments.

Analysis of the dolomites are quoted in Table I and the approximate stratigraphical position of the samples is indicated in the log of strata. The lower limestone is essentially a dolomite, and as such is very different from the Angaston, Paris Creek and Mount Magnificent marbles (Table I), which are almost pure calcium carbonate and which, not without doubt, have been considered contemporaneous [Mawson 1939 (1)].

TABLE I

| Serial No. | Locality | Colour | Analyst | CaCO_3 | MgCO_3 | Insolubles or etc. |
|------------|---------------------|-----------|----------|-----------------|-----------------|-----------------------|
| 1 | - - Torrens Gorge - | l. buff | T. W. D. | 49.2 | 42.5 | 7.8 |
| 2 | - - " " | " | " | 50.9 | 44.1 | 4.7 |
| 3 | - - " " | l. grey | " | 6.5 | 72.0 | 21.6 |
| 4 | - - " " | blue-grey | " | 44.5 | 36.7 | 17.0 |
| 5 | - - " " | " | " | 48.3 | 38.8 | 8.1 |
| 15 | - - Angaston - - | white | " | 96.6 | 1.8 | 2.3 |
| 16 | - - Paris Creek - | " | " | 98.7 | 0.5 | 0.5 |
| 17 | - - Mt. Magnificent | " | W. B. D. | 96.6 | 0.8 | 1.8 |

T. W. D. = T. W. Dalwood, Government Analyst. W. B. D. = W. B. Dallwitz [Mawson 1939, (1)]. 1, 2-Lower Torrens Dolomite of Howchin; 3—"Mawsonella" siliceous magnesite, Upper Torrens horizon; 4, 5—Upper Torrens Dolomites; 15, 16, 17—Angaston Marble.

Several distinct horizons within the Upper Torrens Dolomites are siliceous magnesites. These magnesites are readily recognised by the "Mawsonella" structure associated with them. Chapman described such structure as an algal form (*Mawsonella wooltanensis*) having affinities with the living *Halimeda*. However, field observations on this widely occurring structure leave little doubt that it is inorganic origin, as was shown by Mawson and Dallwitz (1945) during field investigations near Umberatana. Where the structure has been studied in the Torrens Gorge and along the Corkscrw Hill Road many gradations between normal "Mawsonella" and obvious intraformational breccias or edgewise conglomerates have been observed. Some of the "breccias" are of the "desiccation" type of mud curl. The importance of Mawsonella structure stratigraphically will be discussed in a later publication dealing with aspects of sedimentation in the Adelaide Series.

The Thick Quartzite

This massive horizon forms the bolder scenery of the western Mount Lofty Ranges. Repeated dip faulting has displaced the quartzite in such a manner that in outcrop the rock formation now occurs in isolated "slabs" surrounded by slates and limestones. Of the more important of these "islands," the most northerly, forms Black Hill. To the south these are successively the outcrops which form Rocky Hill, Slapes Hill (Stonyfell) and Mount Lofty. The most southerly outcrop commences just to the west of Upper Sturt and continues across the River Sturt towards Cherry Gardens.

The quartzite shows little variation in mean grain size of the sand fraction throughout its entire thickness. The amount of granular felspar (or its alteration product) contained, however, is more variable. The original sediment was obviously a well-washed and sorted sand deposited in an aqueous environment. Where the quartzite forms cliffs, variations in hardness (largely due to irregular secondary silicification) are apparent, and it is seen that some bands are much more massive than others. Some massive bands may measure almost 100 feet in thickness with little apparent macroscopic variation. In other horizons there is a tendency to slabbiness, the relatively thin layers of solid stony being separated by thin partings of clayey or slaty material. There is little apparent gradation in grain size from the Thick Quartzite into both the underlying and overlying sediments. In several localities there is a restricted alternation of thin bands of slate and sandstone quartzite for a short but variable distance above and/or below the quartzite.

The low but variable angle of dip of the quartzite and a scarcity of good dip readings in the bed make estimation of its thickness approximate only. A thickness of about 1,000 feet is indicated, and this agrees with Howchin's (1906) estimate.

Dip is to the south or west and rarely exceeds 20°, except in the vicinity of the larger faults. At the "Three Sugarloafs" a northerly dip of 4° was recorded, but this is probably related to faulting in that vicinity.

In most exposures the base of the quartzite appears conformable with underlying sediments. To the east of Dunstone's Quarries a doubtful slight unconformity with an underlying 20-ft. quartzite has been noticed. It is thought more probable that the apparent convergence here of the two arenaceous formations may be a drag effect in the enclosed relatively incompetent slates in the proximity of the great Stonyfell fault.

The considerable degree of ancient meridional block faulting to which the bed has been subject, in combination with its subhorizontal set, is responsible for its

relatively large area of outcrop and the co-related widespread production of poor, shallow, acid, gravelly and sandy podsolic soils.

The Upper Phyllites

This group constitutes a considerable thickness of dominantly argillaceous sediments in which in the upper portions several quartzites appear together with some very minor limestones (dolomites). When Howchin classified the group as phyllites he correctly observed that the alteration from slates to phyllites is frequently associated with fault movements.

The junction of the Thick Quartzite with overlying slates and phyllites is mostly quite sharp. There is no prominent gradation in grain size of the sediments and little alternation of sandy and slaty bands. The lower portion of the phyllites or slates show little variation, laminations are not pronounced except in restricted horizons and quartzite bands are not prominent. Approximately 650 feet above the base, however, there is a strong quartzite bed. It is 30-40 feet thick and is fine- to medium-grained, cross laminated and banded. A characteristic weathering effect in which certain bands etch out in relief as though in part calcareous, renders it a useful field marker horizon. In some localities the upper 10 feet are finer-grained and well laminated. Foreset laminations in the sandstone, where studied, indicate currents from the south. With this bed is associated a yellow dolomite. A smaller bed, a laminated fine-grained quartzite, occurs about 100 feet below, and with this a thin band of blue limestone is associated.

Additional quartzites occur above the coarser-grained bed. One such is 15 feet thick and occurs 800 feet above the Thick Quartzite.

These several quartzites can be seen to advantage on the south slopes of Waterfall Gully, but they also outcrop one to two miles east of Belair Railway Station and along the escarpment east of Coromandel Valley.

The relations that these beds bear to the Blue Metal or Beaumont Dolomites is not known accurately, as the Beaumont fault has prevented measurement of an unbroken sequence. The thickness of sediments "outfaulted" is probably not great.

The Beaumont Dolomites

Essentially this group is made up of a number of dark grey dolomites set in calcareous slates in which there are also several small quartzites. Beaumont dolomites outcrop in several "isolated" localities, their position being determined largely by faulting. The most northerly occurrence within the area flanks Rocky Hill on the west. To the south the group appears in the Magill-Stonyfell area, at Beaumont, and in Brownhill and Chambers Creeks.

In the preceding sedimentary group, namely the upper phyllites, there is a definite increase in lime content in the upper horizons. Several minor limestones appear, and these are the fore-runners of the Beaumont period of deposition of highly calcareous sediments. In fact, the gradation from the upper phyllites to the Beaumont dolomites is such that if the full sequence was available for study, difficulty would probably be experienced in deciding upon a division. However, the intervention of the Beaumont fault has made a useful if rather arbitrary break.

The slates immediately above the base of the Beaumont group include one or possibly (near Waterfall Gully) two light cream-coloured crypto-crystalline

dolomitic marbles. The main bed overlies a reddish coarse-grained sandstone quartzite. It has been located in association with the Blue Metal (Beaumont) dolomites at Beaumont and in Brownhill Creek, and chemical analysis of samples taken in these two localities indicate a very close correspondence in composition. An apparently similar limestone was located on the western slopes from Rocky Hill, and on the south slope from Sturt Creek immediately to the east of Coromandel Valley.

Typical "Blue Metal" dolomites overlie the cream-coloured dolomitic marble; these beds have been dealt with in detail by Barnes and Kleeman (1934), and readers are referred to this paper for a more complete description of them. The authors measured 370 feet of sediments which included approximately 50 feet of dolomitic limestones disposed in 13 bands, the thickest measuring 15 feet and occurring at the lowest horizon.

Barnes and Kleeman made eight analyses of Beaumont dolomites, and for purposes of comparison made analyses of Howchin's upper and lower Torrens limestones (pre-Thick Quartzite formation). These analyses are reproduced herein in terms of CaCO_3 and MgCO_3 , together with additional analyses by the Government Analyst (Table II).

TABLE II
Dolomites and Dolomitic Limestones of the Beaumont or Blue Metal
Dolomite Series

| Serial No. | Locality | Colour | Analyst | CaCO_3 | MgCO_3 | Insolubles or etc. |
|------------|------------------------------|-----------|----------|-----------------|-----------------|-----------------------|
| 6 | - Beaumont - | I. buff - | T. W. D. | 47.0 | 34.9 | 12.7 |
| 7 | - Brownhill Creek | " | " | 49.9 | 38.0 | 6.9 |
| 8 | - Beaumont - | dk. grey | T. A. B. | 37.8 | 30.5 | 32.7 |
| 9 | - Mountain Hut - | " | " | 38.8 | 30.9 | 30.9 |
| 10 | " " | " | " | 40.9 | 31.7 | 30.6 |
| 11 | - Beaumont - | " | " | 42.7 | 32.3 | 27.4 |
| 12 | - Mountain Hut - | " | A. W. K. | 43.8 | 34.0 | 25.4 |
| 13 | - Beaumont - | black - | T. A. B. | 80.0 | 12.8 | 8.6 |
| 14 | - Mount Osmond turn-off - | dk. grey | " | 34.1 | 29.2 | 35.8 |

T. W. D. = T. W. Dalwood, Govt. Analyst.

T. A. B. = T. A. Barnes.

A. W. K. = A. W. Kleeman.

Referring to their results the authors write: "These analyses show remarkable similarity between the main Blue Metal Limestone over the whole area. The high silica percentage occurs as free quartz in the slide. The carbonate portion is purely dolomite; thus the rocks would be more truly classed as dolomites. The inclusion of the analyses of the two Torrens Limestones is for comparison purposes. It was thought that some distinction might be made between the Blue Metal and Upper Torrens Limestones on chemical grounds. There seem to be no essential differences, the higher percentage of magnesia in the Upper Torrens Limestone being due to weathering, which in these areas tends to the formation of magnesite. Nos. 9 and 17 are representative of the upper beds above the Blue Metal Series. No. 17 is quite regular except for a greater percentage of clay. No. 9 is composed entirely of black calcite with curved faces which give an unusual appearance in hand specimen. It forms an inconsistent band."

The correspondence in chemical composition between the Upper Torrens Limestone and the Upper Blue Metal (Beaumont) Dolomites as indicated by Barnes and Kleeman is interesting. More so since the present author located the white cryptocrystalline marble in the lower Beaumont group which exhibits strong affinities with the Lower Torrens Dolomite. This evidence led the writer to anticipate contemporaneity for deposition of the two groups. Similar impressions apparently were in the minds of Barnes and Kleeman upon completion of their analyses. However, subsequent field mapping has proved such a theory untenable. Stratigraphically the Torrens Dolomites underlie Howchin's Thick Quartzite, but the Beaumont Dolomites occupy a superior position relative to the marker formation.

A moot point raised by Barnes and Kleeman (see above) concerns the higher percentage of magnesia in the Upper Torrens Dolomite, which they attribute to the effects of weathering. This inference may or may not be correct, but the occurrence of magnesitic "Mawsonella" horizons in the Upper Torrens Dolomites favours generally higher percentages of magnesia in that group as a whole. The "Mawsonella" sample submitted for analysis was taken apparently unweathered from a deep road cutting. Similar Mawsonella beds in the Flinders Ranges (*e.g.*, near Port Germein) are almost pure magnesite at the surface, and the high percentage of magnesia has been shown to persist at depth.

The creamy-white or buff coloured cryptocrystalline marble of the Beaumont group has not been recorded previously. The marble exhibits distinct laminations in many instances, but otherwise in hand specimen and in chemical composition is very like the Lower Torrens Dolomite. The unit is not restricted in field occurrence. It was first noted adjacent to the Beaumont fault a little north-east of Goldsack's quarries. The marble is ten to twelve feet in thickness. It occurs again in Brownhill Creek, where it shows similar stratigraphical relations, *viz.*, it overlies a medium coarse-grained reddish sandstone and underlies the principal Blue Metal Dolomites. Apparently the same bed outcrops on the southern slopes to Sturt Creek upstream from the Ochre-Cove block fault, and a similar dolomite was noted immediately west of Rocky Hill about half of one mile north of Waterfall Gully.

The Glen Osmond Slates

Concerning these sediments, the following details given by Barnes and Kleeman (1934) are informative: "The phyllites between the Blue Metal (Beaumont Dolomites—R.C.S.) and the Quartzite (Glen Osmond Arkosic Quartzite—R. C. S.) exhibit a sequence. The beds just above the Blue Metal are calcareous phyllites with a few interbedded thin limestones. These semi-calcareous beds occupy 440 feet above the Blue Metal. Above them come 370 feet of argillaceous rocks without the thin limestones. Then follows 670 feet of silty rocks, which suggest a gradual development of the conditions which lead to the quartzite."

This description probably does not indicate the complete transition to the Glen Osmond Quartzite. Field mapping has revealed an important fault striking north from Brownhill Creek across Mount Barker Road towards Mount Osmond. To the east of this fault the beds are relatively undisturbed, but to the west the Glen Osmond Quartzite is folded severely and even overfolded (in Unley Corporation Quarry).

By reason of this faulting and an absence of better sections the complete relationship that the Glen Osmond Quartzite bears to the Beaumont Dolomites is unknown.

THE MIDDLE ADELAIDE SERIES

Under this heading only sediments from the base of the Glen Osmond Arkosic Quartzite to the top of the Sturtian Tillite are discussed in this paper. The author has dealt with other overlying Middle and Upper Adelaide Series Sediments in a previous publication (Sprigg 1942). These latter sediments include the Tapley Hill Slates and Limestones, and the Brighton Limestones of the Middle Adelaide Series, and the "purple" or Upper Adelaide Series which includes slates and quartzites up to the base of the Cambrian Archaeocyathinae limestones.

Following deposition of the Beaumont Dolomites group, the prevailing conditions of sedimentation suggest that there was once again a slow increase in erosive activity on the adjoining land mass. The Beaumont Dolomites had been deposited under quiescent conditions, during which interval there was little increment of clastic sediment.

From then onwards muds in increasing quantities were carried into the geosyncline. Succeeding sediments increased gradually in grain-size, and became more silty. The gradation generally was excellent. Unfortunately, because of faulting, the full extent of sediments deposited immediately preceding the culmination of this slow change has not been studied. Some degree of lamination is noticeable in the upper zone, more particularly immediately underlying the Glen Osmond Arkosic Sandstone Quartzite.

Despite this slow "build up," the junction of the Glen Osmond Quartzite with the Glen Osmond Clay Slates is sharp. The author feels that this is a convenient lower limit to the Middle Adelaide Series. The arkosic quartzite has certain features which the present author claims foreshadows the glaciation of the Sturtian Ice Age. Arkoses and varve-like associations may reflect a fluvio-glacial origin.

The Glen Osmond Arkosic Quartzite

This quartzite forms a prominent feature in the foothills region, extending from Glen Osmond to Viaduct Gully. Outcrop of this horizon is repeated by folding and faulting in the zone immediately east of the Sturtian Tillite, extending south to and beyond Sturt Gorge.

The quartzite is not homogeneous laterally or vertically. Bands vary considerably in mineral composition from arkosic gravels to laminated hard quartzites. Howchin has recorded that the proportion of felspar to quartz in the arkosic band is 30% to 40% (specimen taken at Mitcham). In view of the relatively close stratigraphical association with the Sturtian Tillite the present author suggests that the presence of so much felspar, much of it very little altered, favours fluvio-glacial origin. The arkose probably reflects rapid accumulation and possibly cold climatic conditions, and the horizon may possibly correspond with the lower tillite which outcrops over much of the north-eastern district of South Australia (Howchin 1908 and Jack 1913).

The Mitcham Slates and Quartzites

This group should include the Glen Osmond Arkosic Quartzite, but as the latter is a valuable marker horizon it has been considered advisable to continue to distinguish the Glen Osmond Quartzite from subsequent quartzites, as Howchin did. Due to this association of the Glen Osmond Quartzite with the Mitcham Slates and Quartzites, the localities of outcrop already given for the Glen Osmond Quartzite also apply to the Mitcham sedimentary group.

As pointed out earlier, the Glen Osmond Quartzite introduces a period of clastic sedimentation characterised by marked fluctuation of coarser- and finer-grained sediments. The slates are frequently silty, siliceous and laminated, and the quartzites show even more variation in type. They range from massive reddish and white quartzites through flaggy and banded variants to fissile finely laminated quartzites and (?) varves. Sandstones are not uncommon, and many of the quartzites exhibit shaly partings. In thickness the quartzites are very variable, indicating considerable instability of either, or more probably, both, the local landmass and/or climate.

The slates immediately overlying the Glen Osmond Arkosic Quartzite exhibit pronounced banding and lamination. In many instances there is a pronounced alternation in coarseness or fineness in grain size from lamination to lamination which strongly suggests varve formation. Also, within 100 feet of the base of the Sturtian Tillite, remarkable varve associations have been found amongst fissile quartzites. In conjunction with other factors, namely the arkosic formation described previously, and the presence in the north-east districts of the State of two well-developed tillites of Upper Adelaide Series age, these varve-like formations strongly suggest fluvioglaciation at about this horizon.⁽¹⁾ The local Sturtian Tillite (in its type area) can possibly be correlated with the upper horizon in the north-east. If this is accepted there is a big possibility that the lower tillite in that area is contemporaneous with the arkosic and the problematical varves of the Glen Osmond Quartzite vicinity.

Regarding the sediments overlying the Glen Osmond varve-like slates, difficulty has been experienced in determining the complete succession. At least four prominent quartzites, and possibly more, are included in the sequence in addition to minor "slaty" quartzite bands. Detailed survey will be required to determine the exact chronological succession, as the extent of deformation to which these beds have been subject renders interpretation difficult and measurement only approximate.

The Sturtian Tillite Formation

The author (1942) has previously dealt with this datum horizon as it occurs at Sturt Gorge. For additional details, readers are referred to the extensive work by Howchin (1908, 1927, etc.) on this subject.

The tillite possesses a well-cleaved slaty or phyllitic base in which, dispersed irregularly, are a typically unassorted collection of sedimentary, igneous and metamorphic "erratics." Larger erratics are frequently several feet in length, and some boulders are strongly faceted. The tillite mass shows effects of considerable stress and many erratics are elongated in the direction of slaty cleavage (fig. 1) and fractured transversely.

The Sturtian formation is not all typical tillite, but certain horizons represent normal fluvioglacial interludes. Several such bands are gritty and gravelly quartzites, and others include laminated slates. The conclusion of glaciation in the locality is anticipated by the appearance of fluvioglacial quartzites and gravelly conglomerates, and limestones interbedded with minor bands of tillite. The tillite and fluvioglacial sediments were deposited in an aqueous environment—a standing body of water.

⁽¹⁾ The author is grateful to Sir D. Mawson for drawing attention to a paper of his in which reference was made to certain of these varve-like associations. The paper was read to the A.A.A.S. meeting in 1907, but only the title was published in the Proceedings of the Association. Sir Douglas referred to the possible fluvioglacial origin of some of these varve-like structures.

Measurements carried out on the tillite formation (including the fluvio-glacial horizon) indicate a thickness of at least 1,200 feet. Unfortunately, over-folding and minor overthrusting has probably reduced the observable thickness and consequently the reliability of the estimate.

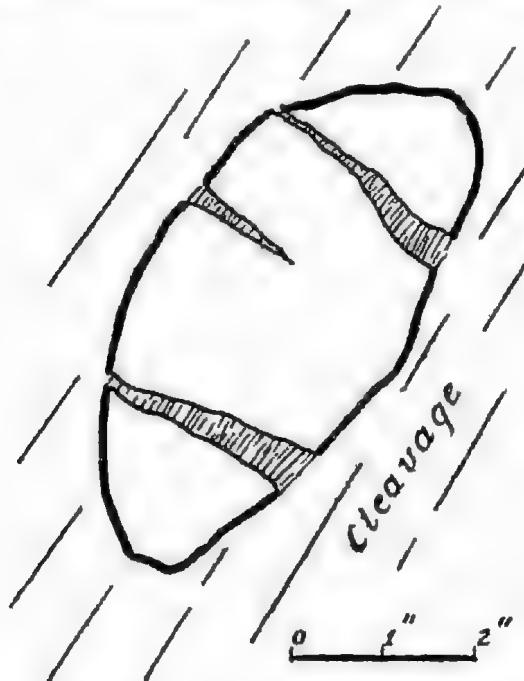


Fig. 1

Sketch section through a deformed tillite erratic as it appears on a vertical plane in the direction of regional cleavage dip. Relationships between cleavage, pebble elongation and transverse fracturing are indicated. The latter tension fractures are frequently partially filled with fibrous quartz.

Howchin (1927, p. 335), in at least one of his papers, refers to an unconformity at the base of the tillite in Viaduct Gully, Eden. He writes: "The unconformity of the tillite to the older rocks is here a conspicuous feature. The Mitcham Quartzites and Slates, which coming from Sleep's Hill quarries, strike south-westerly through Ayliffe's old quarries and, either by a curve in strata or by subsidiary faulting, meet the tillite in the Viaduct valley at right angles." In other publications Howchin indicates an unbroken succession from below the Mitcham Quartzites and Slates through the tillite into the Cambrian Archaeocyathinae series.

The geological sketch map which accompanies Howchin's impression on the possible unconformity shows an "infaulted" block of tillite to the west of Eden with pre-glacial quartzites running directly up against the fault. However, careful observation indicates that this is not the case. The quartzites and slates are folded and overfolded quite severely and are slightly faulted, but the folds definitely pitch south across Viaduct Valley and pass conformably below the tillite (fig. 2). Tillite is preserved in a pinched synclinal trough to the north of the creek, but this exposure was evidently not observed by Howchin.

NOTES ON BROADER SEDIMENTARY FEATURES OF THE ADELAIDE SERIES IN THE ADELAIDE REGION. A SUMMARY

The basal member of the series in the area mapped is an ilmenitic and somewhat arkosic sandstone quartzite. The original sand was a well washed and graded product of erosion from an environment of igneous and metamorphic rocks. The big development of heavy mineral laminations in the sandstone and the occurrence of basal conglomerates in some localities in the Mount Lofty Ranges, suggests proximity to a landmass or more probably deposition in a shallow sea dotted with small islands.

There is some uncertainty as to the next stratigraphical unit. Howchin indicates that the Torrens Dolomites and Phyllites succeed immediately, and such appears to be the case in the Torrens type area. However, in the Crafers vicinity and east of Mount Lofty generally, there appears a thickness of at least 2,000 feet of alternate argillaceous sandstone and silty slates, which near Aldgate and

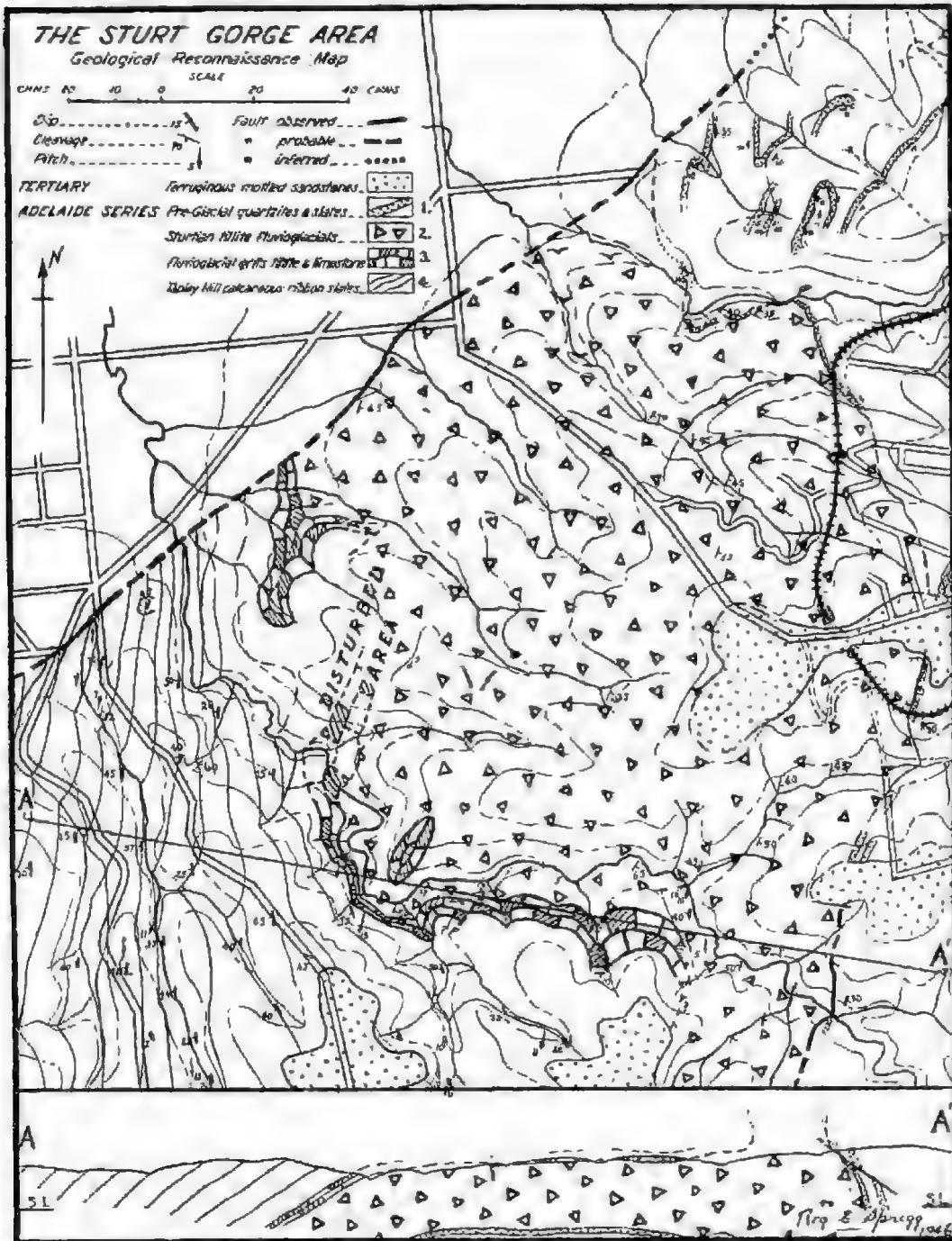


Fig. 2
The Sturt Gorge Area.

Crafers apparently rest conformably on a basal ilmenitic sandstone. It may be that the original Archaeozoic floor to the geosyncline was uneven, presenting a sedimentary environment of the Archipelago type. In this manner rapid variations in sediment type and thicknesses of basal or near basal units would be expected. As more sediments accumulated on the sinking geosynclinal floor, the effects of the original topographic irregularities would be neutralised and consequently lateral variation in younger individual sedimentary units would ultimately be minimised.

The succeeding sedimentary phase is dominated by deposition of calcareous muds and dolomitic limestones (the Torrens stage). Next there is an important development of arenaceous sediments to form the Thick Quartzite, and this is followed by the accumulation of more calcareous and argillaceous sediments of the Beaumont stage. It appears that following deposition of the basal beds there was a prolonged phase during which environmental conditions led to the deposition of a relatively thick series of calcareo-argillaceous sediments. Minor environmental variations led to accumulation of quartzites interbedded with the slates and dolomites, while a major interphase resulted in the formation of the Massive Thick Quartzite. It is suggested that the beds from the base of the Torrens stage to the top of the Beaumont stage, inclusive of the Thick Quartzite, be known as the Dolomites phase.

As a matter of interest, the occurrence of *Mawsonella* structure in magnesite beds associated with dolomites (Torrens stage) below Howchin's type Thick Quartzite but above Mawson's Thick Quartzite of the Flinders Ranges suggests that the two "Thick" Quartzites are not contemporaneous. If this theory is accepted, the complete Dolomites phase of Howchin's sequence (*i.e.*, Torrens to Beaumont stages, inclusive) could be correlated with Mawson's dolomite-magnesite sequence of the Flinders Ranges. In this manner Mawson's Thick Quartzite may prove to be the equivalent of the basal ilmenitic sandstone in Howchin's type area, while Howchin's (type area) Thick Quartzite would probably be contemporaneous with one or more minor quartzites within Mawson's magnesite series of the Flinders Ranges. Detailed field mapping of the magnesite-dolomite beds in an intermediate area (such as at Wirrabara) would probably help to solve these relations.

To return to the consideration of the type sequence. The conclusion of calcareo-argillaceous sedimentation is heralded by the appearance of silty slates and siltstones, some of which are well laminated. The next younger formation is the Glen Osmond Arkosic Sandstone Quartzite. The writer considers that the base of this formation is a convenient line at which to indicate the top of the Lower Division of the Adelaide Series, as the beds which follow, including the Glen Osmond horizons, reflect a new set of environmental conditions.

In general the big development of dolomites and magnesites in the Lower Adelaide Series, in association with the formation of interesting magnesitic intraformational (desiccation) breccias, is thought to indicate a warui climate with deposition in a shallow eperic lake or sea. The absence of red beds suggests that the climate was not arid and that the sediments were deposited in an aqueous environment.

The "Basal" bed of the Middle Adelaide Series, on the author's definition, is the Glen Osmond arkosic formation. The arkose and certain associated varve-like sediments are interpreted to indicate local fluvioglaciation, and so would indicate the onset of the glaciation which later was responsible for the formation of the massive Sturtian Tillite of the type sequence. Laminated and massive slates and quartzites, and finally perhaps true varves, were deposited on the Glen Osmond arkosic formations prior to the deposition of the Sturtian Tillite.

Sedimentary units of the type series above the Sturtian Tillite are not dealt with in this paper, although a complete log of strata for the type series is appended. The Sturtian glaciation fades away through stages of fluvioglaciation into a thick sequence of well laminated (Tapley Hill) calcareous slates, and then into laminated and banded siliceous limestones, culminating in the Brighton Limestone. Elsewhere in the State the equivalent of the Tapley Hill sequence contains thin tillite bands, suggesting that the laminations as a whole echo fluvioglaciation, and, as such, may represent some peculiar variation of varve pairs indicating seasonal influence. Mawson has discussed aspects of the lamination problem previously and refers to the laminated slates as "extraglacial" (Mawson 1912).

At about the top of the Brighton Limestone horizon in the Adelaide region (and probably at a slightly lower but variable stratigraphical horizon in the Flinders Ranges), sediment types and colours reflect a marked environment change. The grey-blue colours of the Tapley Hill Series give way to reds and purples in the overlying alternating slates and quartzites, and continue to the base of the Cambrian Archaeocyathinae limestones. Howchin called these "red" beds the "transitional" series—transitional to fossiliferous Cambrian. Until a reliable decision is reached as to where the base of the Cambrian is to be taken, it is suggested that beds above the Brighton Limestones but below the Archaeocyathinae limestones be considered as the Upper Division of the Adelaide Series.

In the foregoing description it will be noticed that the author has deviated somewhat from the subdivisions of the Adelaide Series as suggested by Howchin, Mawson, and others. It is hoped to discuss the merits of these various subdivisions in a later paper.

The following generalized log of strata for the Adelaide Series in Howchin's type area commences with the youngest stratigraphical unit.

UPPER ADELAIDE SERIES

| Item No. | Feet | |
|----------|-------|---|
| 25. | 1,150 | Pre-Archaeocyathinae grey quartzites and slates. |
| 24. | 2,250 | Alternate purple slates and purple quartzites. |
| 23. | 300 | Massive grey-white quartzites. |
| 22. | 140 | Purple slates. |
| 21. | 270 | Massive quartzites. |
| 20. | 300 | Purple and grey slates. |
| 19. | 180 | Arkoses and quartzites. |
| 18. | 200 | Flaggy quartzites. |
| 17. | 500 | Purple and grey flaggy quartzite and slate. |
| 16. | 630 | Purple siliceous slates with intraformational flakes. |
| | 5,920 | |

MIDDLE ADELAIDE SERIES

| | | |
|-----|--------|--|
| 15. | 100 | Brighton limestones, dolomitic above. |
| 14. | 10,500 | Tapley Hill laminated slates below (7,500 feet), and banded slaty limestones (3,000 feet) above. |
| 13. | 210 | Fluvioglacial sediments and minor limestones. |
| 12. | 1,000± | Sturtian tillite. |
| 11. | 1,000± | Mitcham slates and quartzites with Glen Osmond arkosic gravelly quartzite at base. |
| | 12,810 | |

LOWER ADELAIDE SERIES

| Item No. | Feet | |
|----------|---------|---|
| 10. | 1,540+ | Glen Osmond slates and phyllites. |
| 9. | 450 | Beaumont dolomites. |
| 8. | 1,000± | Upper phyllites. |
| 7. | 1,000 | Thick quartzite. |
| 6. | 1,100+ | Lower phyllites with minor quartzites and dolomites. |
| 5. | 430 | Upper Torrens dolomites with "Mawsonella" magnesites. |
| 4. | 680 | Phyllites with sandstone quartzite bands. |
| 3. | 150± | Lower Torrens dolomites. |
| 2. | *2,000± | Alternate argillaceous sandstones and sandy slates. |
| 1. | 100+ | Basal ilmenitic sandstones. Thickness very variable. |

8,450

Excluding item two, the thickness of the Adelaide Series, in its type locality, taken to the base of the Archaeocyathinae limestones, exceeds 25,000 feet.

TERTIARY TO RECENT SEDIMENTARY FORMATIONS

OLIGOCENE LACUSTRINE SEDIMENTS

In the Adelaide region a great stratigraphical hiatus exists in the geological record following the collapse and folding of the "Flinders" geosyncline. The long period of subaerial peneplanation which followed exposed the "roots" of the early Palaeozoic fold-mountain range. The immense stratigraphical hiatus is broken only by Permian glaciation in all the period between Cambrian and early Tertiary.

Permian glaciogenic are not preserved in the area under discussion, although an outlier of these sediments occurs a few miles to the south-west on the Eden-Moana fault block. The next oldest formation, which in this case does occur in the area, is a series of lacustrine sands and clays. It was laid down on an extremely well developed "base surface."

The series is typically lignitic in South Australia, and it is overlain conformably (or disconformably) by fossiliferous Marine Miocene and possibly Upper Oligocene in some localities. By analogy with similar beds occurring in Victoria, their age is usually considered Oligocene. The sediments are typically grey-white in colour, although yellow clays and reddish sands occur not infrequently.

The uplift of the Mount Lofty Ranges (Kosciusko Epoch) has resulted in extensive stripping of the Tertiary "overmass" from the central "horst" region. On the lower portions of the pivotal or hinged fault blocks flanking the latter region the Tertiary deposits are still in evidence. In the present area the Miocene marine sediments have been removed entirely, although it is obvious that they once covered most, if not all, of it. The underlying lacustrine sediments are now almost gone, but remnants of them occur in the Belair-Blackwood and Ironbank-Cherry Gardens districts. These exposures represent the northern "tonguing out" of the complete series occurring on the Eden-Moana and Clarendon-Ochre Cove fault blocks respectively.

The Belair-Blackwood exposures are described by Howchin (1933) in discussing a system of "dead rivers" of South Australia. In the succeeding section of the present work the application of his "dead river" theory to these sediments is shown to be a fallacy.

* Stratigraphical relations of this horizon are uncertain.

At Belair and Blackwood, road and railway cuttings have sectioned the remnant lacustrine series, which are chiefly light-coloured clays and sandy clays with minor sand beds. Processes of laterization have caused incipient ferruginous mottling or formed bands of gritty ironstone. Floaters and outcropping beds of this ironstone have been of great aid in the field in delimiting the boundaries of the outliers.

About Cherry Gardens there are few excavations in, or natural exposures of, the lacustrine beds, and once more ironstone floaters have been an invaluable aid in field mapping.

HOWCHIN'S DEAD RIVER THEORY (1933)

The author has carried out field investigations in many areas studied by Howchin in forming his dead river theory, and as a result believes that Howchin developed his theory far beyond the limits of his evidence. However, it is not the author's intention to attempt to disprove Howchin's theory in its entirety, as such refutation may be impossible. Where the theory concerns the Adelaide region, it has been questioned previously by Fenner [1939 (1)] and Sprigg [1942; 1945 (1)].

Howchin (1933, p. 2) considered that "the original river systems of South Australia followed an inclined plane from Central Australia to the southern coast. The elevation of the Mount Lofty Ranges, at a comparatively late geological period, formed an east-west barrier to the central drainage by which these older rivers were truncated and formed numerous lakes on the northern side of the barrier. Although the rivers ceased to flow in their lower channels, the physical features incidental to their former existence have persisted, somewhat modified to the present time. Among these features the most remarkable are the extensive deposits of sands and gravels in a consolidated (as well as unconsolidated) condition, which bear testimony to their former existence." He then proceeded to describe in detail features of the numerous broad longitudinal valleys characteristic of the Mount Lofty Ranges and in particular drew attention to many ancient gravels, some of which were preserved in the valley bottoms and others as outliers on hill-tops.

The details concerning multitudinous alluvial, fluviatile and lacustrine deposits which Howchin had carefully collected and put on record on this occasion covered a great range of sedimentary depositional environments, and, as such, were without doubt extremely valuable. Unfortunately, these records were all considered together and assumed to be evidence of a single system of remarkably parallel post-Miocene rivers draining from the far north of this State into the Southern Ocean. Plans of the "trunk streams" indicate an abnormal stream pattern over which, presumably, geological structures wielded supreme control for great distances. Two such streams ran almost parallel courses for 100 miles, separated by a distance of between only six and twelve miles. In one section four streams are indicated in parallel flow for 30 miles and spaced at about 10 to 14 miles interval respectively. It is not suggested that cases of this type are quite impossible, but it is pointed out that in order to make claims of this nature very complete substantiating evidence is required.

Near Adelaide at least one of these "river channels" corresponds with early Tertiary (?Oligocene) lignitic lacustrine deposits preserved in tectonic valleys formed by back-tilting of the sub-parallel Kosciusko Epoch fault blocks [Sprigg 1945, (1)]. One such "channel" was described as passing along Hope Valley, across Blackwood and south along the "back" of the Eden-Moana fault block. To account for the apparent discontinuity of the channel to the east of Adelaide, Howchin suggested that "a remarkable tectonic feature is present in the foothills

of the ranges in the neighbourhood of Adelaide. A crescentic segment has, by faulting, been let down, which broke the continuity of the piedmont plateau . . . The piedmont plateau, to be consistent with the general physiographic features, should be continuous between the Hope Valley plateau and the Belair-Blackwood plateau." However, this is only partially true, as the Para block is a well-defined tilt block with its fossil "base-surface" and overlying oligocene lacustrine and Miocene marine sediments plunging beneath Adelaide [Sprigg 1945, (1)].

Referring to the Belair-Blackwood plateau Howchin records: "In the approach to the Railway Station (Blackwood—R. C. S.) an interesting section is exposed . . . an ancient river channel filled with fluviatile deposits that are not seen at the surface level and have no relationship to any form of existing drainage." This group of sediments outcrops widely in the locality, and, as in the case of similar deposits at Hope Valley, they are outliers or reworked remnants of the once very extensive (?) Oligocene lacustrine sediments.

In the Hope Valley and Blackwood area (?) Oligocene lacustrine sediments are exposed on the higher portions of the tilt blocks, but to the south they plunge conformably beneath Miocene marine sediments. "Rewashing" of the outcropping lacustrine sediments has led to redistribution in the direction of the tilt-down of the block, so that beds of sands and clays extremely like the original beds (although they do not contain lignite) come to overlie the Miocene marine sediments. This fact misled Howchin into believing the whole group of sands and clays in outcrop to be post-Miocene.

In order to make the foregoing argument clearer, a plan has been prepared (fig. 3) to illustrate relationships between Howchin's "dead" Nuriootpa-Barossa-Hope Valley-Blackwood and Noarlunga channel, and the outcropping (and in part redistributed) oligocene lacustrine sediments, the preservation of which has largely been controlled by Kosciusko Epoch block faulting.

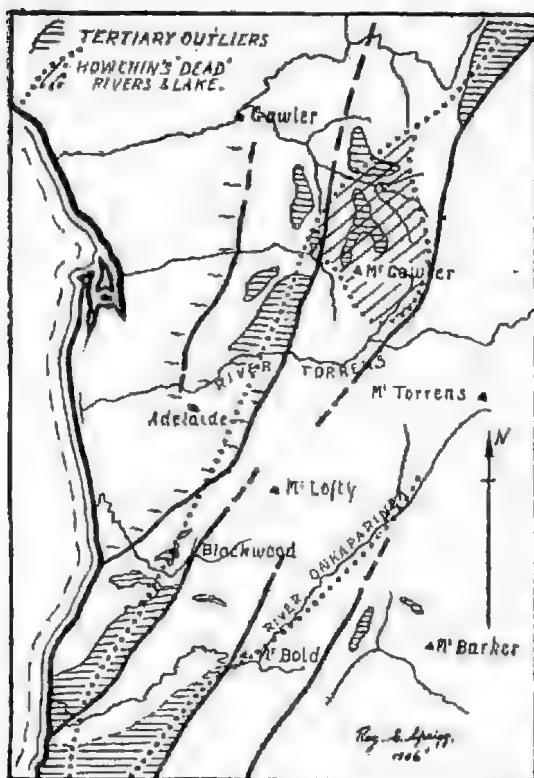


Fig. 3

Portion of the courses of two of Howchin's "dead rivers" have been superimposed on a plan showing Kosciusko Epoch Tectonic Valleys and related lignitic (?) Oligocene freshwater deposits.

TECTONICS

PALAEOZOIC OROGENY

Folding—Before dealing with fold movements in the restricted area surveyed, an attempt will be made to trace very briefly the evolution of ideas on folding of the Adelaide Series in the Mount Lofty Ranges. Only the major stages in the development will be mentioned.

Professor Tate (1893) considered the Adelaide Series to be folded locally in the form of a vast monocline. Howchin (1926) disproved this theory and demonstrated that the beds were disposed in the form of a vast anticline with a core of Archaeozoic rocks exposed along the centre of the Mount Lofty Range Horst. Subsequent field work has only modified this theory.

In the central Mount Lofty region, faulting has complicated the major structure, but its detailed elucidation will follow systematic survey. To the south the regional anticline is overfolded to the west (Madigon 1925, 1927), and satellite major anticlines pitch to the south (Sprigg 1942). Hossfeld's (1935) field mapping has disclosed what may broadly be termed a north pitching anticlinorium occurring to the north of the River Torrens,

Viewed regionally, then, there is a domed anticlinorium with its major axis directed north and south. It has pronounced satellite major and minor folds, some of which on the west are overturned to the west. The whole structure, more particularly in the central region, is greatly disturbed by faulting.

As for the more restricted area mapped by the author the folding is considered to fall naturally into two distinct but interrelated groups. The major group (which lies to the east of the overfold and overthrust zone) is characterised by folds which are essentially gentle undulations with subhorizontal sets. There appear to be two major factors controlling the fold character. Firstly, the subhorizontal beds occupy a location representing portion of the "roof" of the ancient fold-mountain anticline. Secondly, one of the large single sedimentary horizons included is the 1,000 feet thick major "competent" bed of the Adelaide Series—the Thick Quartzite—which protected adjacent formations from more severe deformation.

The second type of folding is much more severe and pronounced in character but is found much less frequently, being restricted to areas west of zones of minor overthrust. Overfolding occurs not uncommonly in such situations, and some excellent examples of this can be seen in Viaduct Gully. In a ballast quarry north of the latter gully one such overfold was recognised by means of a drag fold on the overturned limb.

The severity of folding of this second type in the Clapham—Viaduct Gully area is due to two factors. Firstly, the beds have been caught up in minor overthrust movements. Secondly, the sedimentary formations which have been disturbed are admirably suited to intricate folding (and faulting). Slates and quartzites (chiefly) alternate to form relatively "incompetent" and "competent" layers.

Faulting—It has long been recognised that the Adelaide Series in the Mount Lofty Ranges has been subjected to a considerable degree of major faulting. The author's survey has borne out this contention and resulted in the discovery of many additional faults, some of which are very extensive linearly, in the extent of "throw" and in the breadth of shatter zones. The larger faults conform to a very definite fracture pattern.

For convenience of description the faults are classed in three major groups:
 1. Low angle overthrust faults. 2. High angle faults of the overthrust "shatter belt." 3. High angle faults of the major "meridional" pattern.

1. *Overthrust Faults*—From the outset it is made plain that the extent of over-riding along these faults is not extensive in any locality. Overthrusting largely amounts to movement along planes of weakness where overfolding became too severe.

Broadly speaking, the zone of overthrusting skirts the western foothills of the Mount Lofty Ranges. The zone can be traced at intervals from Sturt Gorge, through Viaduct Gully to Brownhill Creek (Mitcham Quarry area), after which it is lost beneath the Adelaide Plains.

Minor overthrust disturbances are in evidence northward along the foothills from Mitcham. They occur in Glen Osmond "gorge," in Waterfall Gully near Magill, and near Morialta. Still further north an important overthrust zone crosses the Torrens Gorge at the Waterworks tunnel, half a mile downstream from Sixth Creek.

Effects on sediments due to overthrust movements in the Sturt Gorge have been described previously (Sprigg 1942). In this locality it was found that the rather perfect cleavage in the Tillite base provided excellent planes of slippage. At Viaduct Gully, Howchin (1927) referred to an overthrust fault immediately east of the railway line where the upper limb of an overfold has glided over the lower limb.

Exposures in the south quarry near the right angle bend in Brownhill Creek display movement along low angle fracture or cleavage planes. There has been deposition of quartz in associated tension fractures.

A quarry across the gully to the south-west of the Mitcham cemetery has exposed intimate mashing of quartzites in slate. One large mass of quartzite appears to have been forcefully injected into slates and then severed off from its parent bed.

Mashing attributed to overthrust faulting also occurs in the Torrens Gorge at the Waterworks tunnel; the zone extends southwards to the east of the "Three Sugarloafs." Slates and quartzites occur interrelated in confusion. Irregularly dissected masses of quartzite, large and small overfolding pockers, imbricate structure, overthrust gliding, normal and reverse faulting and quartz veins and "gashes" occur in profusion. The zone of severest dislocation and brecciation is at least 200 feet in thickness, but the extent to which movement has occurred has not been determined; it does not appear to have been extensive. Below the main zone of brecciation, and to the west, overfolding dominates.

An excellent small scale example of "imbricate" structure is exposed in the cliff section immediately over the north-western entrance to the Waterworks tunnel to the Torrens Gorge. At least ten segments are plainly visible.

A prominent feature resulting from the overthrusting concerns the marked difference in degree of folding to the east and to the west of the zones of maximum movement. The over-riding segment is mostly only gently folded (normal fault drag effects excluded), whereas the segment over-ridden is steeply folded and overfolded. Both segments have undergone considerable "high angle" faulting and it is probable that overfolds originally existed in the over-riding segments. These could have been "faulted out" and removed by subsequent erosion.

Structural relations of this type have been noted in the Torrens Gorge, at Brownhill Creek and in the Sturt Gorge.

Among the foothills near Mitcham and south to Sturt Gorge many minor overthrust planes have been noted in close association with overfolds.

2. *High Angle Faults of the Overthrust "Shatter Zone"*—Contemporaneously with overfolding and overthrusting, beds caught in the zone of severest dis-

tortion were acutely faulted and shattered. So far, investigation has indicated no very regular fault pattern for these steep "normal" and "reverse" faults, but two dominant sets strike approximately at right angles. Hade and throw of the individual faults is usually small, of the order of 100 feet or less. Such faults were apparently planes of readjustment during the period of overthrusting. The nature of the Glen Osmond and Mitcham series of alternating slates and quartzites appears to have facilitated faulting.

3. The High Angle Faults of the Major Meridional Series—These faults are regional in extent. They are well defined and usually extend many miles. They provide the major lines of weakness and movement in the Adelaide vicinity. The largest of them has been traced for 26 miles, and at either extremity it continues strongly. In general the faults strike N.N.E. and S.S.W. and adhere to a reasonably regular pattern. Drag effect and brecciation is displayed magnificently and there has been heavy deposition of quartz in associated tension fractures. The throw of many of the faults was originally "east-down" with hade nearly vertical, and usually extent of throw is to be measured in hundreds of feet.

The largest fault so far mapped has been named the "Ochre-Cove" fault. Most strata immediately to the west of this fault are strongly influenced in their dip for half a mile in the approach. The great extent of fault-drag suggests that when the original dislocation occurred the beds in question (about the stratigraphical horizon of the Thick Quartzite) were then deeply buried. Fracturing was much less in evidence then than during subsequent periods of movement.

It is evident that this meridional series of regional faults has figured very prominently in the major physiographic evolution of the Adelaide region since the early Palaeozoic era. At least three separate periods of movement along some of the fault planes can be inferred.

Of these, the first probably occurred early in the Palaeozoic era before erosion had "raised" the deeper beds far above the zone of "plastic deformation." Certain stresses acting upon the geosynclinal sediments brought about monoclinal drag folding (more particularly in the relatively "incompetent" beds), which was intensified until faulting occurred in most cases. As mentioned previously, the faulting originally, in many, but by no means all cases, was "east-down" (see Sections A-A', B-B' and C-C', Geological Reconnaissance Map).

The extent to which monoclinal drag-folding and/or faulting occurred during this period was largely governed by the type of rock under immediate stress. The slates and phyllites typically were "dragged" severely prior to faulting, e.g., in Watersfall Gully, whereas the Thick Quartzite usually broke relatively cleanly. However, in some instances (as to the west of Ashton and near Crafers along the strikes of the Coromandel and Crafers faults respectively) argillaceous sandstones and massive quartzites have yielded extensively and are dragged down at high angles of dip.

The second period of faulting along this meridional series of fractures probably occurred during the late Palaeozoic or Mesozoic era, but this is only conjectural. Indirect evidence suggests that it followed a period of prolonged erosion, perhaps penplanation. By then the lower stratigraphical units of the Adelaide Series had been raised very considerably relative to the land surface, and any heating effects of ancient plutonic magmas had faded away. The rocks concerned were now high in the zone of fracture. Little or no definite evidence of drag accompanying the reversal of the direction of fault throw has been observed.

The third period corresponds with the Kosciusko Epoch (see below), when after a prolonged period of peneplanation block faulting occurred again.

Fig. 4 has been prepared to present a simplified view of the fault pattern. The Ochre-Cove fault is one which has shared in all three periods of movement.

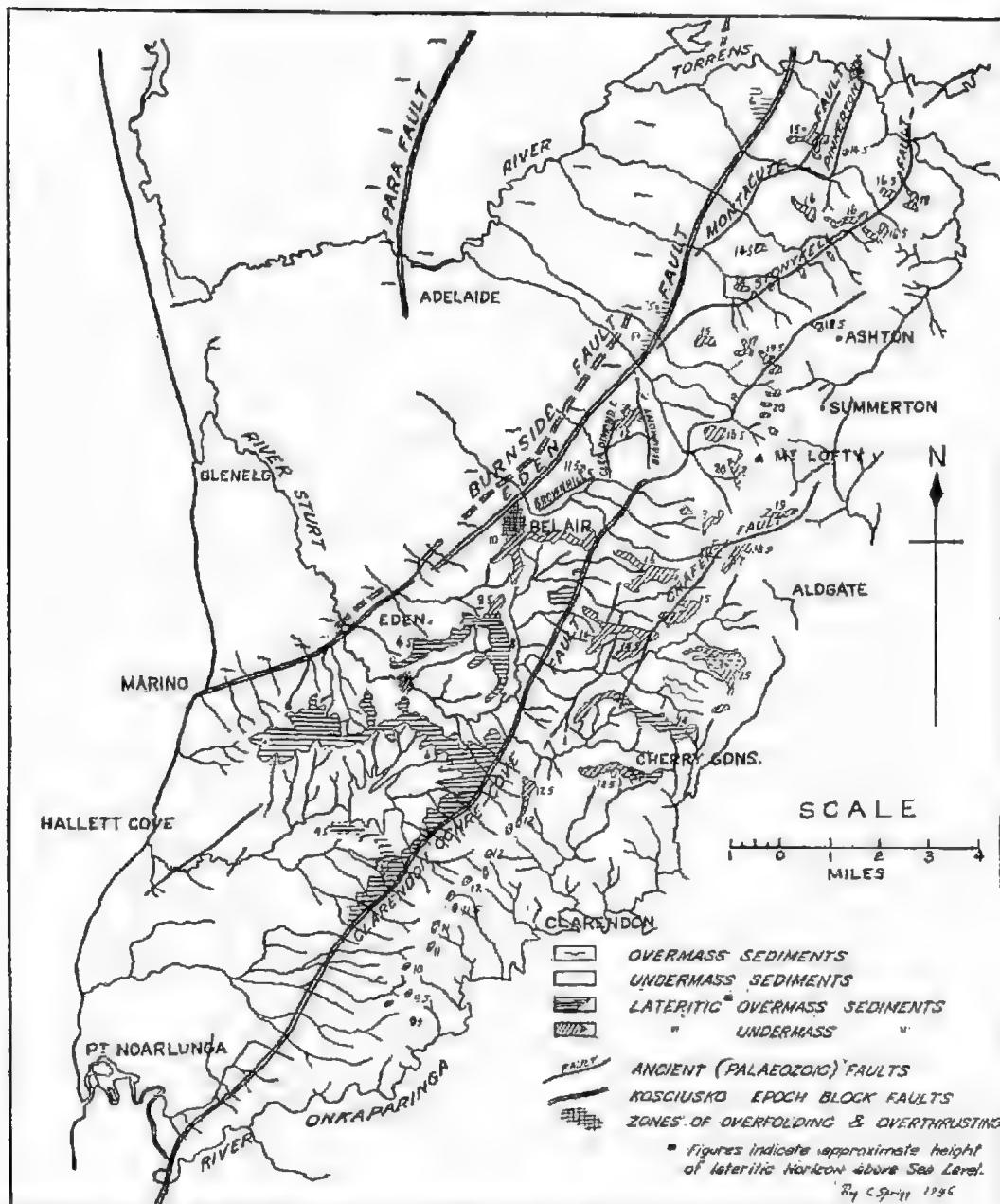


Fig. 4

Generalised plan showing names of faults described in the text. The Kosciusko Epoch Faults are re-opened ancient (Palaeozoic) faults. Also indicated are remnants of lateritic soils and laterized parent rock preserved on Kosciusko Epoch Fault blocks. Laterization has occurred partly on overmass sediments and partly in undermass bedrock. The altitudes at which lateritic remnants occur are indicated in hundreds of feet (e.g., 11·5).

It is probable that the main western escarpment faults (Eden and Burnside faults) have had a comparable history.

Sufficient descriptive data has been included in the geological reconnaissance map to render detailed description of individual faults superfluous. Zones of shatter and brecciation are indicated by cross hatching, and bedding dip readings indicate the extent of drag in the vicinity of the important faults. Quartz deposition in fractured zones is universal in the form of irregular vein infillings, or as massive milky quartz reefs as in Horsnell's Gully and at Upper Sturt. Excellent examples of "Island" masses of quartzite "abandoned" in slates in fault lines occur near Brownhill Creek and along the Black Hill road to Montacute.

THE KOSCIUSKO EPOCH OF BLOCK FAULTING

Faulting of this period occurs extensively in the central portion of South Australia. Benson (1909), Fenner (1931) and Sprigg [1945, (1)] have discussed the general local plan (with particular reference to the central Mount Lofty Ranges), and various authors have referred to still more restricted portions of it. Certain relative movements of the Eden-Moana Pivotal Fault Block have been illustrated (Sprigg 1942) and additional investigations on the Adelaide Plains area is proceeding.

The foothills region surveyed is delineated on the west by the Burnside and Eden faults. North from Viaduct Gully, the Eden fault is the major escarpment-forming fault. The Burnside fault in this region is largely obscured by alluvial debris, although bores sunk short distances to the west of this fault indicate that it is a fault of considerable magnitude. South-west from Viaduct Gully the Burnside fault appears to have become the major escarpment fault, and as such it continues to the sea-board at Marino.

The Ochre-Cove fault, striking from Noarlunga, has its "hinge" point in the vicinity of Eagle-on-the-Hill. This Kosciusko fault represents a re-opening along portion of a more extensive palaeozoic fault which continues N.N.E. beyond Eagle-on-the-Hill, passing to the west of Ashton. Field topography and evidence from generalised contouring suggests a possible fault escarpment striking north and south just to the west of Mount Lofty, and running out to the south in the vicinity of Upper Sturt. Reconnaissance mapping has not located such a fault.

The Kitchener fault may correspond in part with the Stonyfell fault, and if so it "hinges out" near Montacute.

The westerly downthrow of the Burnside fault splinter relative to the northern extension of the Eden-Moana fault block has been calculated; the extent of downthrow at Mitcham, Burnside and Athelstone approximates 600, 900 and 1,100 feet respectively. By coincidence, from Athelstone to Springbank, the Burnside fault splinter preserves a remarkably horizontal surface at about 450 feet above sea level.

The interpretation of "Kosciusko" faults as distinct from more ancient faults has been dependent to a large extent upon obvious breaks in topography or escarpment formations with which normal fault phenomena are in close association. In several instances washouts and quarries along escarpments have exposed the exact fault line. Where such exposures do not occur the location of the fault in many cases can be decided from topographical conditions with reasonable accuracy (providing, of course, stratigraphical and/or other evidences of faulting are present).

Near the bend in the railway before the straight track descending into Belair Station, a washout has exposed the Ochre-Cove fault. The fault is obviously one of the more ancient group re-opened. On the western aspect the wall rock is partly re-washed early tertiary sediments, but the opposing face is of shattered Adelaide Series Slates and quartzites seamed with epigenetic quartz. North, along the same fault, the topographic break is marked by similar disturbances and floaters of epigenetic quartz, but the tertiary beds have been eroded away. At the exposure mentioned above the Tertiary beds dip away westwards from the fault at only a few degrees and the throw here is probably no more than 200 feet. At Ochre-Cove and Noarlunga the same fault has dragged the tertiary beds up to angles of 30° and 40° . The fault-throw in the latter locality is about 600 feet.

The Eden and Burnside faults, in a number of instances, have been delineated within a few feet, but only on two or three occasions were "fault outcrops" noted. One such "outcrop" of the Eden Fault is exposed in Goldsack's Beaumont Dolomite Quarries, where operations have left standing a vertical face of talus and alluvial outwash which marks the trace of the faults. A buried "cliff-like" escarpment is indicated. Further north, in the vicinity of Athelstone, the same fault was noted in natural "outcrop." Partly re-washed and mottled early Tertiary sands and sandstones abut (vertically in section) against the ancient slates and quartzites.

The Kosciusko faults are not necessarily "simple," and a particular example of "compound" faulting will be described to illustrate this point. A site was selected by the Department for Engineering and Water Supply for a second 2,000,000 gallon pressure tank behind Springfield Estate. In excavating for solid foundations, bedrock was encountered over most of the proposed site within several feet of the surface, approximately at depths anticipated. On the western border, however, bedrock was not reached in sinking to 15 feet. Consequently it was found that a fault traversed this western border producing a buried "cliff face" in the basement rock. A sketch section (fig. 5) illustrates the subsurface features. From evidence based on topography the major escarpment fault occurs 100 yards or more to the east, indicating the formation of quite narrow fault splinters and the compound nature of the major fault lines.

For evidence of recent movements along Kosciusko faults the reader is referred to a later section on river deposits.

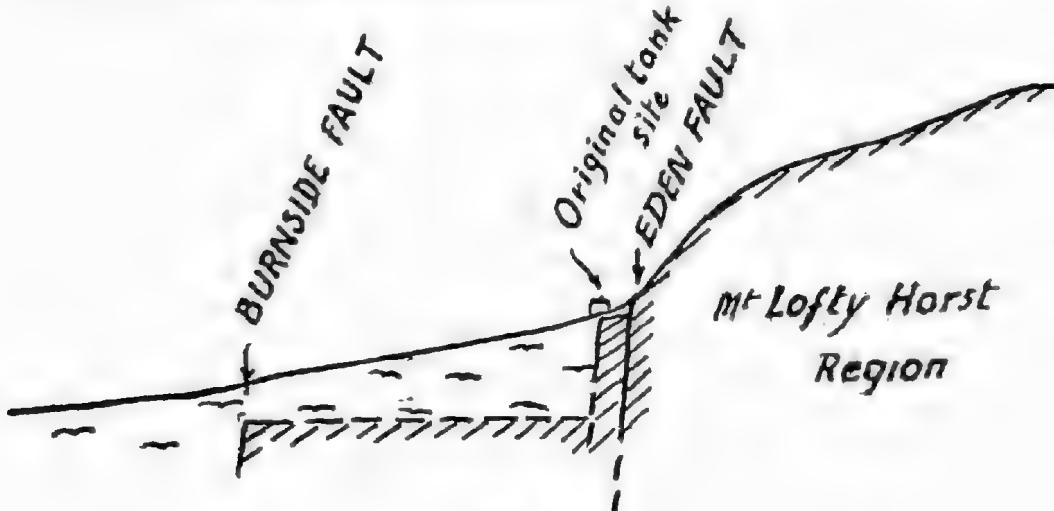


Fig. 5
To illustrate subsurface relations at the original Springfield tank site.

A TENTATIVE SEQUENCE FOR LOCAL TECTONIC EVENTS

An attempt has been made to summarise the major phases in the Orogenic history of the Adelaide Series in the area mapped, by means of simplified hypothetical sketches. The scheme proposed must be regarded as only tentative.

During portion of the Proterozoic Era, the Cambrian and possibly during the earlier Ordovician period, much of South Australia was the site of the accumulation of the vast Flinders [Sprigg 1945, (2)] geosyncline of sediments. Sedimentation was terminated probably as a result of crustal instability due to overloading and consequent collapse of the geosynclinal area. Deformation of

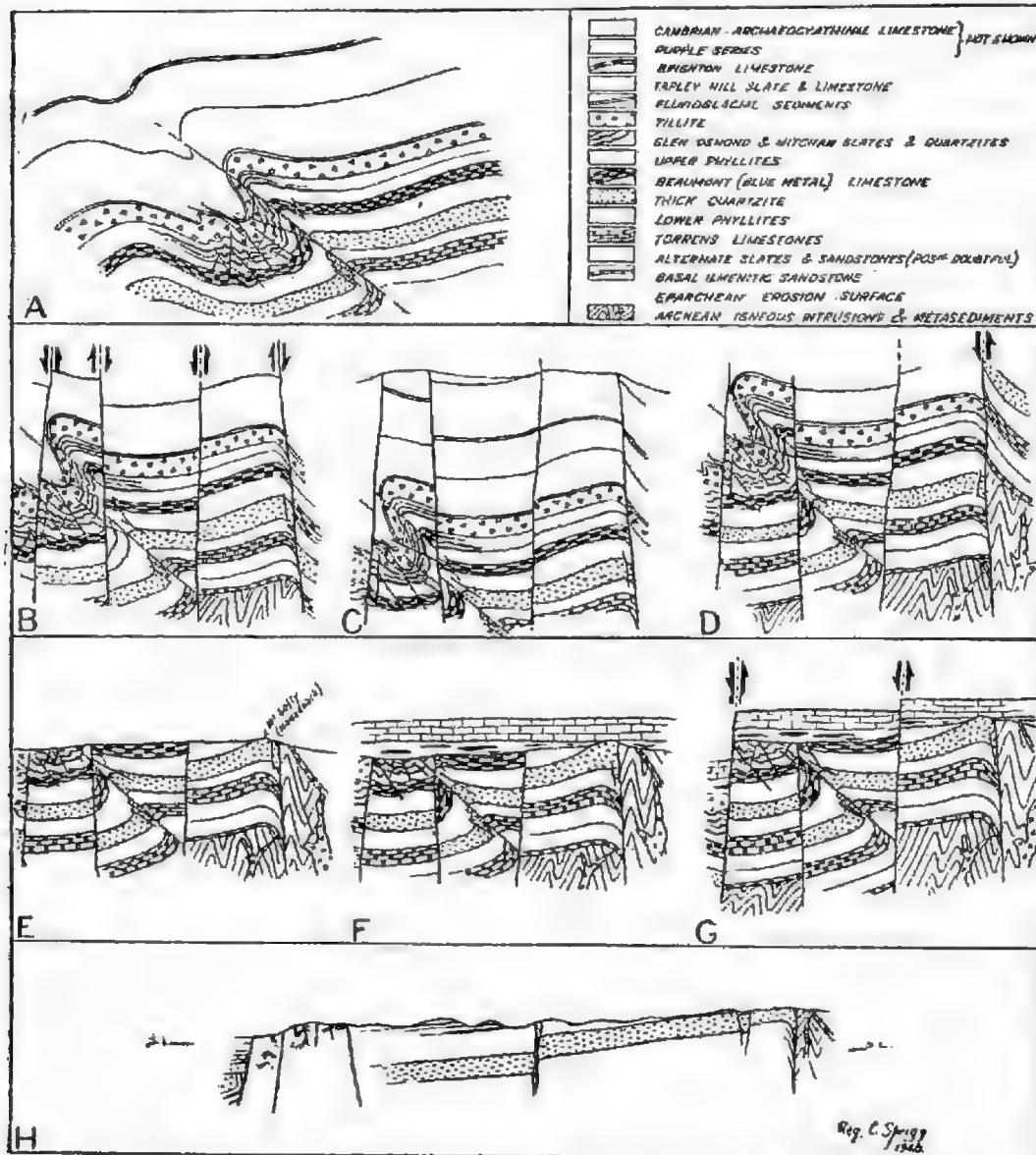


Fig. 6

Diagrammatised cross sections to illustrate major stages in the history of fault movements in the vicinity of Mount Lofty. The series is strictly tentative and greatly simplified.

the strata in the southern portions of the geosyncline (i.e., in the Adelaide region) commenced with major stresses directed westwards. Major regional folds with north-south axes were initiated and the complete east-west section across the basin probably approximated an anticlinorium. Relatively minor pressure from the north (in this area) may have introduced the weak doming influence on the major fold structure. As the westerly directed pressure became more intense a strong cleavage developed, and minor overthrusting commenced in restricted areas. Howchin's type locality for the Adelaide Series is one such area of overthrusting.

Fig. 6 A represents an idealized sketch section across one of these zones of minor overthrust at about the latitude of Belair as it might have appeared in the early Palaeozoic era. In the overfolding of the Mitcham alternate slates and quartzites, variations in competence produced localised shearing stresses which resulted in both high angle and low angle thrust faults upon which displacement developed through flexing of the beds and bedding plane slippage. Isostatic instability caused by the increased mass of beds superimposed in the vicinity of the overthrust and overfold belt at this early period would, presumably, be largely compensated more or less contemporaneously by transference of material in the subcrustal layers.

At a much later stage, when erosion had reduced the land surface very considerably (e.g., had exposed the Brighton Limestones), a new isostatic instability was probably caused by the relatively greater erosion and transport of material from the region of overthrusting. At this stage, presumably, transfer of material in related subcrustal layers apparently would not occur so readily. Differential crustal stresses would build up until relief came in the form of block faulting (fig. 6 B). This first period of major block faulting probably occurred during early or mid-Palaeozoic Era. The older members of the Adelaide Series were still buried deeply, as intense drag effects along many of the original block faults suggest that the beds concerned were near the lower limit of the zone of fracture. In the area major throw was down to the east, although this was not so in all cases. Contemporaneous and subsequent erosion possibly reduced the ancient land surface to a base surface (fig. 6 C) and possibly kept pace with block faulting, but such is only conjectural.

Following this long period of erosive activity, along some of the original block faults of the area, movement occurred again, but frequently in a reversed direction (fig. 6 D), e.g., Stonyfell and Crasiers faults. In such cases where the extent of reversal has exceeded the original throwdown, drag effects suggest faulting down in a particular direction, while stratigraphical relations indicate faulting in quite the opposite direction (sections A.A' and C.C', Reconnaissance map). The extent of displacement in most of these reversed faults is considerable. By now the lower units of the Adelaide Series were much closer to the surface and high in the zone of fracture, and hence in the fault zones brecciation and fracturing were much more strongly in evidence.

A further very prolonged period of peneplanation later reduced the area to a remarkable base surface (fig. 6 E), upon which only low monadnocks (e.g., the "original" Mount Lofty) remained. With a further depression of the land surface, the area (and much of southern Australia) became a site of deposition of a series of (?) Oligocene lacustrine and fluviatile sediments. Much, if not all, of the ancient erosion surface, including many of the monadnocks, were buried partially or completely, and then with a general negative movement of the land-mass, perhaps as early as the late Oligocene period, the sea transgressed the area and left its increment of marine sediments (fig. 6 F).

At approximately the end of Miocene time the instability of the land mass was again apparent (fig. 6 G) and further movements along many of the ancient faults recommenced. Faulting continued actively throughout the Pliocene and Pleistocene times (Kosciusko Epoch), with the formation of a horst range with maximum local uplift at Mount Lofty. Minor fault adjustments made manifest by small or insignificant earthquake tremors continue infrequently to the present day.

With this latest uplift a new cycle of erosion was initiated, and consequently the Oligocene and Miocene sediments were stripped from the higher portions of the horst range and deep dissection of the undermass rocks commenced (fig. 6 H).

MISCELLANIA SANDSTONE DYKES

Several of these dyke formations have been found in the Belair-Blackwood area. At least three of them occur in the road cutting immediately south of the Belair Railway Station, and five or more are exposed in the railway cutting south of Blackwood Railway Station. The dykes vary in width from one inch to four feet six inches.

Two other sandstone dykes are known in South Australia, and the author was present at Yankannina in the Flinders Ranges with Sir. D. Mawson when the first of these was found; the second example was found when making field observations at Biblido dome. In both these cases the dykes occurred

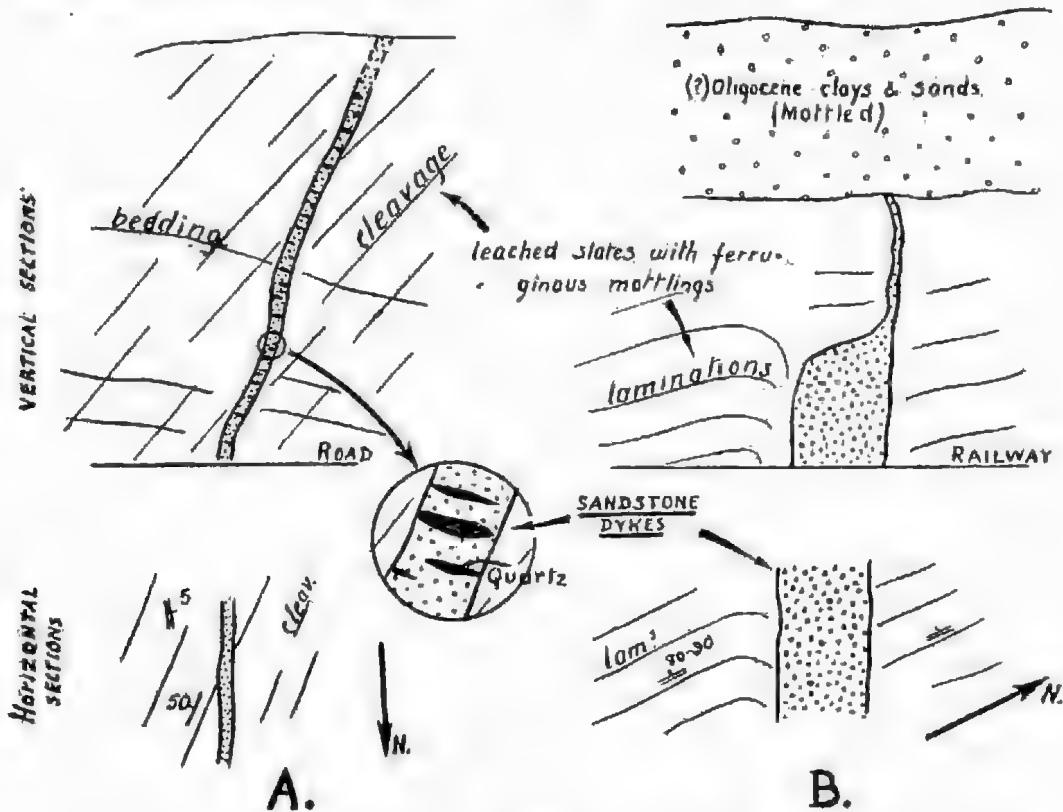


Fig. 7

The sketches illustrate certain structural associations of sandstone dykes discovered in the Belair-Blackwood vicinity. Example A occurs in a road cutting at Belair, and example B in the Blackwood railway cutting.

in Sturtian tillite, and it is to be noted that the latest examples occur in slates which are members of the Mitcham slates and quartzite group, which the writer considers may be members of a fluvioglacial or interglacial phase associated with the Sturtian tillite.

The sedimentary relations of the dykes have been examined carefully in each of the cuttings, and they are rather similar in each case. Generalised sketch plans and sections have been prepared (fig. 7) for two of these structures. The Belair example (fig. 7 A) is strongly discordant, cutting the sedimentary laminations at about 60-80° and lying obliquely to the regional cleavage. This dyke was formed before severe folding commenced, as the structure is influenced by regional cleavage in an interesting manner. During folding, with the "stretching" of the slates in the direction of cleavage (compression at right angles), the dyke structure has been drawn out, allowing deposition of quartz in the tension cracks in the form of small-scale "ladder veins." Subsidiary irregular quartz veins also occur.

Speculation as to the origin of the sandstone dykes is interesting. The dykes probably formed where tension produced open fissures and allowed an ingress of sand, presumably from above. In each case (with due allowance for the effects of erosion) bedded sandstones of apparently similar composition are known to occur stratigraphically above.

However, the Blackwood example (fig. 7 B), which is the largest recorded in the area (approximately 4 feet 6 inches wide), presents some unusual features the development of which are obscure. The bottle-necked (in section) upper portion and the drag affects apparent in the slates adjacent to the dyke are peculiar.

LATERITE

The genesis of laterite in South Australia has recently received much attention, particularly by Prescott (1931) and Crocker (1945). There now seems to be general agreement that prerequisite conditions for the formation of laterite include impeded drainage (e.g., in low lying or peneplaned surfaces) and tropical humidity. Such conditions were fulfilled over wide areas in Australia in the Pleistocene (Whitehouse 1927, David 1932).

Prescott has demonstrated that most of the laterites of Australia are fossil "B" soil horizons, and in South Australia these are almost invariably preserved on plateau areas. Lateritic "ironstones" and laterised horizons occur overlying a very diverse suite of bed-rocks such as igneous rocks (as at Houghton), slates (e.g., Belair), quartzites (e.g., on thick quartzite plateau south of Horsnell's Gully) and Tertiary clayey sandstones (Cherry Gardens). In the Mount Lofty Ranges laterisation was carried out both on overmass and undermass sediments. The period of formation was post-Miocene and probably pre-Pleistocene glaciation.

Occurrences of laterite or lateritic bed-rock are indicated in fig. 4, together with the approximate heights above sea level of the respective outcrops.

If impeded drainage is a requirement in the formation of laterites, then obviously only relatively low-lying and flat (or only slightly undulating) surfaces could provide such conditions. Such conditions of impeded drainage could not obtain immediately adjacent (and on both sides) of prominent fault escarpments. In this way it is obvious (after consideration of the altitudinal distribution of laterites on the area) that very considerable block faulting occurred since their formation. Relative movement between the Eden-Moana and Clarendon Ochre-Cove fault blocks in this manner averages some 600 feet along most of its length, and between the Para block and the major horst region about 1,000 feet.

It is anticipated that when the age relationships of the laterite are known more fully, given that the formation of laterite implies a land surface of very

subdued relief (probably with undulations within the zone of laterization not exceeding, say, \pm 50 feet over considerable areas), one more link will be available in dating periods of, and for calculating extent of, movement along block faults. Already, in the Adelaide region, there are base-levels of (?) Oligocene, Miocene and Lower and Upper Pliocene deposition which offer datum levels for calculating relative movement on a time basis (Sprigg 1942).

Concerning the age of the laterization, if a correlation can be effected between the extensive series of mottled clays (occurring about the gulf region of South Australia) and undoubted laterite, such would offer an excellent basis for age correlation. In the author's mind these mottled clays show many similarities with the bleached and mottled "C" horizons of laterite profiles, and recently F. W. Whitehouse (personal communication), on viewing these mottled clays at Ardrossan, Yorke Peninsula, pronounced them as very probably associated with processes of laterization. The age of the mottled clays is definitely post-Lower Pliocene Marine and almost certainly post-Adelaidean (Upper Pliocene Marine).

A final point of considerable importance concerning laterization concerns D. W. Johnson's "double peneplanation" theory [see Fenner 1930, 1931; Sprigg 1945, (2)]. For reasons which must be obvious from the foregoing discussion (impeded drainage and consequent depressed topography, etc.), the occurrence of laterite over much of the Mount Lofty Ranges suggests that here is one very potent argument in favour of such a theory. This and other aspects of faulting will be considered in a subsequent publication.

EVIDENCE OF RECENT UPLIFT OF THE MOUNT LOFTY RANGES

A search was conducted for any evidence which might indicate periods of prolonged still-stand during the Kosciusko Epoch block faulting. No unquestionable valley-in-valley structure was recorded, although a suggestion of this structure was observed in the Torrens Gorge up-stream from Castambool. River terraces are prominent features in the lower reaches of the larger escarpment streams, as in Waterfall Gully, Brownhill Creek and Viaduct Gully. The average elevation of these terraces above present stream level is about 15 to 20 feet. As anticipated, prominent terraces do not occur up-stream from the first important rapids or waterfalls to the east of the escarpment faults. This feature, together with the writer's view that the modern stream bed has eroded too deeply for the terraces to be normal flood plains, may be evidence of a recent uplift. In contrast, it is noted that where flood plains (usually very small) occur in undoubtedly relation to the modern stream beds in question, they are elevated only a few feet. This is the case above and below the waterfalls, where stream grades are relatively low.

A more ancient feature associated with the block faulting concerns the presence of a very remarkable river boulder conglomerate "perched" about 150 feet above the bed of Brownhill Creek and exposed in quarries to the east of the "mouth" of that valley. The conglomeratic boulders are unusually coarse for the Adelaide region (many exceed 4 feet in diameter), indicating a stream with considerable erosive power. The boulders are largely well rounded quartzites and they rest as a basement of quartzite.

A very similar boulder bed which rests on quartzite in a rail cutting north of Hallett Cove has been described previously (Howchin 1933, Sprigg 1942).

LANDSLIDES AND SCREES

Landslides are not uncommon along steep valley walls, particularly where the bedrock is slate. Excellent examples may be seen in Glen Osmond Gorge

within a mile of the Adelaide Plains. Several slides have occurred in soil and talus along high-grade streamlets on the eastern slope. The slippage has, in several cases, blocked the original channels, and as a result the drainage has been divided, forming parallel streams, as often occurs when lava flows have displaced streams from their original beds.

From near the Montacute Church Howchin describes (1915, p. 7): "the greatest landslip that I have hitherto seen. At the base of the remarkable scarp left by the slide an extraordinary medly of piled-up rocks occurs through which the older "Corkscrew" Road was cut, and its effects can be traced to the level of the valley below. A fault plane may have existed and created a line of weakness from which the imperfectly supported rocks on the side of the steep valley slipped away." The present survey has established that such a fault does exist. It is a minor branch of the Pinkerton fault.

In regions of steep topography where quartzite forms bedrock, landslides are exceptional and their role is assumed by screes. Wherever steep-sided gullies traverse the Thick Quartzite numerous examples are found.

In general, in spite of the common occurrence of extreme slopes and the high grades of minor side valleys, landslides are infrequent in the area. Instead, "youthful" instability is registered by large screes and talus accumulations.

THE SOILS

Skeletal soils figure prominently in the western escarpment foothills. The high grades of stream run-off cause severe erosion, and so deeper soils are limited to valley bottoms.

The soils will ultimately be classified in some detail, but meanwhile several major groupings seem obvious—the soils which overlie sandstone and quartzites, the soils of the slates, phyllites and limestones, and the valley bottom soils.

The major sandstones and quartzite horizons in areas of more subdued topography give rise to podsolized soils. A thin grey humic horizon is underlain by a leached sand, and then by a yellow heavy clay. These soils are acid and generally unsuited for horticulture, although clovers may be established quite well on them. In the natural state the soils support a sclerophyll vegetation dominated by heath, yacca and stringybark.

The slates, and to a lesser extent the limestones, give thin brown or reddish loams and clay loams. Travertine is frequently deposited in the "B" horizon. Such soils commonly support apple orchards. In virgin state they support a savannah type vegetation association.

The valley bottom soils are normally grey to black at the surface, and commonly contain a high humus content. They are the most valuable agriculturally and are eminently suitable for market gardening.

ECONOMIC GEOLOGY

The Adelaide Series locally have only been mineralised to small degree. Small quantities of a number of ore minerals have been prospected along the foothills region. Two deposits have been worked on a very moderate scale, the Glen Osmond silver-lead mines opened in 1841 and the Montacute copper mines in 1843. These were the earliest mines in South Australia, and among the first in Australia.

Fourteen lodes were discovered at Glen Osmond. Of these, six were prospected and worked. The lodes varied in width from one to four feet and consisted of siderite, iron oxides, barytes and quartz in calcareous slates. Shafts were sunk on at least four parallel lodes to a maximum of 310 feet (see S.A. Mining Reviews). During the period 1847 to 1850 an English company extracted

ore to the value of £30,000; the ore averaged 21 ounces silver and 71% lead per ton.

These associated parallel lodes were deposited in major regional joints, along some of which movement appears to have occurred and which strike approximately east and west and dip 70 to 90° to the south. This same persistent joint system has also provided the locus of ore deposition at the Mount Malvern deposit (Section 269, Hundred Noarlunga). The galena occurs separately or intimately associated with barytes and a little copper pyrites. In the oxidised zone cerussite occurs in association with cerargyrite and copper carbonates.

The extent to which faulting controls ore deposition in the foregoing cases is not known. At least one north-south fault is known to strike from Brownhill Creek to Glen Osmond through the mineralised belt, and some silver-lead lodes are associated with coarse fault breccias.

At Morialta (Section 1,164, Hundred Adelaide) silver is recorded in association with lead and antimony deposited in a broken zone.

Several copper lodes have been prospected and mined in or near the Torrens Gorge. Of these the Montacute mines were most important. During 1843 to 1844, 1,500 tons of 18% copper ore were won. Bornite, chalcopyrite and a little native copper and copper carbonates were mined from a wide compound fault shatter zone in Sixth Creek.

Gold has been prospected in very small quantities in several localities. Alluvial gold has been taken from Morialta, Torrens Gorge and Sixth Creek.

Quartz crystals, usually small, are found in most quartzite quarries in considerable numbers; a few are satisfactory for radio requirements.

The area is very convenient to Adelaide for building stone and ballast. The Thick Quartzite has been quarried extensively as road metal, and in some cases provides a good freestone. The Glen Osmond and associated quartzites have provided another valuable source of road metal and railway ballast. The more arkosic facies of the Glen Osmond quartzite is in considerable demand as a moulding sand.

At one time slates were quarried extensively along the foothills, but they are no longer fashionable in building construction. For fancy walls and "crazy-paving" there is still a limited demand.

The Beaumont Blue Metal dolomites have been used to a limited degree in "lime burning" as well as for road metal.

ACCURACY OF SURVEY DATA

The use of the term "reconnaissance" to describe the accompanying geological map requires a few words of explanation. Reconnaissance here should not be taken to imply the lack of accuracy associated with sketch mapping, but as an attempt to describe that degree of detail which a scale of 40 chains to the inch permits. Field survey was carried out using base maps on a scale of 6 inches to one mile, and practically all roads, major creeks and ridges were traversed. Unsuitable outcrops in several localities reduced the reliability of some recordings, while in others extensive soil or vegetation cover prevented observation altogether. Unfortunately, aerial photographs of the area were not available until field work was in its final stages.

Particular attention is drawn to the thick group of alternate slates and sandstones included very tentatively in the foregoing work near the base of the Adelaide Series. These sediments outcrop extensively on the eastern limits of the mapped area, but because of unsuitable outcrops in critical localities the solution of certain puzzling problems associated with them must await the completion of field mapping in other areas.

Concerning the plan illustrating distribution of laterite or lateritic bedrock no claim is made for finality. Boundaries, in many cases, have simply been sketched in. Some outcrops may have been omitted, and in other instances it may not have been correct to interpret certain ferruginization as lateritic.

Finally, attention is drawn to the reliability of bed thicknesses indicated in the stratigraphical table for the Adelaide Series. It will be readily appreciated that the essentially subhorizontal set of strata over much of the area in association with numerous major faults has introduced many difficulties, which in several instances have prevented measurement of unbroken sequences. As far as practicable such indefiniteness has been indicated by plus and/or minus signs in the stratigraphical table. In particular, the principal exposures of the lowest members of the Adelaide Series occur in the Torrens Gorge region where the full extent of faulting is still uncertain. In order to arrive at a more accurate picture of the geological structure in this area and of the stratigraphical sequence, if anywhere complete in outcrop, more detailed survey will be necessary.

ACKNOWLEDGMENTS

The author is indebted to Mr. S. B. Dickinson, Government Geologist of South Australia, for willing assistance on many occasions during the final phases of the preparation of the foregoing work for publication, and for undertaking the redrafting of the geological map. The author also wishes to thank Professor Sir Douglas Mawson for securing for him aerial photographs of the area.

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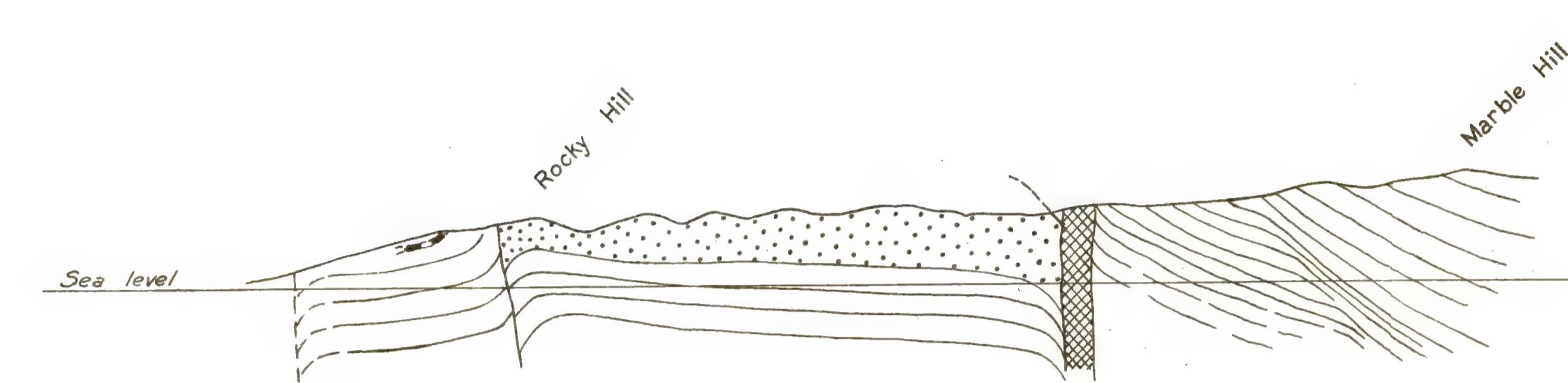
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MOUNT LOFTY RANGES

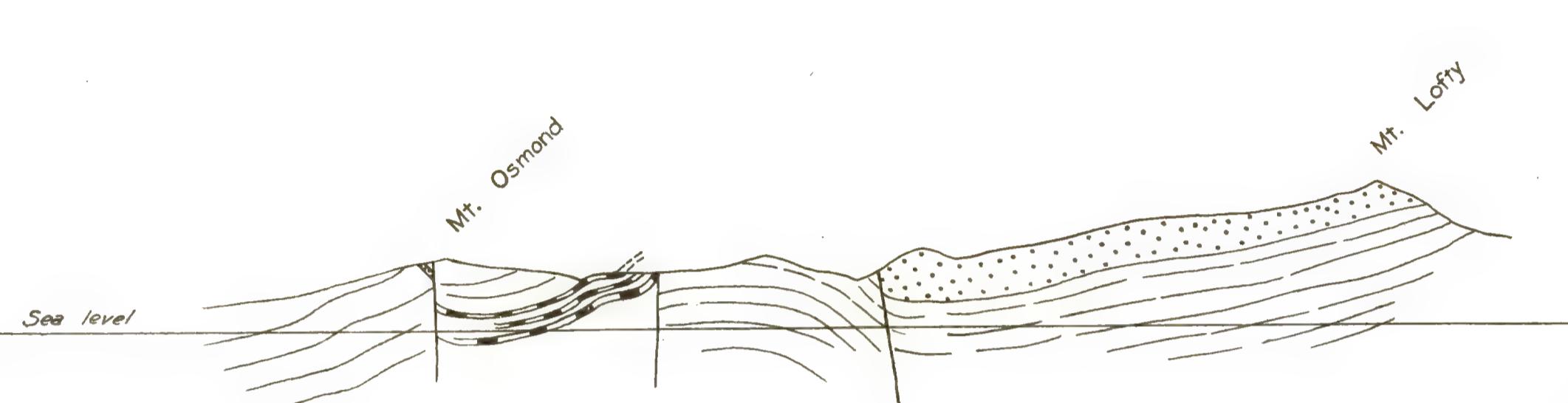
RECONNAISSANCE SURVEY OF THE WESTERN SCARP.

SCALE

MILES 1 ½ 0 1 2 3 MILES



SECTION A-A



SECTION B-B



LEGEND

TERTIARY BEDS

100 BRIGHTON LIMESTONE.

1050 TAPLEY HILL LAMINATED SLATES
AND
BANDED SILICEOUS LIMESTONES

210 FLUVIOGLACIAL SEDIMENTS INCLUDING
MINOR TILLITES AND LIMESTONES.
210 STURTIAN TILLITE AND
MINOR FLUVIOGLACIALS.

1000 ± MITCHAM SLATES AND QUARTZITES.
LAMINATED, ARKOSIC AND
VARVE-LIKE IN PART.
GLEN OSMOND ARKOSIC
QUARTZITE AT BASE.

1540 ± SLATES AND PHYLLITES.

450 BEAUMONT DOLOMITES AND
INTERBEDDED SLATES & QUARTZITES.
1000 ± PHYLLITES AND SLATES WITH
MINOR QUARTZITES.

1000 "THICK" QUARTZITE.

1400 ± PHYLLITES.

430 UPPER TORRENS BLUE-GREY
DOLOMITES INCLUDING "MAWSONELLA."
PHYLLITES WITH MINOR
QUARTZITE BANDS.
680 LOWER TORRENS (CREAM-COLOURED)
DOLOMITES.

150 ? ALTERNATE SLATES AND SANDSTONES
STRATIGRAPHICAL RELATIONSHIPS
UNCERTAIN.

2,000 ± 100 EP-ARCHEAN EROSION SURFACE.
ARCHAEZOIC IGNEOUS AND
METAMORPHIC COMPLEX.

LIMESTONE SAMPLES

| Sample No. | Analyst | CaCO ₃ | MgCO ₃ | Insolubles |
|------------|---------|-------------------|-------------------|------------|
| ① (673) | T.W.D. | 49.2 | 42.5 | 7.8 |
| ② (674) | T.W.D. | 50.9 | 44.1 | 4.7 |
| ③ (202) | T.W.D. | 6.5 | 72.0 | 21.6 |
| ④ (78) | T.W.D. | 44.5 | 36.7 | 17.0 |
| ⑤ (76) | T.W.D. | 48.3 | 38.8 | 8.1 |
| ⑥ (74) | T.W.D. | 47.0 | 34.9 | 12.7 |
| ⑦ (72) | T.W.D. | 49.9 | 38.0 | 6.9 |
| ⑧ (B.M.L.) | T.A.B. | 37.8 | 30.5 | 32.7 |
| ⑨ (13) | T.A.B. | 38.8 | 30.9 | 30.9 |
| ⑩ (34) | T.A.B. | 40.9 | 31.7 | 30.6 |
| ⑪ (3) | T.A.B. | 42.7 | 32.3 | 27.4 |
| ⑫ (2) | A.W.K. | 43.8 | 34.0 | 25.4 |
| ⑬ (9) | T.A.B. | 80.0 | 12.8 | 8.6 |
| ⑭ (17) | T.A.B. | 34.1 | 29.2 | 35.8 |

REFERENCE TO SIGNS

- BEDDING
- CLEAVAGE
- FAULTS
- PITCH
- SANDSTONE DYKES

Rep. C. Sprigg

Assist. Govt. Geologist.
S. A. Geological Survey.

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THE MOORUMBUNNA METEORITE

BY A. B. EDWARDS

Summary

As this siderite was found adjacent to Anna Creek Station's Moorumbunna Paddock, it has been named the Moorumbunna Meteorite to distinguish it from other falls from that region.

THE MOORUMBUNNA METEORITE

By A. B. EDWARDS

With an Introductory Note by D. Mawson

[Read 12 September 1946]

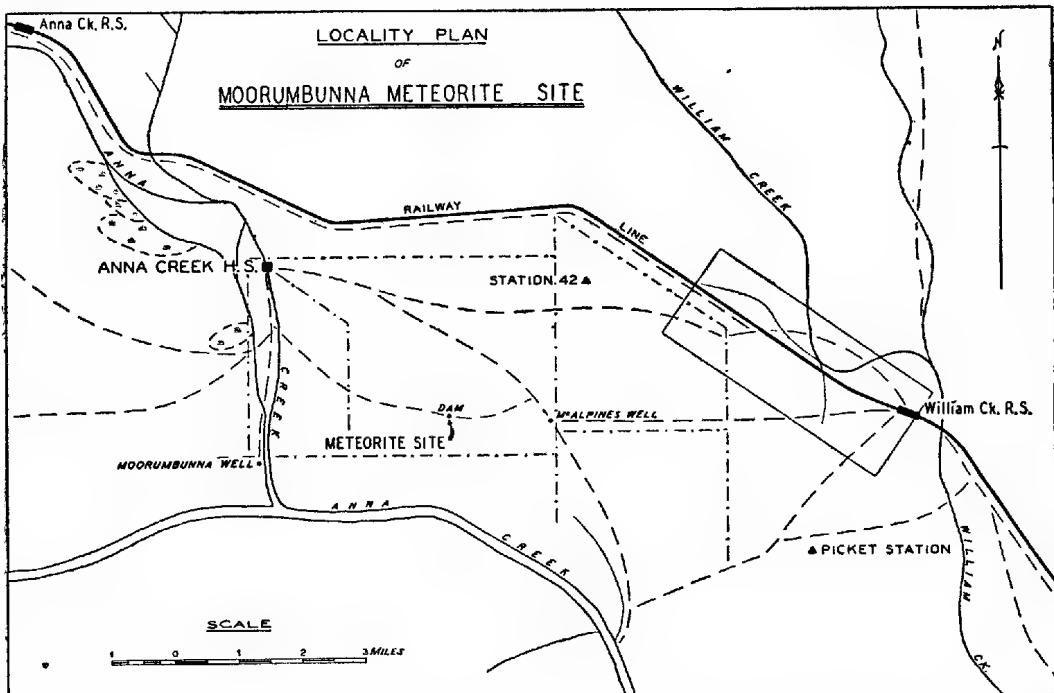
PLATES XLVIII AND XLIX

LOCATION AND DISCOVERY

(Note by D. Mawson)

As this siderite was found adjacent to Anna Creek Station's Moorumbunna⁽¹⁾ Paddock, it has been named the Moorumbunna Meteorite to distinguish it from other falls from that region.

It was kindly presented to the University of Adelaide by Mr. G. K. G. Warren, of Springfield, Mount Crawford, acting on behalf of his brother in whose Anna Creek sheep station it was discovered by an aboriginal in the year 1943. As originally observed, only a small part of the meteorite projected from the soil. It was found near a dam on the track leading from Anna Creek Head Sheep Station to William Creek Railway Station (see plan), *via* McAlpine's



Dam. William Creek Station is a point on the railway track to Central Australia, situated south-west of Lake Eyre and 547 miles by rail from Adelaide.

The Moorumbunna Meteorite is a siderite of a total weight of 169 lb. 14 oz. It is elongated but compact in form, as illustrated in pl. xl ix, fig. 3; extreme length 50 cm., breadth 31 cm., and width 19 cm.

⁽¹⁾ Spelt Moorambuna in the survey plan of the district, but Mr. Warren advises that the spelling should be Moorumbunna if to accord with the aboriginal pronunciation.

The entire surface is pitted, apparently the result of corrosion which must have continued over a long period of time. The pitting reaches a maximum depth of 5 cm. below the mean surface level, thus indicating that the fall is by no means of recent occurrence.

Dr. A. B. Edwards, of the C.S.I.R. Micrographic Laboratory, Melbourne, kindly undertook to investigate its composition and texture. A slice was sawn from one end of the mass and submitted to him for examination.

THE COMPOSITION AND TEXTURE OF THE MOORUMBUNNA METEORITE

The following observations were made on a piece of the Moorumbunna meteorite, measuring about 8 cm. x 7·5 cm. x 3·5 cm. and weighing about 1·5 lb., put at my disposal by Professor Sir Douglas Mawson. The piece had been cut so as to include a sulphide nodule, and portion of the exterior surface, which is coated with a film of limonite.

CHEMICAL COMPOSITION

An analysis of the metal was made by Mr. F. D. Drews, of the Melbourne University Ore Dressing Laboratory, and is as shown in Table I, column 1, where it is compared with some other South and Central Australian meteoric irons that show similar texture.

TABLE I.
Analyses of Some South and Central Australian Meteoric Irons

| | | 1 | A | B | C |
|---------|-----|-------|--------|-------|-------|
| Fe | ... | 89·53 | 91·77 | 91·54 | 90·57 |
| Ni | ... | 8·82 | 7·80 | 7·54 | 7·30 |
| Co | ... | 0·56 | 0·44 | 0·37 | 0·39 |
| P | ... | 0·29 | 0·08 | 0·08 | nil |
| S | ... | 0·02 | 0·03 | 0·01 | 1·12 |
| Cl | ... | 0·07 | n.d. | n.d. | tr. |
| C | ... | n.d. | 0·05 | 0·01 | 0·13 |
| Insol. | ... | 0·30 | 0·01 | 0·03 | 0·22 |
| Totals | ... | 99·59 | 100·18 | 99·58 | 99·73 |
| Sp. Gr. | ... | | 7·80 | 7·53 | 7·73 |

1. Moorumbunna iron. Analyst, F. D. Drews.
- A. Boxhole iron (Madigan, 1940, Min. Mag., 25, 481).
- B. Henbury iron (Alderman, 1932, Rec. S. Aust. Mus., 4, 555).
- C. Kyancutta iron (Spencer, 1932, Min. Mag., 23, 329).

The sample analysed consisted of freshly-cut filings obtained by drilling 10 holes to a depth of about 1 cm. within an area 7 cm. x 7 cm., taking care to exclude any limonitic skin.

The Moorumbunna iron is distinctly richer in nickel (plus cobalt) and in phosphorus than either the Boxhole (Madigan 1940), the Henbury (Alderman 1932), or the Kyancutta (Spencer 1932) iron.

MACROTEXTURE

The iron is a medium octahedrite, with a well-developed Widmanstätten texture (pl. xlviii, fig. 1), in which respect it resembles the three other irons referred to above. The individual lamellae of kamacite are 0·5 to 1·5 mm. wide and 1 to 2 cm. long. In places, the regularity of the Widman-

stätten pattern is interrupted by irregular veinlets of schreibersite swathed in kamacite, but otherwise the texture persists practically to the margin, where there is a "skin" of limonite less than 0·5 mm. thick.

The iron also shows a series of "Reichenbach lamellae," consisting of thin blades of troilite encased in kamacite (pl. xlvi, fig. 1, 3 and 4), in which respect it resembles the Kyancutta iron. In addition, there is an occasional nodule of troilite.

MINERAL COMPOSITION AND MICROTEXTURES

Microscopical examination of polished sections shows that the meteorite consists chiefly of kamacite (α -nickel-iron) with lesser amounts of taenite (γ -nickel-iron), schreibersite, troilite, limonite and lawrencite.

Nickel-Iron Alloys

The α -nickel-iron (kamacite) which forms the broad blades in the Widmanstätten texture is iron-white and isotropic, strongly magnetic, and is readily scratched by a steel needle. Its behaviour with standard etching reagents is as follows: 1:1 nitric acid produces an immediate etching, bringing up grain boundaries, cracks and scratches, and roughening the surface, but without effervescence; 1:1 hydrochloric acid fumes tarnish the iron, but the effects are inconsistent; 20% potassium hydroxide, and 20% potassium cyanide are negative; 20% ferric chloride instantly darkens the iron, bringing up grain boundaries and scratches; saturated mercuric chloride darkens the surface at once.

The γ -nickel-iron (taenite) is also iron-white, isotropic, strongly magnetic, and is readily scratched by a steel needle, so that it is not easily distinguished from the kamacite in unetched surfaces, although it is harder than the kamacite, as can be seen by examining the polishing scratches brought up by etching in fig. 3. It is readily distinguished, however, by etching with 2% nitric acid in alcohol, or with picric acid or bromine, which attack the kamacite, roughening its surface, and leave the taenite practically unaffected. The standard etching reagents, 1:1 nitric acid, 1:1 hydrochloric acid, 20% potassium hydroxide, 20% potassium cyanide, 20% ferric chloride, and saturated mercuric chloride do not attack taenite.

The taenite occurs as narrow impersistent lamellae between the kamacite bands (pl. xlvi, fig. 1), and rather more abundantly in finer lamellar intergrowths with kamacite in so-called "plessite" areas (pl. xlvi, fig. 1 and 2). These are commonly triangular or rhomboid areas interspersed to the groups of large kamacite blades, and probably represent the last portions of the iron to invert to the α -form. They may show a simple lamellar intergrowth of kamacite and taenite lamellae, or they may repeat the octahedral pattern on a microscale (pl. xlvi, fig. 2, 3, 4). They are equivalent to patches of fine octahedrite texture.

Associated with these "plessite" areas are smaller areas of so-called "dense plessite" which consist of minutely fine intergrowths of taenite and kamacite enclosed by taenite (pl. xlvi, fig. 1). This "dense plessite" after etching generally appears almost black at low and medium magnifications, owing to the etching of the innumerable kamacite boundaries.

Schreibersite

The phosphorus in the meteorite occurs as the iron-nickel phosphide, schreibersite $(Fe, Ni, Co)_3P$, which appears tin-white to the unaided eye. In polished sections it has a brownish tinge compared with the kamacite or taenite, and is weakly anisotropic. It is strongly magnetic, and is hard and brittle, so that it cannot be scratched with a steel needle, and is difficult to polish, developing

numerous cracks. It effervesces slowly with 1:1 hydrochloric acid, the bubbles rising from the cracks in the surface, but is negative to the other standard etching reagents.

It occurs as blebs (pl. xl ix, fig. 1) and as irregular or branching veinlets in the interstices of the kamacite plates. Several veinlets of schreibersite, appearing dark grey, "swathed" in kamacite, can be seen interrupting the regularity of the Widmanstätten texture in pl. xl viii, fig. 1, 2 and 4. These veinlets are 0.5 to 1 mm. wide.

Troilite

A nodule of troilite, FeS, cut in section, occurs in the margin of the piece of iron (pl. xl ix, fig. 1). The nodule measured about 2 cm. x 2 cm. x 1 cm. and consisted of allotriomorphic grains of troilite separated from the iron by a narrow rim of schreibersite next to the sulphide, and a further rim of limonite between the schreibersite and the iron. The limonite appears to have developed from the oxidation of kamacite, since the fall of the meteorite, for it contains residual lamellae of taenite. The schreibersite is negative to all etching reagents other than HCl, which caused slow effervescence. It is thus quite distinct from the "swathing" kamacite reported by Perry (1944, p. 87) as enclosing troilite nodules. The iron adjacent to the nodule in pl. xl viii, fig. 1, has been darkened by the action of hydrogen sulphide set free during the etching of the specimen.

The troilite resembles pyrrhotite in all respects, except that it effervesces vigorously with 1:1 hydrochloric acid with the evolution of hydrogen sulphide, which is a distinguishing feature. Normally troilite also effervesces with 1:1 nitric acid, but this specimen failed to do so. The troilite also occurs as occasional lamellae—the so-called "Reichenbach lamellae," about 0.1 mm. wide and up to 3 cm. long, enclosed in "swathing" kamacite (pl. xl viii, fig. 1, 3 and 4)). These lamellae appear to occur in two (? three) parallel sets whose relationship to each other is not clear. Each appears to be parallel to the long axis of the enclosing kamacite blade. One of these troilite lamellae (pl. xl viii, fig. 4) appears to cut through several small areas of schreibersite, enclosed in the kamacite.

Lawrencite

Minute drops of ferrous chloride (containing some nickel chloride) ooze from freshly cut or freshly polished surfaces. If exposed to the air, they oxidise first to ferric chloride and then to ferric oxide, deeply corroding the kamacite in the process. If the specimen is immersed in kerosene the droplets are retained as ferrous chloride.

ORIGIN OF THE MICROTEXTURES

It is established that the Widmanstätten textures in meteoric irons arise from the transformation of original γ -nickel-iron to α -nickel-iron (Edwards and Hodge-Smith 1941; Perry 1944). The transformation proceeds according to equilibrium relationships as outlined by Marsh (1938). The newly precipitated α -iron grows most readily in the octahedral planes of the γ -iron, so that oriented blade-like crystals of α -iron develop. The α -iron carries a maximum of about 5.5% nickel, and any nickel (and cobalt) in excess of this amount is retained in the untransformed γ -iron, which becomes isolated in the interstices between the widening blades of α -iron. This transference of nickel is probably caused by the fact that the γ -iron has a face-centred structure, and the α -iron to which it transforms has a body-centred structure, whereas nickel can only form a face-centred structure, and hence cannot substitute for iron so freely in the new lattice. The effect of transferring the excess nickel to the residual γ -iron is to depress the temperature at which transformation to α -iron occurs, so that above a cer-

tain nickel content the temperature of transformation falls below the temperature at which solid diffusion ceases, when any untransformed γ -iron, now enriched in nickel, remains as taenite.

The mass of iron thus becomes stable as an intergrowth of lamellae of α -iron (kamacite) of varying widths, according to the nickel-content of the original γ -iron, separated by bands or lamellae of nickel-enriched γ -iron (taenite). Each α -iron lamella is oriented in one or other of the octahedral crystallographic directions of the original γ -iron. Other conditions being uniform, the coarseness of the resultant Widmanstätten texture will be in inverse proportion to the nickel content of the original γ -iron, *i.e.*, to the nickel (plus cobalt) content of the meteoric iron as a whole. With nickel (and cobalt) in excess of 20%, the temperature of the γ - to α -transformation is depressed to such a degree that no transformation is possible, and the iron remains as a γ -iron ataxite. Iron with 15% to 20% nickel develops an incipient Widmanstätten texture, and becomes an "eotaxite." Iron with 10% to 15% nickel form a fine octahedrite, that with 7% to 10% nickel forms a medium octahedrite. Iron with less than 5% to 6% nickel transforms more or less completely to α -iron, and forms a nickel-poor or α -iron ataxite (hexahedrite).

The areas of "plessite" and "dense plessite" represent interstitial areas where enrichment in nickel has increased the proportion of taenite, and slowed down the rate of diffusion, particularly in the case of the "dense plessite" areas, where segregation of the minute kamacite and taenite bodies has been prevented.

The coarseness of the Widmanstätten texture is also affected by the rate of cooling, which sets a limit to the extent of solid diffusion. In Ni-poor irons, the transformation to α -iron takes place at temperatures sufficiently high for diffusion to be rapid, so that the effect of different rates of cooling is minimised, and the range of composition which can yield a particular coarseness of texture is small. With higher nickel contents, and slower rates of diffusion, the effect of different rates of cooling is more pronounced and the range of composition which can yield a particular coarseness or fineness of texture is widened. Thus the analyses cited in Table I show that medium octahedrites of similar texture can develop from irons containing from 7.7% to 9.4% nickel (plus cobalt).

The troilite nodules appear to arise from onset of immiscibility between sulphide and iron, caused by the presence of impurities, at temperatures when the iron sulphide is still above its melting point. The "Reichenbach" lamellae, on the other hand, suggest unmixing of iron sulphide from solid solution in the iron at a considerably lower temperature.

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FIG. 2

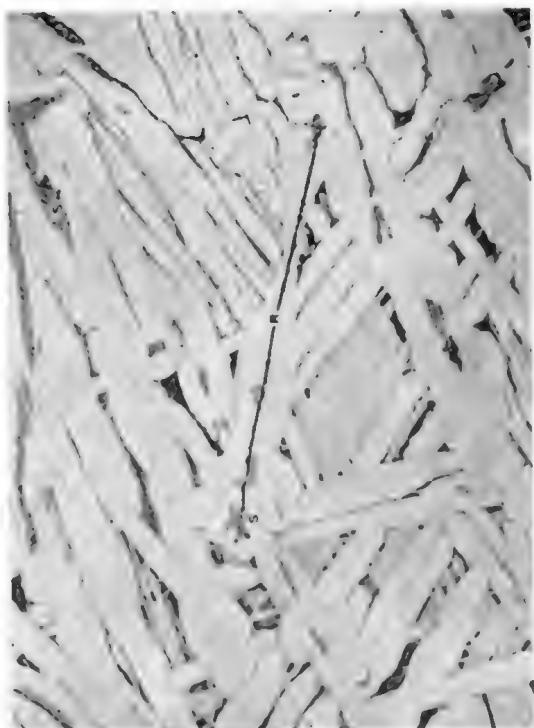


FIG. 1

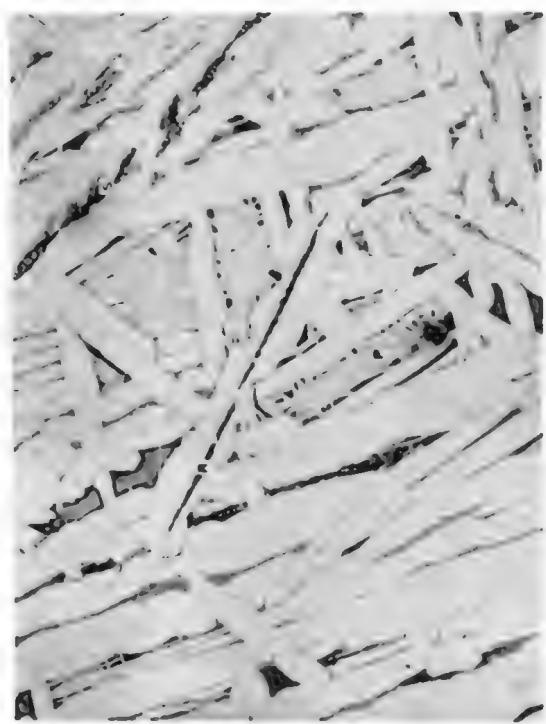


FIG. 3



Fig. 1



Fig. 2



Fig. 3

EXPLANATION OF PLATE XLVIII

Fig. 1

Section of the Moorumbunna meteoric iron, showing Widmanstätten texture of a typical medium octahedrite, with troilite nodule on the margin. Etched with 2% HNO₃ in alcohol. Reduced $\frac{1}{4}$ diameters.

Fig. 2

Portion of fig. 1 enlarged to show irregular lamellae of schreibersite (S) swathed in α -iron (kamacite). A "Reichenbach" lamella (R) crosses the field on the left, and several areas of "plessite" (P) can be seen. Magnified $3\frac{1}{2}$ diameters.

Fig. 3

Portion of fig. 1 enlarged to show a "Reichenbach" lamella (R) enclosed in α -iron (kamacite), and areas of "plessite" (P) and schreibersite (S). Magnified $3\frac{1}{2}$ diameters.

Fig. 4

Portion of fig. 1 enlarged to show a "Reichenbach" lamella (R) intersecting areas of schreibersite (S). Magnified $3\frac{1}{2}$ diameters.

EXPLANATION OF PLATE XLIX

Fig. 1

Interstitial area of "plessite" consisting of lamellae of residual γ -iron or taenite (T), inter-leaved with orientated α -iron or kamacite. Etched with 2% HNO₃ in alcohol. Magnified 120 diameters.

Fig. 2

Area of "plessite" and "dense plessite" (D) adjacent to a broad lamella of α -iron (kamacite) which encloses blebs of minute schreibersite (S), and is bounded by thin lamellae of γ -iron (taenite) (T). Etched with 2% HNO₃ in alcohol. Magnified 63 diameters.

Fig. 3

A general view of the Moorumbunna meteorite. Scale in inches.

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Receipts and Payments for the Year ended 30 September 1946

| RECEIPTS | | | | PAYMENTS | | |
|---|------|-----|----|----------|----|----|
| | | £ | s. | £ | s. | |
| To Balance 1 October 1945 | | 161 | 19 | 11 | | |
| ,, Subscriptions | | 148 | 1 | 0 | | |
| ,, Life Member Composition | | 15 | 15 | 0 | | |
| ,, Government Grant for printing, etc. | | 294 | 4 | 9 | | |
| ,, Sale of Publications and Reprints:— | | | | | | |
| University of Adelaide | 84 | 11 | 8 | | | |
| Sundries | 46 | 16 | 6 | | | |
| | 125 | 8 | 2 | | | |
| ,, Miscellaneous | | 0 | 8 | 2 | | |
| ,, Interest — Transferred from Endowment Fund | | 204 | 6 | 6 | | |
| | £950 | 3 | 6 | | | |
| | | | | | | |
| By Transactions (Vol. 69, Pt. 2; Vol. 70, Pt. 1) | | | | | | |
| Printing | | 461 | 8 | 1 | | |
| Illustrating | | 181 | 0 | 3 | | |
| Publishing | | 20 | 7 | 6 | | |
| | | | | 662 | 15 | 10 |
| ,, Reprints | | | | 87 | 10 | 3 |
| ,, Librarian | | | | 31 | 14 | 0 |
| Lighting | | | | 3 | 0 | 10 |
| Printing, Postages and Stationery | | | | 24 | 8 | 9 |
| Petties, Cheque Book, etc. | | | | 5 | 5 | 0 |
| Insurances | | | | 6 | 10 | 0 |
| Cleaning Rooms | | | | 12 | 15 | 0 |
| Legal | | | | 2 | 12 | 6 |
| | | | | 54 | 12 | 1 |
| ,, Balances—30 Sep. 1946— | | | | | | |
| Savings Bank of S.A... | | 41 | 14 | 10 | | |
| Bank of Australasia— | | | | | | |
| General A/c £71 10 4 | | | | | | |
| Less Outstanding | | | | | | |
| Cheques | 18 | 1 | 1 | | | |
| | | | | 52 | 19 | 3 |
| Cash to Bank | | | | 3 | 2 | 3 |
| Endowment Fund | | | | 15 | 15 | 0 |
| | | | | 113 | 11 | 4 |
| | | | | £950 | 3 | 6 |

ENDOWMENT FUND as at 30 September 1945
(Capital—Stocks, etc., Face Value, £6,042 18s. 7d.; Cost, £6,041 8s. 7d.)

| | £ | s. | d. | £ | s. | d. |
|----------------------------------|--------|----|----|--------|----|----|
| 1945—October 1 | | | | | | |
| To Balance— | | | | | | |
| Aust. Inscribed Stocks | 6,008 | 10 | 0 | | | |
| Savings Bank of S.A. | 17 | 3 | 7 | | | |
| | 6,025 | 13 | 7 | | | |
| ,, Life Member Composition | | 15 | 15 | 0 | | |
| ,, Interest— | | | | | | |
| Inscribed Stocks | 200 | 9 | 6 | | | |
| Savings Bank of S.A. | 3 | 17 | 0 | | | |
| | 204 | 6 | 6 | | | |
| | £6,245 | 15 | 1 | | | |
| | | | | | | |
| 1946—September 30 | | | | | | |
| By Revenue Account | | | | 204 | 6 | 6 |
| ,, Balance— | | | | | | |
| Aust. Inscribed Stocks | 6,000 | 8 | 10 | 0 | | |
| Savings Bank of S.A. | 17 | 3 | 7 | | | |
| Bank of Australasia | | 15 | 15 | 0 | | |
| | | | | 6,041 | 8 | 7 |
| | | | | £6,245 | 15 | 1 |

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. } Hon.
F. M. ANGEL } Auditors

HERBERT M. HALE,
Hon. Treasurer

Adelaide, 8 October 1946

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