VOL. 87 DECEMBER, 1963

TRANSACTIONS OF THE ROYAL SOCIETY OF SOUTH AUSTRALIA

INCORPORATED

ADELAIDE

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

Price: Three Pounds Three Shillings

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BY N. H. LUDBROOK

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CORRELATION OF THE TERTIARY ROCKS OF SOUTH AUSTRALIA*

by N. H. LUDBROOK†

[Read 12 July 1962]

SUMMARY

Marine and non-marine sediments of Paleocene to Pliocene age are represented in South Australia, although parts of the sequence are known only from subsurface sections. The Tertiary sequence is most complete in the Murray Basin, where *Hantkenina alabamensis compressa* occurs near the top of the Eocene and the evolutionary series *Globigerinoides triloba-Orbulina universa* occurs in the Miocene. Three members with distinctive molluscan faunas occur in the so-called Pliocene of the Adelaide Plains Basin. Charts are given showing the sequence of key foraminiferal faunas throughout the Tertiary and of the vertical distribution of mollusca in the "Pliocene" sediments west of Adelaide. A table is given showing the correlation of all known formations of Tertiary age.

INTRODUCTION

The continually increasing volume of information which becomes available for palaeontological research from extensive economic exploration of South Australia by the Department of Mines and by private companies emphasizes the need for reviewing the present state of knowledge of the Tertiary sediments which cover a large part of the State and which are of major economic importance as one of the main sources of underground water.

Correlation of the Tertiary rocks of southern Australia generally passed through many vicissitudes in the first fifty years of this century and it must be difficult for the reader to assess the validity of the ages attributed to Tertiary sediments where no indication is given of the evidence upon which the age is determined and where no attempts are made to appraise the data available.

The remoteness of Australia from Europe increases the difficulty of dating Tertiary strata in terms of European type stages, but within the last ten to fifteen years micropalaeontologists have tended to attach increasing importance to planktonic foraminifera as Tertiary biostratigraphic indices. Although agreement is not yet general, particularly on mid-Tertiary correlation, there are several microfaunal datum planes, notably in the Upper Eocene and Lower Miocene, which can be extended over long distances.

When planktonic foraminifera are rare or absent, which is frequently the case in South Australia where sedimentation in some basins took place with only partial access to the open sea, one must rely on benthonic foraminifera and other groups. The mollusca have received more attention than other phyla, but they have limited application in detailed subsurface correlation where percussion drilling has been used.

* Presidental address delivered to the Royal Society of South Australia on 12th July, 1962.

† Senior Palaeontologist, Geological Survey of South Australia; published with the permission of the Director of Mines.

I have attempted in Fig. 1 to draw up a correlation chart for all the Tertiary rocks known to me in South Australia.

These include not only the normal marine sediments but also paralic and non-marine carbonaceous sediments which have yet to be precisely correlated from palynological data. I have also prepared a biostratigraphic column to demonstrate the more important faunal bases upon which the correlations have been made. Most of the faunas are as yet undescribed.

Working independently, Carter (1958, 1959) and Jenkins (1960) made subdivisions of the Victorian Tertiary, mainly on the evidence of planktonic foraminifera. Carter established a sequence of 11 faunal units for the Eocene-Miocene of Victoria while Jenkins proposed 11 zones for a sequence in Lakes Entrance Oil Shaft corresponding approximately to Carter's faunal units 6 to 11.

A similar succession in the Murray Basin in South Australia has also been identified (Ludbrook, 1961, Tables X, XI).

On the correlation chart (Fig. 1) I have indicated the correspondence between Carter's and Jenkins's faunal units or zones and the faunal succession in South Australia so far as it is known at present.

With the exception of the drawings of foraminifera, the figures have been prepared by Mr. M. B. Langsford and Mr. J. Dambergs of the Department of Mines.

PALEOCENE

Although no outcrops of Paleocene rocks are known in South Australia, glauconitic sands and grits occurring at depths of from 3,000 to 4,000 feet in the Gambier Sunklands are to be correlated in part at least with the Bahgallah Formation which unconformably overlies the Cretaceous Runnymede Formation at Killara Bluff eight miles south-south-west of Casterton in Western Victoria.

Ferruginization indicates that these greensands were exposed before the overlying Dartmoor Formation was deposited. Both are included in the Knight Group.

LOWER TO UPPER EOCENE PARALIC SEDIMENTS

During most of the Eocene, deposition under paralic conditions took place over much of the southern part of the State. The sediments laid down are considered to be of Middle and Upper Eocene age for the most part, but it is likely that the Lower Eocene is also represented in some areas of deeper sedimentation.

Most of the Tertiary lignites and carbonaceous beds occur at different levels within this sequence. Their considerable distribution, particularly along the margins of the major basins up against the bedrock highs or in areas of shallow basin developments in crystalline basement rocks has been proved by extensive drilling programmes. None have as yet been economically exploited.

In the west of South Australia, at Maralinga lignite occurred in Bore 3B at 220 feet and in 11B at 457 to 462 feet; the Malbooma area has recently been drilled by the S.A. Department of Mines, but results are not yet published. At Pidinga in the Eucla Basin lignitiferous clays outcrop; a 48-foot borehole proved two lignite seams 5 ft. 9 in. below 23 ft. 6 in. and 7 ft. below 34 ft. depth.

On Eyre Peninsula Eocene carbonaceous sands and silts occur in the Minnipa, Cummins, Wanilla and Lincoln Basins. In the Cummins Basin the Eocene

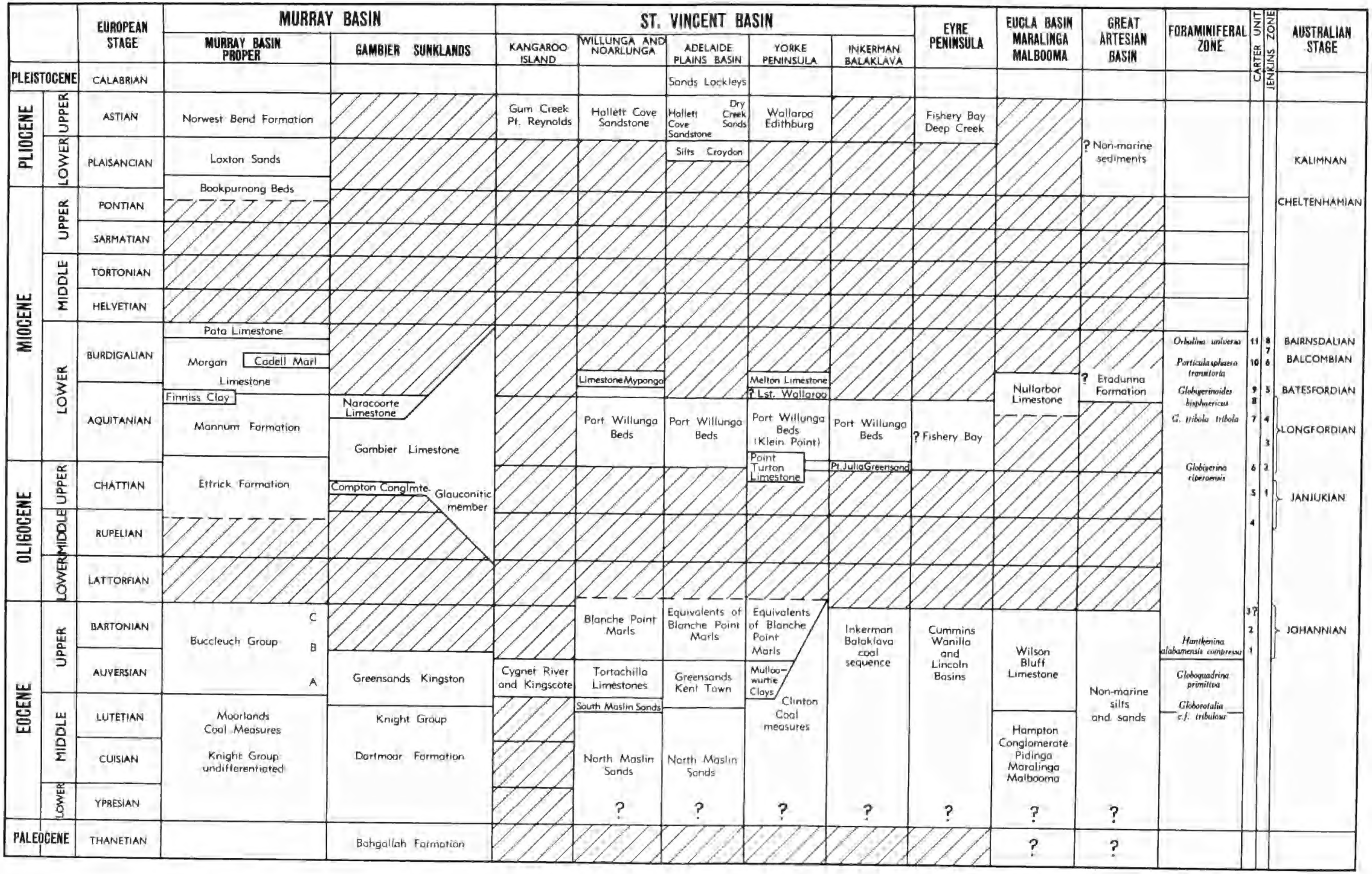

Fig. 1. Correlation of the Tertiary rocks of South Australia.

occurs between depths of 85 and 330 feet, with black earthy lignites between 115 and 195 feet. A few pauperate and mostly planktonic foraminifera are usually present also. Dark grey lignitic and pyritic sands with *Globigerina*, *Chara* and pyritized gastropoda are present below 62 feet in the Wanilla Basin. Similar sediments occur in the Lincoln Basin.

In the St. Vincent Basin the North Maslin Sands at the base of the Tertiary sequence are of considerable economic importance. They were described by Reynolds (1953) from Maslin Bay and are being extensively exploited in the vicinity of Maslin Bay for building sands. They are unconformably overlain by the South Maslin Sands from which R. Brown of the University of Adelaide collected a small fauna of rare mollusca containing *Pronucula tatei* (Finlay), *Glycymeris lenticularis* (Tate), *Arca equidens* Tate, *Glans curta* (Tate), cf. *Mitra varicosa* Tate, and species of *Emarginula*, *Turbonilla*, *Cerithiella* and *Amphithalamus*. This fauna may be compared with that occurring in the greensands of Kent Town Bore and bores at the Children's Hospital at depths of about 65 feet.

Low rank coal occurs at intervals throughout the Eocene of the St. Vincent Basin. At Clinton 19 bores proved coal at an average depth of 292 feet with average thickness of seam 21·8 feet. In the Inkerman-Balaklava field 34 bores proved lignite of average thickness 18 feet at 233 feet depth. Coal seams occur on the upthrow side of the Para Fault in the Adelaide area. At North Adelaide they are at 111-156 feet below 80 feet of Tertiary marls and silts. Near Hope Valley and Golden Grove 46 holes proved a small tonnage with an average overburden of 150 feet. At Noarlunga nine holes proved coal at depths varying from 70 to 810 feet due partly to disturbance and partly to the stratigraphic position of the seams. Coal with fossil fruits was intersected at 80-90 feet in a water bore in the North Maslin Sands at Kangarilla.

Remnants of carbonaceous sediments with fossil fruits in the Barossa Valley and outcropping near Lyndoch are thought to be equivalents of the North Maslin Sands.

Lignitic sands of presumed Eocene age occur in the Pirie-Torrens Basin, while Tertiary carbonaceous sediments at present not precisely dated occur in the Willochra Basin.

Carbonaceous sands with Eocene microfloras are known also from the Great Artesian Basin in Lake Eyre (Ludbrook, 1963, in press) and in the Frome Embayment.

In the Murray Basin the earliest Tertiary is represented by the Knight Group, the formations of which for the most part are unnamed and undifferentiated. Apart from those briefly described (Ludbrook, 1961, pp. 13-14), the Dartmoor Formation is well represented at depth in the Gambier Sunklands. *Cyclammina* spp., *Ammodiscus parri* and fish teeth occur throughout most of the sequence ("Anglesea facies") and marine intercalations with *Turritella aldingae*, *Ledella leptorhyncha* and corals occur irregularly. The foraminifera of this assemblage, however, are facies indicators for the most part and do not either give any direct indication of the age of the sediments in which they were deposited or permit correlation over more than a limited area. However, they underlie sediments with *Globoquadrina primitiva* and *Globorotalia* cf. *tribulosa* and are therefore of Lower to Middle Eocene age.

The Moorlands Coal Measures and other lignitic deposits in the Hundred of Bower, Hundred of Anna, and in County Grey occur within and probably towards the top of the Knight Group.

All the early Tertiary sediments are characterized by an abundance of *Nothofagus* pollen of a type occurring now only in New Guinea and New Caledonia. The extinction of *Nothofagus* is a matter needing urgent investigation for the dating of non-marine Tertiary sands and silts. Other plant remains which have been recorded as microfloras or fruits include the ferns *Schizaea* and *Gleichenia*, the conifers *Podocarpus* and an *Agathis* similar to *Agathis palmerstoni* from North Queensland, *Sapindaceae* species close to the Queensland rainforest tree *Mischocarpus pyriformis*, and members of *Casuarina*, *Myrtacea*, Banksias, Proteas, mosses.

The geographical setting for deposition of this material was probably similar to that of North Queensland and New Guinea today, with rainforest bordering salt estuaries and marshes.

MIDDLE EOCENE MARINE FACIES

The Mayurra Microfaunule

The first distinctive microfaunal assemblage in the South Australian Tertiary is an association of *Globigerapsis index*, *Globigerina linaperta* and *Globoquadrina primitiva* which occurs in yellow limonitic quartz sand at the top of the Knight Group at 510 feet depth at Cellulose Australia Limited works at Snuggery, Hundred of Mayurra, Section 78. The same fauna occurs in the lower unexposed glauconitic member of the Wilson Bluff Limestone in the Eucla Basin where it is associated also with *Rotaliatina* sp., *Marginulina* sp., *Maslinella chapmani* and *Pseudohastigerina micra* (Ludbrook, 1960).

The fauna occurs also at the base of the greensands intersected at Kingston in the Hundred of Lacepede at 214 to 227 feet where it is associated with a species of *Globorotalia* very close to *G. tribulosa* Loeblich and Tappan. *Globoquadrina primitiva* is recorded as occurring commonly in the Middle Eocene but rarely in the Upper Eocene in New Zealand and its known range in South Australia suggests that the base of the Wilson Bluff Limestone is of Middle rather than Upper Eocene age. *Globorotalia* cf. *tribulosa* and its associated fauna would place the base of the greensands at Kingston also in the Middle Eocene. Normal marine sedimentation continued in the Eucla Basin, but oscillating conditions, particularly in the Murray Basin, tended to cause the removal of late Eocene sediments, the correlation of which is complicated by rapid facies changes.

UPPER EOCENE

(1) *The Tortachilla microfaunule.* *Globoquadrina primitiva* persists in the Wilson Bluff Limestone into the next fauna which is well represented in the upper member of the Wilson Bluff Limestone of the Eucla Basin, the Tortachilla Limestone of the St. Vincent Basin, the limestone "A" of Buccleuch Group in the Murray Basin, and limestone at Kingscote and Cygnet River and at depth in the Hundred of Menzies on Kangaroo Island.

Greensands between 190 and 214 feet depth at Kingston in the Hundred of Lacepede, greensands intersected at depths of about 60 to 70 feet at North Adelaide, and the Muloowurtie[1] Clays are to be correlated stratigraphically with these limestones. The foraminiferal assemblage contains the planktonic species *Globigerapsis index* and *Globigerina linaperta* nearly always accompanied by *Asterigerina adelaidensis*, *Maslinella chapmani*, and a large *Pseudopolymorphina*.

[1] By a typographical error, Muloowurtie has been mis-spelt in Fig. 1.

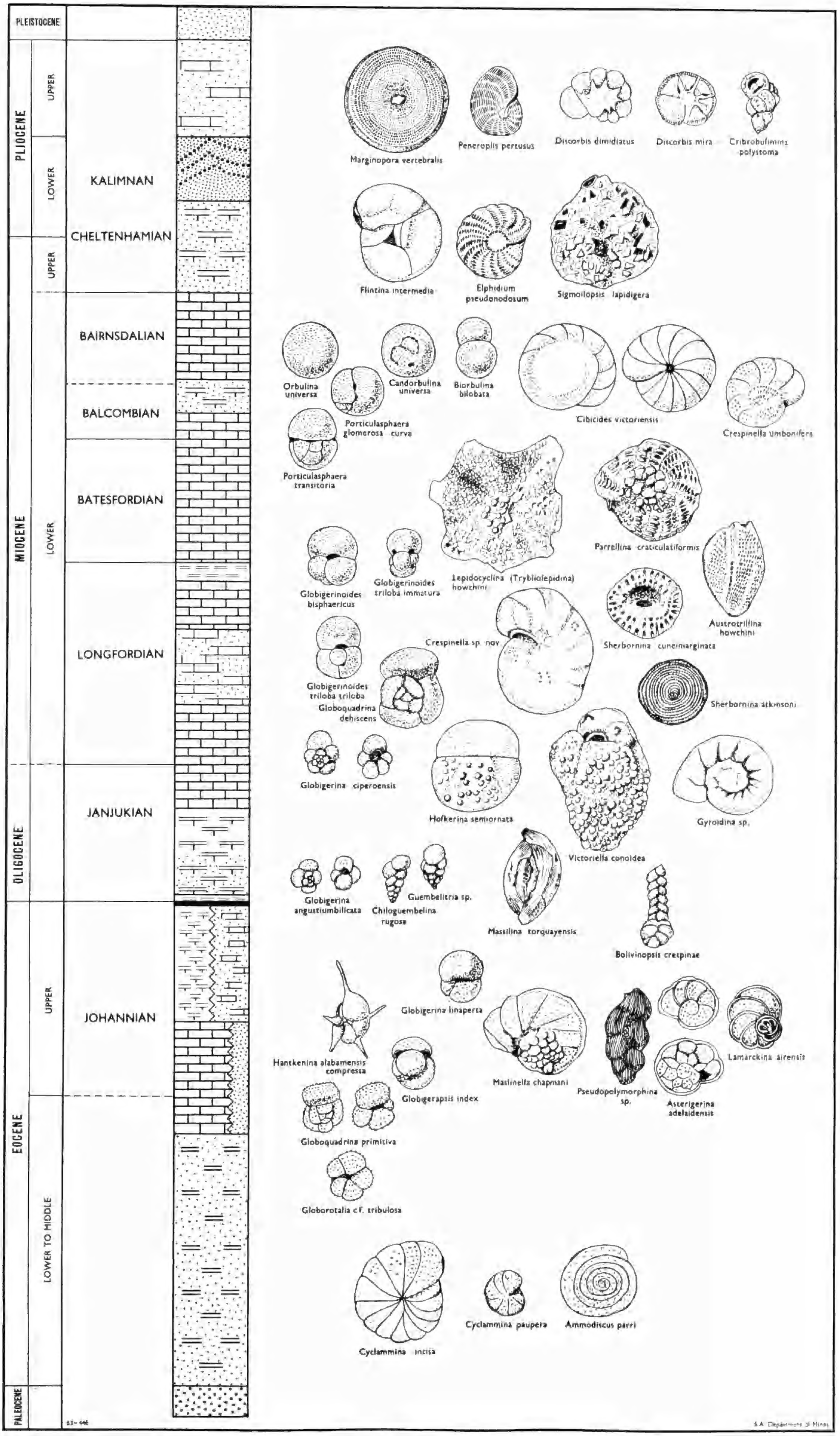

Fig. 2. South Australian Tertiary Foraminifera.

Halkyardia, *Linderina*, and *Crespinina kingscotensis* occur in the calcareous sediments while *Sherbornina atkinsoni* may be present if the facies is sandy (quartzose). The probable synonymy of *Sherbornina atkinsoni* and *S. crassata* has been indicated (Ludbrook, 1961, p. 86).

Associated mollusca invariably include *Turritella aldingae* and *Ledella leptorhyncha*.

(2) *Zone of Hantkenina alabamensis compressa.* In both the St. Vincent and Murray Basins the rare and diagnostic *Hantkenina alabamensis compressa* occurs above or near the top of the unit contained in the Tortachilla and Buccleuch A limestones.

In the St. Vincent Basin it occurs, though very rarely, about three feet above the base of the Transitional Marl Member of the Blanche Point Marls and in the Murray Basin at a depth of 187-190 feet near the top of the sequence of greensands at Kingston. These greensands carry a similar microfauna to that of the limestone of Buccleuch A and are considered to be equivalent in part at least to Buccleuch A. The microfauna associated with *Hantkenina* contains *Globigerapsis index*, *Globigerina linaperta*, *Asterigerina adelaidensis*, *Pseudohastigerina micra*, and the ostracode *Cythereis hostizea* which according to Hornibrook (1953, p. 38) is one of the most characteristic in the Upper Eocene and Lower Oligocene of New Zealand.

This fauna is Carter's Faunal Unit 1.

Carter's faunal unit 2 is probably represented by the fauna of the Banded Marl Member of the Blanche Point Marls, but if his faunal unit 3 is represented in South Australia, it appears to be recognizable only by Carter's criterion—the absence of species restricted to the Upper Eocene Units 1 and 2. It may possibly be represented by the upper part of the Blanche Point Marls in the St. Vincent Basin, but is so far not identifiable above the *Hantkenina* zone of the Murray Basin, the sequence in this part of the Tertiary being governed by oscillation producing rapid facies change and erosion before deposition of the Gambier Limestone. Carter (1959, p. 48) has used the stage name Johannian for strata containing his units 1, 2 and 3.

OLIGOCENE

The basal glauconitic member of the Gambier Limestone occurs at depth in the Millicent-Beachport-Kingston area and is entered at a depth of 440 feet in borings at Cellulose Australia Ltd., Snuggery. The fauna contains elements of Carter's Units 3 and 4. Unit 3 is represented by the persistence of *Vaginulinopsis acanthonucleus*, *Bolivinopsis crespinae* and abundant *Chiloguembelina rugosa*, but *Globigerina linaperta* is replaced by *Globigerina angustiumbilicata*, which appears to be long-ranging (Eames *et al.*, 1962, p. 85). *Guembelitria* sp. also occurs sparingly in this fauna, which includes also *Gaudryina* (*Pseudogaudryina*) *crespinae*, *Stomatorbina concentrica*, *Vulvulina* sp., *Ammodiscus parri*, *Cyclammina paupera*, *C. rotundata*, *Vaginulinopsis* cf. *gippslandicus*, and *Epistomina elegans*. *Victoriella conoidea* appears immediately above this fauna in the Beachport area, but makes its first appearance at this level at Kingston and Snuggary where the faunas also contain *Cibicides umbonifer* and an unornamented, probably new, species of *Hofkerina*. All available evidence points to an Oligocene age for this unit. In Victoria it is represented by the lower episode of the Janjukian stage (Carter's Unit 4). It is known so far only from the Murray Basin in South Australia.

The upper episode of the Janjukian is represented in the lower part of the upper member of the Gambier Limestone with abundant *Victoriella conoidea* accompanied by *Hofkerina semiornata*. Most of the associated globigerines are probably *G. praebulloides* and *G. angustiumbilicata*, but *Globigerina ciperoensis* is occasionally present. It makes its appearance only 10 feet above *Victoriella conoidea* in Canopus No. 1 Bore (Ludbrook, 1961, Table IX) and is present also in dark grey mudstone associated with *Guembelitria* sp., *Chiloguembelina rugosa*, *Sherbornina atkinsoni*, and *Bolivinopsis crespinae* at the top of the Ettrick Formation in Department of Mines Bore 996/61, Hundred of Finniss, Section 456/7, four miles east of Mannum at 58 ft. 6 in. depth. *Globigerina*

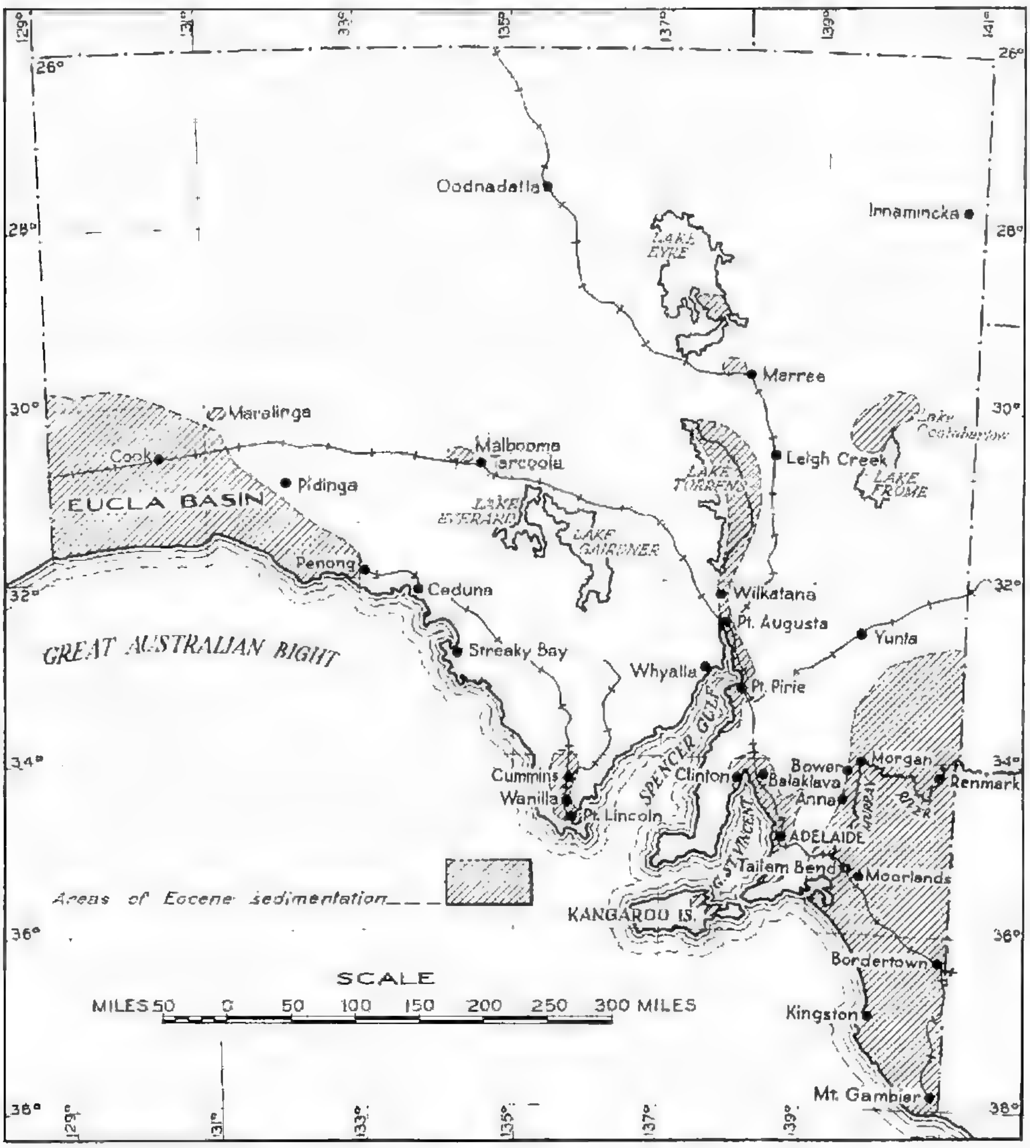

Fig. 3. Areas of Eocene Sedimentation in South Australia.

ouachitaensis and *Globigerina angustiumbilicata* are also present in this fauna. *Globigerina euapertura* Jenkins occurs at a depth of 101 to 138 feet in the same bore associated with *Sherbornina atkinsoni*.

The marls of the Ettrick Formation almost always contain *Massilina torquayensis* and *Cassidulina subglobosa*. Planktonic foraminifera are rare. However, the planktonics occurring in the more varied strata of the Formation in the Mannum area confirm that the Ettrick Formation is "Janjukian", with a fauna equivalent to Carter's Unit 5. Carter's Unit 6, Jenkins's Zone 2, with *G. ciperoensis*, is represented only at the very top of the Formation.

The Point Turton Limestone on western Yorke Peninsula also carries *Victoriella conoidea* and is to be correlated with part of the Gambier Limestone, although its fauna is very inadequately known.

The Oligocene-Miocene boundary is still a matter of some uncertainty. Eames and his colleagues (1962, p. 21) have presented reasons for regarding faunal Unit 5 as lower Aquitanian, but the strong Paleogene element represented by *Chiloguembelina rugosa, Bolivinopsis crespinae, Guembelitria* sp., and *Sherbornina atkinsoni*, combined with the facts that at least along the margins of the Murray Basin there is discontinuity between the Ettrick and the overlying Mannum Formations and that there is no evidence to suggest that the Paleogene elements could be derived, tends to support the Oligocene age attributed to the Ettrick Formation and its equivalents (Ludbrook, 1957, 1961).

MIOCENE

The Miocene sequence in the Murray Basin has been described (Ludbrook, 1957, 1961), the Longfordian Stage being represented in the Mannum Formation. Carter's redefinition of the Longfordian (1959, p. 50) to include his units 6, 7 and 8 necessitates the inclusion of the Finniss Clay and the basal part of the Morgan Limestone, which contains unit 8, within the Longfordian.

The fauna contained in the Gambier Limestone at its type locality (Ludbrook, 1961, p. 28) with *Globigerinoides rubra* but without *G. bisphaericus* appears to belong rather to the top of Jenkins's Zone 4, i.e. below unit 8, there being some discrepancy between Carter's and Jenkins's planktonic ranges at this level.

Equivalents of the Mannum Formation with Longfordian faunas are to be found in the Port Willunga Beds on both sides of Gulf St. Vincent in the Willunga and Noarlunga Sub-basins with the type locality at Port Willunga and on the eastern side of Yorke Peninsula notably at Klein Point near Stansbury. They usually have abundant *Sherbornina atkinsoni* near the base and *Sherbornina cuneimarginata* and a new species of *Crespinella* at higher levels. *Operculina victoriensis* is common except at the lower levels. The Longfordian Stage is believed on the evidence of the planktonic foraminifera to be approximately equivalent to the European Aquitanian.

The Batesfordian Stage with Carter's Unit 9, occurs within the Morgan Limestone where *Lepidocyclina (Trybliolepidina) howchini* occurs in exposures at Caloote, Mannum and Blanchetown. Bryozoal limestones with the same fauna occur in borings at Myponga, while the Melton Limestone exposed in a large sinkhole two miles north of Melton on Section 388, Hundred of Kulpara, is rich in *Lepidocyclina howchini* also.

Limestones occurring at and to the north of Wallaroo are not yet studied in detail and their correlation is uncertain.

The upper part of the Morgan Limestone and the lower part of the Pata Limestone, in which the evolutionary series leading to *Biorbulina bilobata* and *Orbulina universa* occur (Ludbrook, 1961, pp. 88-89), contain Jenkins's Zones 6 and 9 and Carter's faunal units 10 and 11, which, according to Carter (1959, p. 50) occur in the Balcombian and Bairnsdalian respectively.

This sequence, according to Eames *et al.* (p. 28) has been dated as Burdigalian (and/or Aquitanian).

The position of the Nullarbor Limestone of the Eucla Basin is a little uncertain as the faunas have not been adequately studied. Most of the palaeontological data are contained in unpublished reports (Ludbrook, 1954a, 1954b, 1956, 1959b, 1959c) of the Department of Mines, which are available for reference.

The base of the Nullarbor Limestone measured at the Head of the Bight (Ludbrook in Glaessner and Parkin, 1958, p. 133) and also at Madura in Western Australia, is correlated with the upper part of the Mannum Formation and is probably uppermost Longfordian (Aquitanian) particularly on the western and northern margins of the Eucla Basin. *Austrotrillina howchini* occurs commonly in the dense miliolid limestone frequently in association with *Flosculinella bontangensis* and *Marginopora vertebralis* (Ludbrook, 1954a, b). This part of the Nullarbor Limestone has been correlated (Ludbrook, 1954a; Crespin, 1956) with the Trealla Limestone of Western Australia and is regarded as Burdigalian.

The molluscan fauna of the limestone quarried at Watson and also at Naretha in Western Australia contains such elements as *Miltha* sp., and *Diastoma* which are usually present only in the late Miocene or Pliocene. So far the *Austrotrillina howchini-Flosculinella bontangensis* association has been seen only in material from Naretha.

Dating of Etadunna Formation (Stirton, Tedford and Miller, 1961, pp. 31, 51-53, 56-57) can be only approximate until the microfloral sequence in South Australian Tertiary deposits is studied in detail. At present it is thought to be post-Oligocene from tentative dating by B. E. Balme of carbonaceous sediments which have been lateritized and which underlie the Etadunna Formation in Lake Eyre (Balme, 1963, in press). I have elsewhere (Ludbrook, 1963, in press) suggested that the Etadunna is possibly not older than Miocene. The dolomitic nature of sediments at Maralinga which may be equivalent to the Etadunna Formation makes it possible that these were deposited in lagoons marginal to the Lower Miocene seas in which the Nullarbor Limestone was deposited.

?MIOCENE-PLIOCENE

The Position of the Bookpurnong Beds

In the Murray Basin an unconformity or disconformity occurs between the top of the Pata Limestone and the Bookpurnong Beds, and the Bookpurnong Beds are not at all to be located in the position where they have been placed by Eames *et al.* (1962, Fig. 4). As has been pointed out (Ludbrook, 1961, p. 89) the Bookpurnong Beds are richly glauconitic and give evidence of a marked change in sedimentation. The base of the Bookpurnong Beds at the type exposure at Loxton (Ludbrook, 1961, p. 65) and also in the standard subsurface section (*ibid.*, pp. 68, 70-71) contain Miocene elements. To what extent these have been derived in the subsurface section it is impossible to say but in the exposed section on Section 11, Hundred of Pyap, *Operculina victoriensis* is

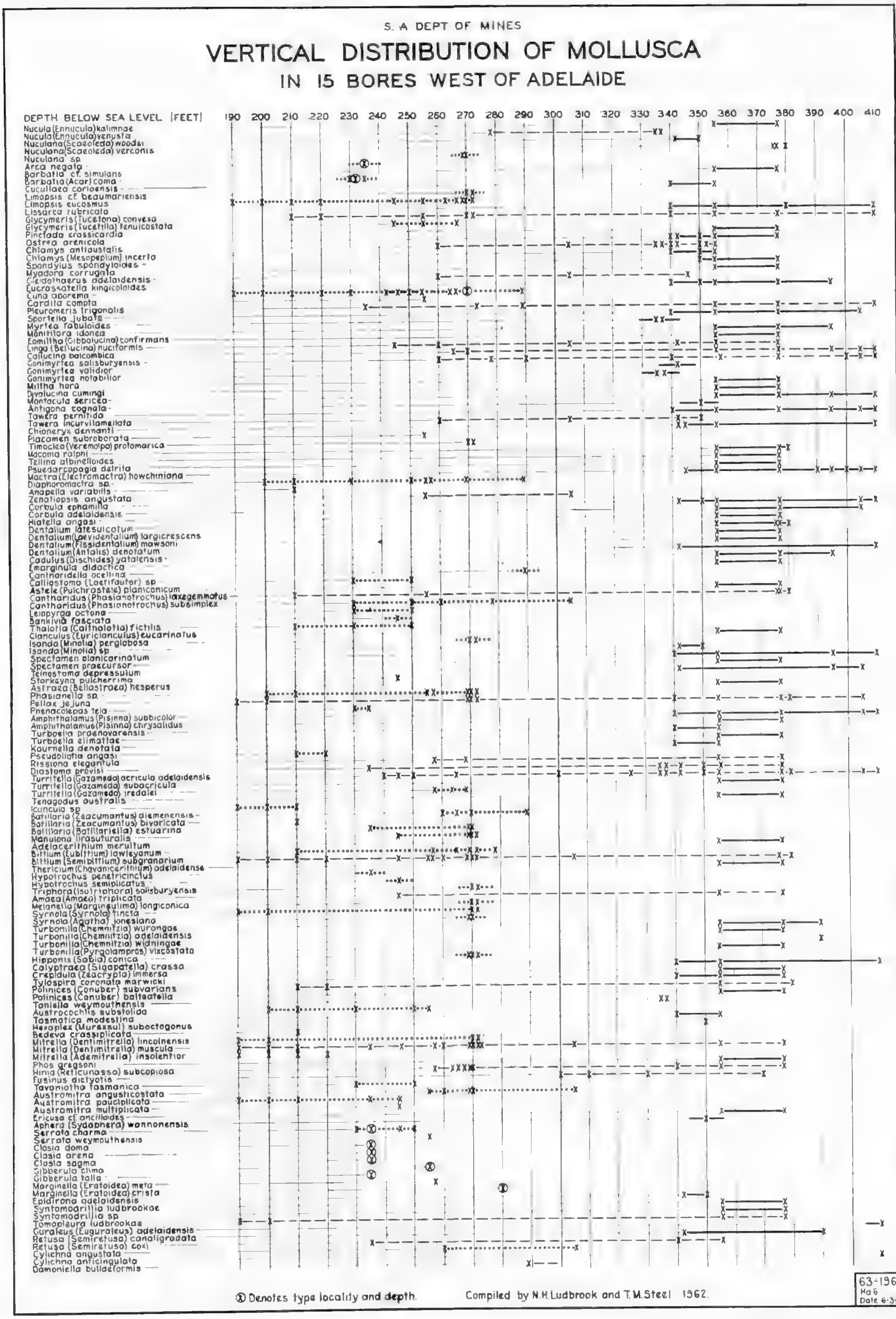

Fig. 4. Vertical Distribution of Mollusca.

entirely derived. The molluscan fauna from this section has not yet been studied but a preliminary inspection shows the presence of Miocene elements such as *Eotrigonia*.

Late in 1961 during the laying of a pipe line at 5 to 10 feet depth below the bed of the River Murray at Loxton Mr. M. J. Paul made a valuable collection of megafossils from the Bookpurnong Beds at this level. The mollusca include *Pinctada crassicardia* (Tate), *Miltha hora* (Cotton), *Cucullaea corioensis* McCoy, *Mytilus* cf. *linguatulus* Tate, *Glycymeris convexa* (Tate), *Glycymeris* cf. *caino zoica* (T. Woods), *Eucrassatella kingicoloides* (Pritchard), *Neotrigonia trua* Cotton, *Cypraea amygdalina* Tate, *Tylospira coronata* (Tate), *Polinices* (*Polinices*) *subjugum* (Cotton), and *Cottonia* cf. *heptagonalis* (Tate). This is a predominantly Pliocene assemblage containing the Kalimnan *Tylospira coronata*. The associated microfauna is also predominantly Pliocene. The Bookpurnong Beds are therefore here placed higher in the sequence than before and are regarded as Upper Miocene to Lower Pliocene in age.

PLIOCENE

If the Bookpurnong Beds are partially at least of Pliocene age then the overlying Loxton Sands are entirely Pliocene and not Upper Miocene or Cheltenhamian as hitherto tentatively stated (Ludbrook, 1957, p. 179; 1961, p. 89). As the Loxton Sands are estuarine and contain only shallow water faunas dominated by *Ostrea sturtiana* they are difficult to correlate biostratigraphically. No other rocks in South Australia are known to contain the molluscan fauna of the Loxton Sands (Ludbrook, 1961, p. 75).

The overlying Norwest Bend Formation has been correlated with limestone containing characteristic mollusca such as *Anodontia sphericula* and *Campanile triseriale* which occur at many localities from Fishery Bay on Eyre Peninsula to Moorlands in the Murray Basin (Ludbrook, 1959a). The Hallett Cove Sandstone and the Dry Creek Sands of the Adelaide Plains Basin have been placed at this level. Authors have in the past used the time-rock term "Adelaidean Stage" for the Dry Creek Sands and their fauna. The name was abandoned because of its confusion with the Precambrian Adelaide System and no substitute stage name is now in use. Because of its distinctive molluscan assemblage, I propose to use the name *Yatalan* for the fauna of the Dry Creek Sands and their equivalents, the faunal unit being represented in Dry Creek Bore from 320 to 410 feet depth, Abattoirs Bore 341 to 500 feet, Croydon Bore 395 to 525 feet, Kooyonga Bores 371 to 562 feet. The geographical name is taken from the Hundred of Yatala in which many of the bores are located.

The so-called Pliocene of the Adelaide Plains Basin is divisible into three members — a basal unnamed silt member which is present in Croydon, Kooyonga and other bores (Steel, 1962), the richly fossiliferous pale grey shelly sands (Dry Creek Sands) from which the foraminifera (Howchin and Parr, 1938) and the mollusca (Ludbrook, 1954-1958) have been described (the Yatalan fauna), and an upper member of fine to medium quartz sand with a distinctive assemblage of small mollusca, the most common of which are *Bittium* (*Eubittium*) *lawleyanum* and a species of *Diaphoromactra*. The accompanying chart (Fig. 4) shows the vertical distribution in relation to sea-level of mollusca in 15 bores in the Adelaide Basin to the west of Adelaide, including Cowandilla bore. From this analysis it is obvious that the Dry Creek Sands with the Yatalan fauna of large warm-water mollusca occur below 340 feet below sea-level and are overlain by a younger member with a distinct fauna from 190 feet to 305 feet. Most of the mollusca described by Cotton (1947, 1949) as will be seen from the chart, came from this member, which is of limited geographical extent to the west of Adelaide in the general Lockleys area.

The molluscan fauna of the upper member inhabited a lagoonal environment or very shallow water. Its general composition is similar to that of the marginal salt lagoons at Lake McDonnell. If the extinction of the warm-water Yatalan fauna represents the onset of colder conditions at the end of the Pliocene, then the Pliocene-Pleistocene boundary for the Adelaide Basin should be placed between the Dry Creek Sands and the upper member occurring in the Lockleys area. This would be in conformity with the present placing of the boundary in New Zealand between the Waitotaran and the Nukumaruan. The Dry Creek Sands have previously been related to the New Zealand Waitotaran Stage (Ludbrook, 1954, p. 54).

Sediments overlying the Norwest Bend Formation in the Murray Basin have not yet been defined.

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THE BRUSH-TAILED OPOSSUM OF KANGAROO ISLAND, SOUTH AUSTRALIA

BY H. H. FINLAYSON

Summary

Trichosurus vulpecula from Kangaroo Island is compared in series with the animal from the adjacent mainland of the Adelaide district and is found to be subspecifically distinct, and named *T. v. raui.* The evidence is presented in detail.

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[Read 9 August 1962]

SUMMARY

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INTRODUCTION

In his treatment of *Trichosurus vulpecula* Kerr in the "Mammals of South Australia", Wood Jones (1924, pp. 196-203) gave a succinct account of what he considered were the essential differences which separated the animal of Kangaroo Island from that of the adjacent mainland. He was especially familiar with the island form through his intimate connection with Flinders Chase and his frequent visits to that sanctuary at the western end of the island, where for a time the dense opossum population was kept within bounds by an annual snaring for the fur market.

It is clear from his account that he regarded the Kangaroo Island opossum as a distinct geographical subspecies, as he compared and constrasted it with what he called "the typical variety as it occurs round Adelaide". He did not, however, give a formal definition nor apply a distinguishing trinomial to it, and there now seems reason to believe that the prepared specimen on which he chiefly relied for his description was somewhat atypical of the population (*infra*).

In August, 1928, the present writer made a visit to the Chase in company with the Taxidermist of the South Australian Museum, and with the assistance of the then Ranger, Mr. Harold Hansen, collected a satisfactory series of opossums, which were measured and weighed in the flesh and preserved in the conventional ways. This collection was deposited in the South Australian Museum and, together with specimens in my own possession, forms the basis of the present account.

The question of what are the true characters of the "typical", primary, or nominate race of *T. vulpecula* is easier to ask than to answer, and many similar questions continue to bedevil the trinominal treatment of early described species which like it have no surviving holotypes nor modern descriptions. That it came from the immediate or near vicinity of Sydney in New South Wales is probable but the currently accepted view, which stems from Iredale and Troughton (1934, pp. 30-31), that *T. vulpecula vulpecula* occurs over the greater part of south-eastern Australia, including southern Queensland, New South Wales, Victoria and South Australia, is more in the nature of a working hypothesis than an established fact.

However, this uncertainty does not invalidate the real differences which separate the two populations studied by Wood Jones which have been amply confirmed and extended in the present work, and which appears to place the Kangaroo Island form morphologically further from that of New South Wales as far as it is known, than from that of the Adelaide district. Unlike most other present day insular occurrences of the species in South Australian waters, which are either known to be due to deliberate introduction or are under suspicion of such, the Kangaroo Island population is undoubtedly indigenous, of large extent both numerically and territorially and of homogeneous character. It has been isolated from that of the adjacent mainland for a period generally estimated at 10,000 years at least, and possibly much longer. To continue to deny it trinomial distinction is more likely to confuse the general overall conception of the radiation of the species, than to clarify it, and for these reasons I propose to define it as follows:

Trichosurus vulpecula raui[1] subsp. nov.

An insular subspecies from Kangaroo Island, St. Vincent Gulf, South Australia.

General characters similar to those of the population of the Adelaide district and south Mt. Lofty Range of the adjacent mainland (currently regarded by authors as representing *T. vulpecula vulpecula* Kerr), but distinguished by its larger size, richer pelage, and somewhat darker and colder dorsal colouration. The dark markings of the head and hind foot are larger, more saturate and conspicuous, and the black portion of the tail brush is longer.

The skull is longer, relatively narrower and with narrower nasal bones, and shows other differences noted below.

In the dentition, the molar rows are longer, Ms^{1-3} in adults yielding an approximate mean of 15·1 mm. as against 13·9 mm. on the mainland.

Type Locality: The scrubs of Rocky River in the sanctuary of Flinders Chase at the western end of the island.

Type: Filled skin and skull of a young adult ♂, South Australian Museum, registered number M.2518. Collected August, 1928. A series of contemporary topotypes is also registered. Thirty specimens examined.

Dimensions of Type (for definition of dimensions see below): Head and body, 435 mm.; tail, 320; pes (total *s.u.* length), 71; pes (length of naked sole *s.u.*), 61; ear, length, 56; ear, breadth, 28; weight in grammes, 2,270.

Skull Dimensions of the Type: Basal length, 77·7; zygomatic breadth, 51·4; nasals, length, 34·0; nasals, greatest breadth, 14·0; interorbital constriction, 10·1; palate length, 46·0; anterior palatal foramina, 6·0; basi cranial axis, 24·4; basi facial axis, 53·5; facial index, 219; $Ms.^{1-3}$, 15·5; P^4, 5·0.

EXAMINATION OF THE MATERIAL

South Australian mainland material, available for comparison with the island form, is copious, but much of it is only broadly localized and probably comes from localities considerably north of Adelaide and in drier districts where, as Wood Jones has shown, the size falls off considerably. Preliminary tests having shown it to be much too heterogeneous for treatment *en bloc*, a

[1] Commemorating the late F. J. Rau, for many years Taxidermist of the South Australian Museum, and a senior member of a family which has rendered conspicuous service in that craft in Australia.

restricted sample from the Adelaide-Wakefield Plain (including the urban area) and the south Mt. Lofty Range, was selected comprising about 25 specimens in good condition and sufficiently documented for the purpose.

The age criterion adopted was the closure of the basioccipital-basisphenoid suture, which, though it takes place fairly early, yet serves to exclude obviously immature examples, and gives a sample of fairly uniform size. This test reduced the Kangaroo Island series to 14 examples (7 ♂ : 7 ♀), and the Adelaide district one to 13 (5 ♂ : 3 ♀ : 5 not sexed).

Flesh Dimensions

The range and approximate mean of seven items under this head are quoted for the Kangaroo Island series in Table 1.

(a) The head and body length represents the total length of the dorsal contour measured with a steel tape from the upper extremity of the rhinarium to the end of the tail excluding the terminal hair tuft, minus the length of tail.

(b) Tail length is from the cloaca to apex (excluding hair) measured along the ventral surface with the tail stretched at right angles to the trunk.

(c) Total pes length is the usual dimension from the extremity of the hairy heel to the extremity of the most distant apical pad and therefore excluding the claw.

(d) Length of sole of pes represents the nude portion of the above.

(e) Ear length is the distance from the bottom of the tragal notch to the apex of the pinna, taken with the zero of a rigid rule, within the notch.

(f) Ear breadth is the greatest transverse breadth across the trough of the pinna, at right angles to the above.

(g) Weights were ascertained on removing animals from neck snares approximately 6-10 hours *post mortem*.

TABLE 1

	7 Adult ♂		6 Adult ♀		Combined Adult ♂+♀	
Head and body	410-460	(442)	415-485	(450)	410-485	(446)
Tail	290-350	(319)	290-340	(311)	290-350	(315)
Pes (entire s.u.)	62-74	(68)	60-69	(65)	60-74	(67)
Pes (nude sole only)	55-61	(57)	55-57	(56)	55-61	(57)
Ear length	53-59	(56)	52-58	(55)	52-59	(56)
Ear breadth	27-30	(28)	28-31	(29)	27-31	(28)
Weight (in grammes)	1,816-2,724	(2,335)	2,043-2,724	(2,406)	1,816-2,724	(2,370)

Range and approx. mean of flesh dimensions in *Trichosurus vulpecula rubi* subsp. nov.

The question of the relation of the external dimensions of the populations from the island and the Adelaide district has had to be left in abeyance owing to lack of data for the latter, sufficiently adequate to justify a comparison. Most of the published figures for the species are doubtfully comparable with the above, having been derived from stuffed skins or by methods based on uncertain landmarks. The lengths of pes quoted in literature are particularly dubious, suggesting in some cases that the measurement made was actually of the nude portion of the plantar surface only, which (as shown above) may be a full 10 mm. less than the true dimension from the calcaneum.

Wood Jones (op. cit.) considered the island form to be larger than that of the Adelaide district and the evidence of cranial dimensions reviewed below supports this, but it should be noticed that the male measured by him is (in respect to head and body length at least) excessively large, exceeding the maxima of the series here measured by 15 p.c.

Pelage

In general characters the pelage of the Kangaroo Island opossum is quite similar to that of the Adelaide district, exhibits a similar range of variation and a proportion of each series is scarcely distinguishable in this regard. There are, however, valid average distinctions, and where these are most decidedly developed the total dissimilarity may be considerable. Variation due to seasonal and age changes are marked in both groups, but if these are eliminated by confining the comparison to adults in mid-winter coat, the following distinctions hold:

(1) The dorsal pelage in the Kangaroo Island animal is darker in tone and colder in hue, the neutral grey being modified towards glaucous rather than fulvous. The length of the ivory or white subterminal band of the fur is also less and the grizzling of the dorsal coat correspondingly finer. Aged males are sometimes strongly reddened on the fore back as in the mainland animal, but the latter distinction remains.

The male described by Wood Jones (which is now in the South Australian Museum collection) is an extreme example of this secondary reddening, but a warm tawny dorsal colouration is not characteristic of the series as a whole; quite the contrary in fact.

(2) Ventrally the two series show comparatively slight differences, both being generally distinctly buffy in external colour. In the island group the colour possibly averages a little warmer, being near Ridgway's ochraceous buff in the richest examples, but the "rusty" belly mentioned by Wood Jones is only shown by one or two aged males in the present series, and is partly due to an unusual extension posteriorly of the brown colouration of the sternal gland site, which may occur in mainland examples also.

(3) There are considerable differences between the two series, in the extent and intensity of the dark markings of the head and feet. In the Kangaroo Island form the dark patch at the base of the ear backs is increased in area, so that the upper white or buff portion is sometimes reduced to a narrow strip on the posterior upper margin; the colour is generally darker and more saturate also; a dark brown black approaching jet black in some examples.

Similarly, in the pes the dark irregular markings on the tarsus and the dark fringe around the heel and on the outer margin of the foot are increased in area and density and invade the dorsum over the metatarsals, giving a more or less strongly pied effect to it, in which the light coloured grey or buff area may be less than half the whole.

In the Adelaide series the markings of the foot are not strongly developed and usually the entire dorsum is pale.

(4) The brush of the tail is better developed in the island animal and the black portion more extensive in relation to the grey, always covering more than half and sometimes three-quarters of its total length. In the mainland analogue it is frequently less than half the total length.

TABLE 2

	Kangaroo Island			Adelaide District and S. Mt. Lofty Range		
	7 Adult ♂	7 Adult ♀	♂ + ♀ Ad. (14 skulls)	5 Adult ♂	3 Adult ♀	♂ + ♀ Ad. (13 skulls) (5 not sexed)
Greatest length	85·8–91·5 (87·3)	84·0–86·0 (84·9)	84·0–91·5 (86·1)	83·0–86·5 (84·3)	80·0–80·0 (80·0)	80·0–86·5 (82·5)
Basal length	76·6–82·0 (78·5)	75·4–79·7 (78·4)	75·4–82·0 (78·4)	75·0–78·8 (75·9)	72·5–72·7 (72·6)	72·5–78·8 (74·9)
Zygomatic breadth	50·5–54·7 (52·2)	48·6–52·3 (50·4)	48·6–54·7 (51·3)	50·0–52·3 (51·0)	48·3–52·5 (50·3)	50·0–52·5 (51·0)
Nasals, length	33·4–36·3 (34·4)	30·0–32·9 (31·5)	30·0–36·3 (32·9)	30·3–34·5 (32·2)	28·2–32·4 (30·0)	28·2–34·5 (31·2)
Nasals, greatest breadth	14·0–16·1 (14·8)	13·8–15·8 (14·7)	13·8–16·1 (14·7)	14·5–15·7 (14·9)	14·1–16·3 (15·1)	14·1–17·0 (15·3)
Interorbital constriction	7·2–11·9 (9·9)	9·6–11·3 (10·2)	7·2–11·9 (10·0)	7·6–11·0 (9·4)	9·5–13·3 (10·8)	7·6–13·3 (10·0)
Palate length	45·0–47·4 (46·0)	43·8–46·4 (45·0)	43·8–47·4 (45·5)	41·5–44·5 (43·4)	40·8–42·0 (41·4)	40·8–44·5 (42·6)
Anterior palatal foramina	5·4–6·7 (6·1)	5·5–6·4 (5·9)	5·4–6·7 (6·0)	5·5–6·3 (6·1)	5·5–6·2 (5·9)	5·4–6·6 (6·0)
Basicranial axis	24·7–26·9 (25·7)	25·3–27·1 (26·2)	24·7–27·1 (25·9)	23·5–27·0 (25·5)	20·9–23·8 (22·8)	20·9–28·0 (24·5)
Basifacial axis	51·2–55·2 (52·9)	48·8–53·1 (50·5)	48·8–55·2 (51·7)	47·5–52·2 (50·2)	48·3–51·4 (49·6)	47·5–52·2 (49·8)
Facial index	195–223 (208)	180–203 (193)	180–223 (200)	180–220 (197)	203–207 (205)	172–220 (196)
Ms^{1-3} *in situ*	14·6–15·7 (15·3)	14·4–15·2 (14·9)	14·4–15·7 (15·1)	13·8–14·6 (14·3)	13·1–13·4 (13·3)	13·1–14·6 (13·9)
P^4	4·6–5·0 (4·7)	4·4–4·9 (4·6)	4·4–5·0 (4·6)	4·4–5·0 (4·7)	4·2–4·2 (4·2)	4·2–4·9 (4·5)

Range and approx. mean of cranial and dental dimensions of *Trichosurus vulpecula* from Kangaroo Island, and from Adelaide district and S. Mt. Lofty Range, South Australia.

Cranial Characters

Seventeen dimensions and indices were examined in the two groups and the more conventional are summarized in Table 2. In absolute dimensions the ranges overlap in most items but the approximate means for the Kangaroo Island series are almost always higher, and in the chief longitudinal dimensions by 5-6 p.c.

The Kangaroo Island skull is generally narrower zygomatically, the breadth/greatest length ratio giving a mean of 59·5 as against 61·8 in the mainland skull and the nasal bones are also narrower with a breadth index of 44·7 as against 48·7. The interorbital breadth and length of anterior palatal foramina are also relatively slightly less.

A visual impression that the skull of the island animal was longer muzzled could not be substantiated by an appeal to the cranial index, except in the male group. The basisphenoid-presphenoid suture in almost all skulls examined was obscured by overlapping plates of the pterygoids, and as a substitute landmark in the determination of the index, the apex of the visible portion of the basisphenoid was used. Although this frequently coincides with the position of the suture, it proved a somewhat erratic feature, and the figures for the index and the originating axes are approximations only. An approximate rostral index derived from the length of nasals in relation to greatest length of skull confirmed a slightly increased length of muzzle in the Kangaroo Island males only — these are also slightly narrower in the muzzle.

In non-metrical characters, variation in both series is high, comparatively small age changes effecting considerable differences in general appearance, especially in the frontal and interorbital region; however, the differences detected metrically are often quite apparent visually. The foramen magnum in *T. v. raui* is decidedly larger both absolutely and relatively and is deeper from above downwards than in the Adelaide series.

Dentition

The upper molars and upper secators only were examined quantitatively, and the former provide one of the most useful and constant distinctions between the two series. In the Kangaroo Island race, the length of Ms^{1-3} *in situ* yields a range of values almost entirely above that for the mainland series and an approximate mean which is 8 p.c. higher.

O. Thomas (1888, p. 187) used the length of the molar rows in his key of characters differentiating "*T. vulpecula typicus*" on the one hand from *T. v. fuliginosus* and *T. caninus* on the other, the former having a length of Ms^{1-3} *in situ* of less than 14·5 mm. and the two latter more than 14·5 mm.[a] The mainland population from the Adelaide district here studied conforms approximately to Thomas's definition, giving a range for Ms^{1-3} of 13·1-14·6 (13·9) mm. in adult skulls; but the Kangaroo Island group (though much closer to that of the mainland in all other characters than to that of Tasmania) approximates the latter in its longer rows with a range of 14·4-15·7 (15·1).

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[a] The context and the dimensions in the table on p. 208 seem to indicate that the reference to Ms_{1-3} on p. 187 is a mistake for Ms^{1-3}.

THE LARVAE OF AUSTRALIAN DYTISCIDAE (COLEOPTERA)

BY C. H. S. WATTS

Summary

The larvae of eighteen species of Dytiscidae are described for the first time. These are *Bidessus bistrigatus,* Clk., *Bamabilis* Clk., *Hyphydrus australis,* Clk., *Sternopriscus cluvatus,* Wehn., *Paroster insculptilis,* Clk., *Chostonectes latus,* Sharp, *C. nebulosus* McLeay, *Antiporus gilbertii,* Clk., *A. femoralis,* Boh., *A. blakei,* Clk., *Necterosoma penicillatus,* Clk., *N. dispar,* Germ., N. *wollastoni,* Clk., *Macroporus gardenerii,* Clk., *Platynectes decumpunctatus,* Fab., *Lancetes lanceolatus,* Clk., *Copelatus extensus,* Sharp, and *Homoeodytes scutellaris,* Germ. These include the first descriptions of larvae of species belonging to the following genera: *Sternopriscus* Sharp, *Paroster* Sharp, *Chostonectes* Sharp, *Antiporus* Sharp, *Necterosoma* McLeay, *Macroporus* Sharp, *Platynectes* Reg. and *Homoeodytes* Reg. A key to the genera of Australian Dytiscids using larval characters is given. Notes on the rearing of Dytiscid larvae and the method of feeding in *Copelatus* are included.

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by C. H. S. WATTS*

(*Communicated by Dr. S. J. Edmonds*)

[Read 9 August 1962]

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The larvae of eighteen species of Dytiscidae are described for the first time. These are *Bidessus bistrigatus*, Clk., *B. amabilis* Clk., *Hyphydrus australis*, Clk., *Sternopriscus clavatus*, Wehn., *Paroster insculptilis*, Clk., *Chostonectes latus*, Sharp, *C. nebulosus* McLeay, *Antiporus gilbertii*, Clk., *A. femoralis*, Boh., *A. blakei*, Clk., *Necterosoma penicillatus*, Clk., *N. dispar*, Germ., *N. wollastoni*, Clk., *Macroporus gardenerii*, Clk., *Platynectes decempunctatus*, Fab., *Lancetes lanceolatus*, Clk., *Copelatus extensus*, Sharp, and *Homoeodytes scutellaris*, Germ.

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Notes on the rearing of Dytiscid larvae and the method of feeding in *Copelatus* are included.

INTRODUCTION

The Dytiscidae of Australia have received little attention since Sharp's monograph in 1882, and I do not know of any published description of the larvae of an Australian species. However, the larvae of some Northern Hemisphere species, belonging to genera that are represented in Australia, have been described. Some of them differ in important characters from Australian species in the same genus.

The Australian region is especially rich in Hydroporinae, most of our genera in this group being endemic and the discovery of the larvae of these genera fills a large gap in our knowledge of the larval Hydroporinae. This is not so true of the other groups; there are few endemic genera, and most genera include non-Australian species, whose larvae have already been described. In these groups, larvae from all but two genera have been described from outside Australia. The two genera for which larvae have been described for the first time in this paper are *Homoeodytes* in the Cybistrinae and *Platynectes* in the Colymbetinae. The first is endemic to Australasia; the second is wide-spread throughout Australasia and South-East Asia.

The following descriptions are based on exuvia of last instars of larvae that have been reared through to the adult stage in small aquaria made from two petri dishes. The aquarium itself was simply the bottom of a small petri dish which was placed inside a much larger petri dish bottom, and the space around it filled in with damp sand. With the inner dish full of water and the lid of the larger dish in place, the sand remained moist. Under these conditions larvae placed in the aquaria and fed at intervals survived well

* Department of Zoology, University of Adelaide.

and eventually pupated in the surrounding sand. Apart from feeding the larvae and removing carcases, these aquaria need little attention and take up very little space. The larger larvae are mostly cannibalistic and have to be kept separate, but the smaller Hydroporinae and some larger larvae such as *Copelatus* can be kept together quite safely. With the Hydroporinae I found it necessary to put some cotton wool in the aquaria, as this makes it easier for them to capture their prey. I used cotton wool in preference to algae or other plant material as the latter die quickly in such small containers and soon foul the water. Dead prey, if at all large, will also foul the water quickly if not removed.

All the following species have been reared in aquaria of this design with few failures. In captivity the larvae were fed on mosquito, chironomid and dragon fly larvae or *Daphnia*. The actual prey used depended on the size of the larvae. The only genus that has proved difficult to breed under these conditions has been *Copelatus*, where, out of a total of five species and numerous specimens, only one adult has been reared. In most cases the mature larvae have crawled out on to the sand but have not pupated or even attempted to construct a cell. It seems, therefore, that the conditions necessary for pupation to take place in this genus were lacking.

STRUCTURES USED IN THE CLASSIFICATION

In the Hydroporinae the most useful taxonomic characters are to be found in the form of the frontal projection and the last abdominal segment, the shape of the labium and the arrangement of setae on the cerci.

The frontal projection is a projection from the front of the head and is used to help hold the prey during feeding, the prey being held against it by the mandibles which are strongly curved upwards in this group. The frontal projection is relatively simple in genera such as *Hyphydrus* (Fig. 10), although even in this genus it is furnished with lateral teeth. In others it is a more complex structure. In *Paroster* (Fig. 8) and *Sternopriscus* (Fig. 9) there is a weak projection from the side of the main structure, this projection being better developed in *Chostonectes* (Fig. 6) and in *Antiporus* (Fig. 1). I have called it the lateral projection. When the lateral projection is small as in *Paroster* it gives the frontal projection the appearance of being notched. In the more developed forms such as *Antiporus* this effect is lost, but I have still used the term "notch" in referring to the space between the frontal projection and the lateral projection. In most species there are well-developed teeth on the underside of the frontal projection, the majority being near the tip but they often extend backwards along the margin, as in *Bidessus* (Fig. 7) or on the margins of the lateral projections, e.g. *Chostonectes*.

In some genera the larvae have a pair of spines on the underside of the frontal projection as well. These are very small in *Chostonectes*, *Necterosoma* and *Macroporous*, but are large in *Antiporus*, especially *A. gilbertii* (Fig. 1) where they are placed on the top of a downward outgrowth from the frontal projection (Fig. 18).

The last abdominal segment is often produced into a long tube with the spiracles at its tip. I have used the term siphon in referring to this elongation which is usually well marked off from the rest of the segment. In genera such as *Hyphydrus* where it is not clearly marked off from the rest of the segment, I have taken it to end opposite the base of the cerci. The length of the siphon varies a lot, being long in *Macroporus* and *Chostonectes* (Figs. 25, 27), but virtually absent in *Sternopriscus* and *Antiporus* (Figs. 15, 28).

In most Dytiscid larvae there are a row of stout spines along the lateral margin of the head: these are the temporal spines. In the genus *Agabus*, from the Northern Hemisphere, they lie on a line that, if extrapolated forward, would pass well below the ocelli; in all the known Australian genera with the exception of some Hydroporinae they lie on a line that will pass through or just below the ocelli. Temporal spines are absent from the Bidesseni and *Paroster* and are poorly developed in the other Hydroporinae.

The shape and orientation of the maxillary stipes are characters useful in the classification of most groups, as are the shapes of the labium and its ligula, if the latter is present. The maxillary stipe may be either long and thin or short and thick. In the first case the galea, which in this family is reduced to a finger-like process, is rather small and inconspicuous; in the second case it is larger and is usually a very noticeable part of the maxillae. In some genera, e.g. *Lancetes,* the stipes have a number of small hooks on their inner edge; in *Copelatus* these are large and slender and are placed directly below the galea. The labium is wider than long in most Dytiscid larvae, other than the Hydro-

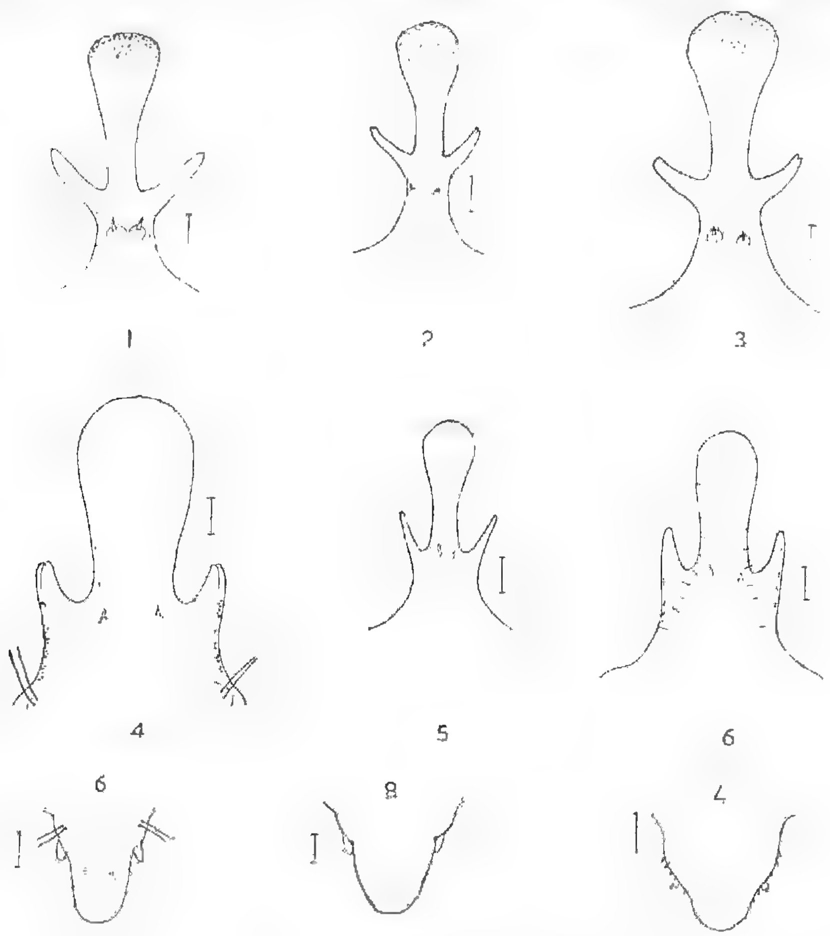

PLATE 1

Figures 1-9. Line represents ·1 mm. Frontal projections of (1) *Antiporus gilbertii,* Clk. ventral surface; (2) *A. blakei,* Clk., ventral surface; (3) *A. femoralis,* Boh., ventral surface; (4) *Macroporus gardnerii,* Clk., dorsal surface; (5) *Chostonectes nebulosus,* McLeay, dorsal surface; (6) *C. latus* Sharp, dorsal surface; (7) *Bidessus amabilis,* Clk., dorsal surface; (8) *Paroster insculptilis,* Clk., dorsal surface; (9) *Sternopriscus clavatus,* Wehn, dorsal surface.

porinae, where it is usually slightly longer than wide, or sometimes much longer, as in the Hyphidrini. A ligula, which is a projection forward from the front of the labium, is present in several genera. It varies greatly in development: at one extreme it is small and naked, e.g. *Homoeodytes*; at the other long and spiny, e.g. *Rhantaticus*.

The cerci are of very variable length. They are usually long but the length varies a lot between species and between genera. They may have only a few long setae which are usually placed in whorls, or they may have a lot of smaller setae irregularly placed along them. The former condition is often referred to as "cerci with primary hairs"; the latter "cerci with secondary hairs". In some species, mostly among the Hydroporinae, the cerci are made up of two parts. The basal part is robust and bears setae; the apical part is devoid of setae and is often very fragile. There are great differences in the relative length of these different parts. In some, the apical portion is reduced to a small knob, e.g. *Platynectes*; in others it is long and thin and gives the impression of being a very thick apical seta. In species with a slender apical portion, i.e. *Bidessus* spp., the junction between the basal and apical portions is weak and the apical portion is often broken off.

The key to the genera has been drawn up from the characters visible in unmounted material. In order to give as complete a key as possible, several genera, indicated with an asterisk in the key, are included which I have not seen. The characters used in these cases are from published figures and descriptions of Northern Hemisphere species and might not apply to Australian species. The key thus produced includes twenty out of the twenty-five Australian genera.

Where measurements are given these refer to the last instar larvae, unless otherwise stated. It should be remembered that these larvae show a large increase in length during an instar, and also, that whereas spirit specimens are often in a rather contracted condition, mounted specimens are often expanded. The length measurements are therefore meant as a rough guide only. They were made from spirit specimens that appeared to be full grown last instar larvae in a more or less natural condition. The lengths given do not include the cerci. The lengths of head capsules of the Hydroporinae include the frontal projection.

KEY TO THE GENERA OF AUSTRALIAN DYTISCIDAE BASED ON THE CHARACTERS OF LARVAE*

1. Head with frontal projection (Fig. 18); maxillary palps 3-segmented (Hydroporinae) ... 2
1. Head without frontal projection; maxillary palps more than 3-segmented ... 10
   2. Frontal projection without lateral projections ... 3
   2. Frontal projection with lateral projections ... 5
3. Labium short and broad. Siphon less than twice the length of the rest of the segment ... 4
3. Labium long (Fig. 19). Siphon more than twice the length of the rest of the segment (Fig. 24) ... *Hyphydrus*
   4. Larva not greatly widened. Frontal projection short and wide, with numerous lateral teeth extending nearly to base (Fig. 7) ... *Bidessus*
   4. Larva greatly widened in middle. Frontal projection elongated, with only a few lateral teeth restricted to apical half ... *Hydrovatus**
5. Last abdominal segment not greatly elongated, siphon less than twice the length of rest of segment ... 6

* The asterisk indicates that I have not seen a larva of any species from these genera.

5. Last abdominal segment greatly elongated, siphon more than twice the length of rest of segment (Fig. 25) .. .. *Macroporus*
   6. Width of notches on frontal projection equal to, or greater than, width of frontal projection between the notch bases 7
   6. Width of notches on frontal projection less than width of the frontal projection between notch bases 8
7. Apical segment not, or only slightly, produced into a siphon (Fig. 28). Paired spines on underside of the frontal projection well below notch bases .. .. *Antiporus*
7. Apical segment produced into a short siphon (Fig. 27). Paired spines on underside of the frontal projection on a level with or just below notch bases .. .. *Chostonectes*
   8. Apical segment produced into a short siphon 9
   8. Apical segment not produced into a short siphon (Fig. 15) *Sternopriscus*
9. Legs short and stout; notch in frontal projection slight (Fig. 9). Labial palpi 3-segmented (Fig. 21) .. .. *Paroster*
9. Legs not short and stout; notch in frontal projection large (Fig. 11). Labial palpi 2-segmented (Fig. 12) .. *Necterosoma*
   10. Maxillary stipe short and broad 13
   10. Maxillary stipe long and narrow 11
11. Cerci absent, or rudimentary. Antenna 9-segmented 12
11. Cerci present, antenna 6-segmented .. .. *Hydaticus**
   12. Ligula short (Fig. 39), lobes on front of head strongly dentate (Fig. 38) .. .. *Homoeodytes*
   12. Ligula long, lobes on front of head not strongly dentate .. *Cybister**
13. Ligula absent, last abdominal segment without lateral fringes of long setae 14
13. Ligula present, lateral fringes of long setae on last abdominal segment 18
   14. Cerci very short, less than length of last abdominal segment (Fig. 26); mandibles toothed on inner edge .. *Copelatus*
   14. Cerci as long as or longer than last abdominal segment; mandibles not toothed 15
15. Cerci more than twice the length of the last abdominal segment with numerous setae 16
15. Cerci about the same length as the last abdominal segment, with a few or with numerous setae 17
   16. Last abdominal segment produced into a small siphon; last joint of antenna less than half the length of the third joint .. *Laccophilus**
   16. Last abdominal segment truncate at the apex (Fig. 22); last joint of antenna more than half the length of the third joint (Fig. 35) *Lancetes*
17. Last joint of antenna more than two-thirds the length of the third joint (Fig. 36); cerci with numerous setae; underside of head with small spines .. .. *Rhantus*
17. Last joint of antenna less than half the length of the third joint; cerci with a few long setae (Fig. 23); underside of head without spines *Platynectes*
   18. Ligula short with four spines .. .. *Eretes**
   18. Ligula long, nearly the length of the first joint of the labial palpi, with six spines .. .. *Rhantaticus**

* The asterisk indicates that I have not seen a larva of any species from these genera.

HYDROPORINAE

Genus Bidessus Sharp

Head wide with no well-marked neck region and without temporal spines. Frontal projection wide, with a ventral row of strong teeth around lateral margin. Antenna short; labium bilobed. Siphon short, about half the length of the rest of the segment. Cerci variable, either with a few long setae or with numerous shorter ones.

The presence of cerci with only a few setae (primary hairs) was previously thought to be a generic character. The presence of cerci with numerous setae (secondary hairs) in *B. bistrigatus*, Clk., indicates that this character is only of specific rank as far as *Bidessus* is concerned.

Bidessus bistrigatus, Clk.

(Fig. 13)

Dorsal surface pale yellow-brown, temporal sutures bordered with dark brown. Ratio of length of siphon to length of rest of last segment, 1/2·2. Cerci eight times length of siphon, covered with numerous setae. Ratio of basal portion to apical portion of cerci 5·2/1.

Length, 3·6-3·8 mm. Head capsule, ·57 mm. wide, ·76 mm. long.

Larvae collected from a concrete drainage ditch, Canberra, January 1961, and from a sheep trough, Adelaide, March 1960.

Bidessus amabilis, Clk.

(Figs. 14, 7)

Dorsal surface dark brown, area enclosed by temporal sutures and frontal projection paler. Ratio of length of siphon to length of rest of last segment 1/1·8. Cerci short: 5·5 times length of siphon, with about six long setae. Ratio of basal portion to apical portion of cerci 1/1.

Length, 3·6-3·9 mm. Head capsule, ·62 mm. wide, ·78 mm. long.

Larvae collected from Hobart, August 1961; a salty pool, Robe, South Australia, August 1961; a pool with decaying leaves, Cradle Mt., National Park, Tasmania, January 1960; and a weedy ditch, St. Helens, Tasmania, January 1962.

Genus Hyphydrus Ill.

Head small, body compact, and with a hunch-backed appearance. Frontal projection long and thin, with fine teeth on ventral margins of upper two-thirds. Labium greatly elongated. Siphon elongated, about twice the length of the rest of the segment. Cerci short with numerous strong setae.

Hyphydrus australis, Clk.

(Figs. 24, 19, 10)

Compact, with a pronounced hump-backed appearance. Black; frontal projection, middle of head, a band across the prothorax, abdominal segments 5, 6 and 7, tip of siphon and cerci, and underside, light brown. Body densely covered with fine setae. Frontal projection and last abdominal segment as in Figs.

Length, 7·9-8·1 mm. Head capsule, last instar, ·80 mm. wide, 1·26 mm. long, second instar, ·55 mm. wide, ·85 mm. long.

The larvae were collected from a small pool full of decaying leaves at Stanthorpe, Queensland, January 1961; in a grassy pool 30 miles S.W. of Canberra, January 1961; and in a slow flowing creek full of the algae *Nitalla* sp. near Adelaide, December 1960.

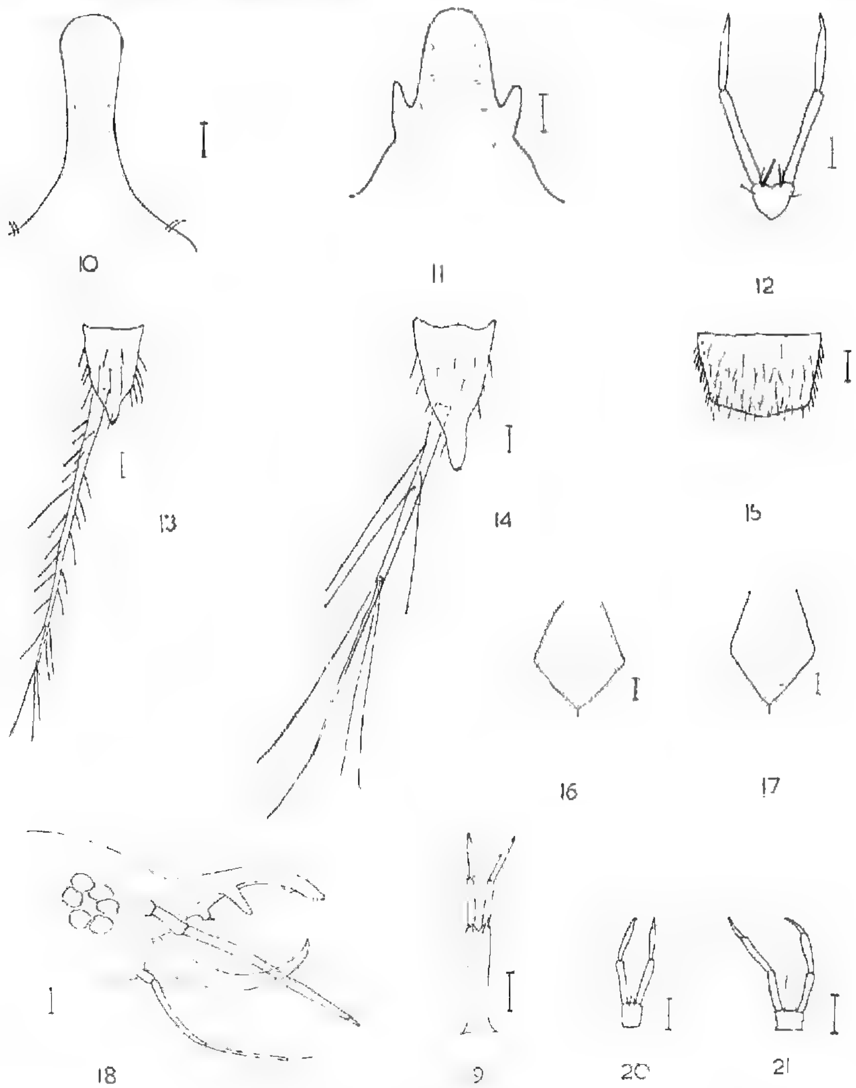

PLATE 2

Figures 10-21. Line represents ·1 mm. (10) Frontal projection of *Hyphydrus australis*, Clk., dorsal surface; (11) frontal projection of *Necterosoma dispar*, Germ.; (12) labium and labial palpi of *N. penicillatus*, Clk.; (13) last abdominal segment and cerci of *Bidessus bistrigatus*, Clk.; (14) last abdominal segment and cerci of *B. amabilis*, Clk.; (15) last abdominal segment of *Sternopriscus clavatus*, Wehn.; (16) epistome of *Necterosoma penicillatus*, Clk.; (17) epistome of *N. dispar*, Germ.; (18) lateral view of head of *Antiporus gilbertii*, Clk.; (19) labium and labial palpi of *Hyphydrus australis*, Clk.; (20) labium and labial palpi of *Sternopriscus clavatus*, Wehn.; (21) labium and labial palpi of *Paroster insculptilis*, Clk.

Genus Sternopriscus Sharp

Head with neck region not greatly narrower than the rest of the head. Frontal projection with small notches and small teeth on ventral margin of upper quarter, otherwise smooth. Temporal spines very short. Labium rectangular, rounded at the tip. Siphon reduced to a slight bulge. Cerci long with numerous setae.

The larvae of *Sternopriscus* have strong affinities with the Hydroporini, especially with the genera *Necterosoma* and *Paroster*, and appear to be intermediate between these two genera. The lateral projections are smaller than those of *Necterosoma* and larger than those of *Paroster*. The temporal spines are reduced in size from those found in *Necterosoma* but are not absent as in *Paroster*.

Sternopriscus clavatus, Wehn.

(Figs. 9, 15, 20)

Dorsal surface variegated light and dark brown, abdomen slightly darker than rest of body, base of cerci and band about one-third of way along it pale. Frontal projection and antenna as in Figs.

Length, 5·5-6·0 mm. Head capsule ·59 mm. wide, ·94 mm. long.

Larvae have been collected from bare dams at Glenn Innes, New South Wales, January 1961, and Adelaide, October 1960.

Genus Paroster Sharp

Head wide with no well-marked neck region. Frontal projection very wide, notches small and narrow, small teeth on ventral margins of upper quarter. Labium slightly bi-lobed, labial palpi three-segmented. Sides of head smooth with no temporal spines. Legs short, thick and covered with stout setae. Siphon small, less than half the length of last segment. Cerci long with numerous setae.

The lack of temporal spines in *Paroster* is unique among the Hydroporinii. This feature, together with its small lateral projections and a wide neck are characters that resemble or approach those in *Bidessus* of the Bidessinii. The three-segmented labial palpi is a character not found in other Hydroporinae; although the palpi of many genera, especially among the Hydroporini, have a constriction near the top of the second joint which often gives the palpi the appearance of being three-segmented.

Paroster insculptilis, Clk.

(Figs. 21, 29, 8)

Dorsal surface light brown, middle abdominal segments a little darker. Ratio of length of siphon to length of rest of segment 1/3·5. Cerci long, 6·5 times the length of the last abdominal segment. Posterior edges of tergites with long setae.

Length, 4·4-4·8 mm. Head capsule ·66 mm. wide, ·92 mm. long.

Larvae were found in a grassy, temporary pool at Williamstown, South Australia, October 1960 and September 1961.

Genus Chostonectes Sharp

Head with neck region moderately developed. Frontal projection with very wide deep notches, fine teeth on the ventral margin of upper quarter and ventral margin of lateral projections and a pair of small spines on the ventral surface between the notch bases. Antennae and legs long. Siphon short and sharp, about the same length as the rest of the segment. Cerci long, with numerous long fine setae.

Chostonectes latus Sharp.

(Fig. 6)

Dorsal surface variegated dark and light brown; frontal projection and outline of temporal sutures pale. Lateral projections with outer edges roughly parallel, blunt at the tips. Two very small ventral spines on frontal projection, separated by many times the width of their bases. Legs long and thin, claws on front tarsi nearly equal and both long and thin.

Length, 6·5-7·0 mm. Head capsule last instar, ·98 mm. wide, 1·5 mm. long. Second instar, ·55 mm. wide, ·85 mm. long.

Numerous larvae collected from creeks in the Lower Ferntree Gully area of Melbourne, December 1961.

Chostonectes nebulosus McLeay.

(Figs. 5, 27)

Dorsal surface mottled dark and light brown, frontal projection and outline of temporal sutures pale. Frontal projection thin, with a few small teeth on ventral surface of upper third. Lateral projections thin, acutely pointed, with their outer margins at 45° to each other. The two ventral spines are small and are separated by twice the width of their bases. Legs long, claws on front tarsi unequal, both long and thin.

Length, 5·5-5·7 mm. Head capsule, ·73 mm. wide, 1·28 mm. long.

Two larvae were taken in February 1961 from a dam at Collector, New South Wales.

Chostonectes gigas Boh.

One larvae of this species was found in a weedy pond near Lower Ferntree Gully, Melbourne, in December 1961. Unfortunately, the frontal projection of the exuvia was damaged. From what can be seen the lateral projections are thicker and blunter than in *C. nebulosus*, more or less parallel-sided and they slope downwards to a greater degree than in the other species in the genus. The spines are displaced in the specimen.

Length, 10 mm. Head capsule 1·15 mm. wide, 1·75 mm. long.

Genus Antiporus Sharp

Head narrow, neck not much narrower than rest of the head. Frontal projection with very wide deep notches, fine teeth on ventral margin of top quarter, a pair of strong raised spines on the ventral surface some distance below base of notches. Legs long with numerous setae. Siphon greatly reduced or absent. Cerci long with numerous setae.

The presence of spines on raised areas on the frontal projection is a distinctive feature of the genus. Other genera (*Chostonectes*, *Macroporus*) have an isolated pair of spines but these are much smaller and placed further forward on the frontal projection. The size and relative position of these spines are useful taxonomic characters.

Antiporus gilbertii, Clk.

(Figs. 1, 18, 28)

Dorsal surface light brown, frontal projection and area within temporal sutures pale, large pale areas on rest of dorsal surface of head, cerci pale. Pair of spines on frontal projection large and separated by four to eight times the width of their bases. There are a few small teeth on the ventral side near the apex of the frontal projection. Last abdominal segment not produced into a siphon.

Length, 9·0-9·5 mm. Head capsule 1·01 mm. wide, 1·86 mm. long.

It is in this species that the spines on the frontal projection reach their maximum development.

Larvae collected from a bare dam, Wilcannia, New South Wales, June 1961, and a bare dam at Mt. Compass, South Australia, August 1961.

Antiporus femoralis Boh.

(Fig. 3)

Dorsal surface dark brown, frontal projection pale with pale strip extending to temporal suture, rest of head and thorax with several pale patches, cerci with basal half darker than apical. Pair of spines on frontal projection separated by 1·8 to 2 times the width of their bases. Numerous very small teeth on ventral side of top half of frontal projection. Last abdominal segment produced into a short siphon.

Length, 6·8-7·2 mm. Head capsule, ·89 mm.-·94 mm. wide, 1·65 mm.-1·75 mm. long.

It is separated from *A. gilbertii* by its much darker colour, smaller size, position of spines on the frontal projection and the presence of a short siphon.

Larvae collected from the deeper parts of a pool 30 miles south-west of Canberra, January 1961; a weedy pool, Hobart, August 1961 (1st and 2nd instars); and a moderately saline pool, Robe, August 1961 (numerous).

Antiporus blakei, Clk.

(Fig. 2)

Dorsal surface a rich brown; frontal projection pale, with a pale strip extending from this across the middle of the head and prothorax; sides of the head also pale, the rest dark; basal portion of cerci dark, rest pale. Pair of spines on frontal projection separated by twice the width of their bases. A few small teeth near the tip on the ventral side of the frontal projection. Last abdominal segment produced into a slight siphon.

Length, 5·8-6·5 mm. Head capsule, ·78 mm.-·83 mm. wide, 1·58 mm.-1·61 mm. long.

It is readily separated from the other species by the conspicuous pale strip on its dorsal surface, characters of the frontal projection and its slimmer shape and smaller size.

Larvae collected from a weedy creek, Deloraine, Tasmania, January 1961; a weedy creek (with algae *Nitella* sp.) Adelaide, April 1960.

Genus Necterosoma McLeay

Head with a narrow neck region. Frontal projection deeply notched, with small teeth on ventral margin of upper quarter, and a pair of very small spines on the ventral surface. Labium bi-lobed. Siphon short, about half the length of the rest of the segment. Cerci long with numerous setae.

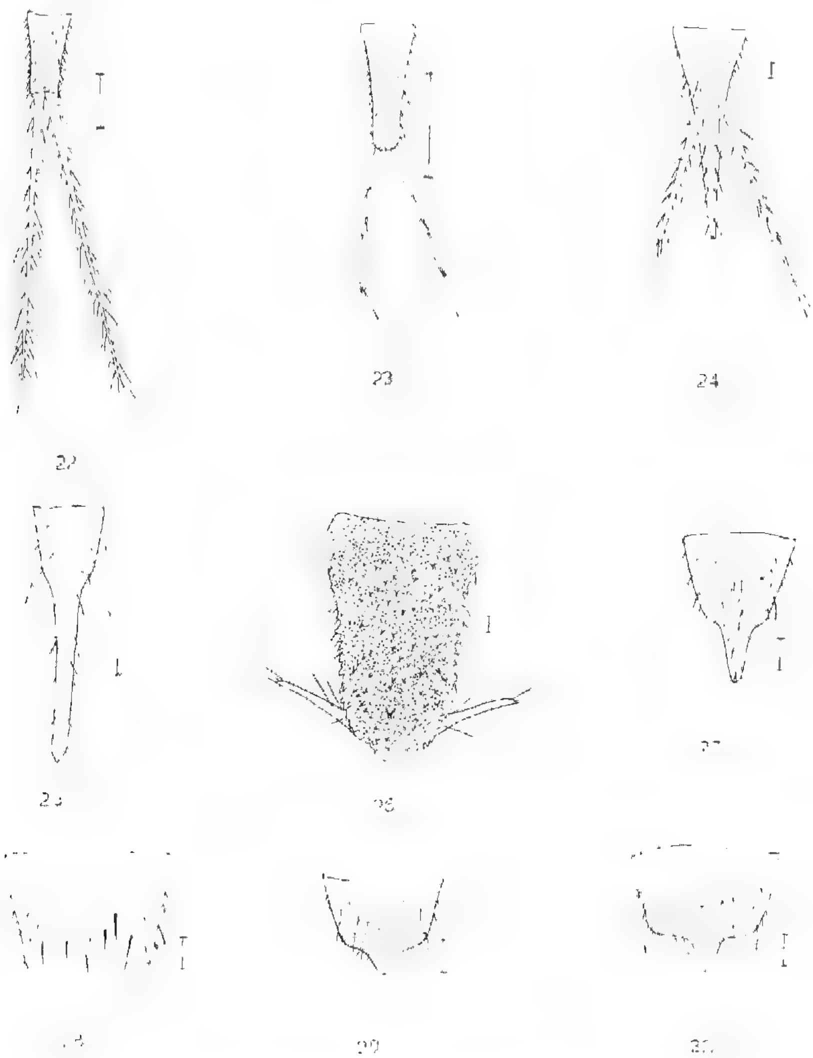

Plate 3

Figures 22-30. Line represents ·1 mm. in all except Figs. 22 and 23, where it represents 1 mm. (22) last abdominal segment and cerci of *Lancetes lanceolatus*, Clk.; (23) last abdominal segment and cerci of *Platynectes decempunctatus*, Fab.; (24) last abdominal segment and cerci of *Hyphydrus australis*, Clk.; (26) last abdominal segment and cerci of *Copelatus extensus*, Sharp; (25) last abdominal segment of *Macroporus gardnerii*, Clk.; (27) last abdominal segment of *Chostonectes nebulosus* McLeay; (28) last abdominal segment of *Antiporus gilbertii*, Clk.; (29) last abdominal segment of *Paroster insculptilis*, Clk.; (30) last abdominal segment of *Necterosoma penicillatus*, Clk.

Necterosoma dispar, Germ.

(Figs. 11, 17)

Necterosoma wollastoni, Clk.

Necterosoma penicillatus, Clk. = N. costipenni Lea.

(Figs. 30, 12, 16)

Dorsal surface brown. Head and thorax variegated light and dark brown. Frontal projection with two very small spines on ventral side half way between apex and notch bases, and placed nearer the margins than the centre. Ratio of length of the siphon to the length of the rest of the segment is 1/2. Cerci long, 23 times the length of siphon, basal portion 5·5 times the length of apical portion.

Length, 6-8 mm. Head capsule, ·89-·92 mm. wide, 1·24-1·28 mm. long.

This description applies to all three species which are very closely allied and the differences between them very slight.

N. penicillatus differs from the other two species in the greater width of the epistome, the basal angle of this sclerite being 90 deg., compared to 100 deg. in the others. *N. dispar* has a very noticeable pale band on the cerci about one-third of the way along it, this being less noticeable in *N. penicillatus* and nearly absent in *N. wollastoni*. The pale areas on the head are well marked in *N. penicillatus*, less so in *N. dispar*, and in *N. wollastoni* where the whole head is pale except for the outline of the temporal sutures.

N. wollastoni Clk. collected from a tank near Wilcannia, north-west New South Wales.

N. dispar Germ. collected from numerous dams and creeks near Adelaide.

N. penicillatus Clk. collected from numerous dams and creeks throughout New South Wales, Victoria, South Australia, Tasmania and from southern Queensland.

Genus MACROPORUS Sharp

Head wide, neck region relatively narrow. Frontal projection with deep, wide notches, fine teeth on ventral margin of upper third and on the outer ventral margins of the lateral projections and a pair of spines on the ventral surface between the notch bases. Labium short and weakly bifid. Siphon with parallel sides, about twice the length of the rest of the segment. Cerci relatively short with numerous setae.

The siphon in this genus is larger and narrower than that of any other known Hydroporinii. The nearest approach to it is *Chostonectes*.

Macroporus gardnerii Clk.

(Figs. 4, 25)

Dorsal surface brown; frontal projection, areas of head and apical half of cerci paler. Ventral surface of frontal projection smooth except for teeth as for genus. Six to seven teeth on ventral margin of lateral projection. The two ventral spines fourteen times the width of their bases apart. Ratio of length of siphon to length of rest of segment is 2·6/1.

Length, 10 mm.-12 mm. Head capsule 1·56 mm. wide and 2·25 mm. long.

Larvae collected from a weedy creek (with algae *Nitella* sp.), Adelaide, September 1960.

COLYMBETINAE

Genus Platynectes Reg.

Head squarish with well-developed neck region. Temporal spines on a line that will meet the ocelli. Mandibles about three times as long as wide. Last segment of antenna less than half the length of the third segment. Labium rather wide, maxillary stipes broad, about twice as long as wide, without hooks.

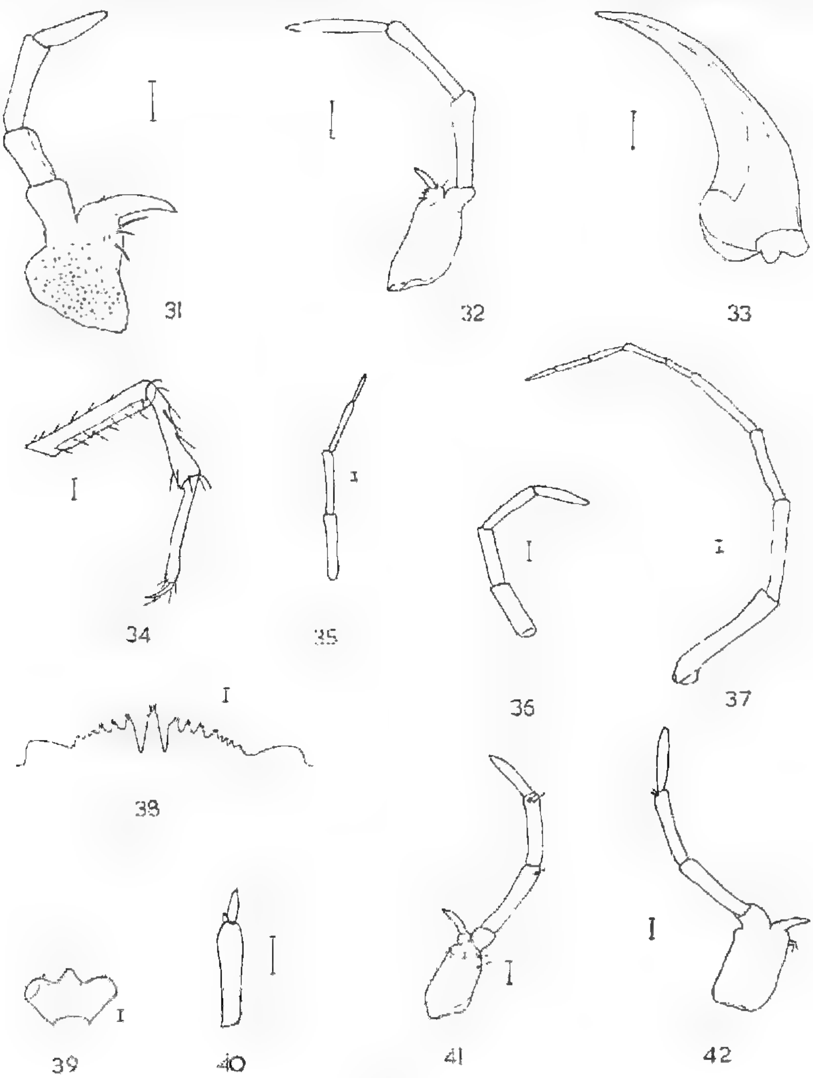

Plate 4

Figures 31-42. Line represents ·1 mm. (31) Maxilla of *Copelatus extensus*, Sharp; (32) maxilla of *Platynectes decumpunctatus*, Fab.; (33) mandible of *Platynectes decumpunctatus*, Fab., (34) dorsal view of portion of hind leg of *P. decumpunctatus*, Fab.; (35) antenna of *Lancetes lanceolatus*, Clk.; (36) antenna of *Rhantus pulverosus*, Steph.; (37) maxilla of *Homoeodytes scutellaris*, Germ.; (38) front of clypeus of *H. scutellaris*; (39) labium of *H. scutellaris*; (40) tip of antenna of *Copelatus extensus* Sharp; (41) maxilla of *Rhantus pulverosus* Steph.; (42) maxilla of *Lancetes lanceolatus*, Clk.

Legs long, femora with spines on dorsal and ventral surfaces, tibia with several scattered spines, and tarsi with a few spines at their apex. Last abdominal segment not greatly produced backward between the cerci. Cerci short, with a few long setae.

This genus appears to be closest to *Ilybius* Erichson from the northern hemisphere from which it differs in having the last abdominal segment only a little produced.

Platynectes decempunctatus Fab.

(Figs. 23, 33, 34, 32)

Colour variable, maxillary stipe as long as wide, bilobed at apex, the inner lobe carrying the galea. Legs thin; tibia with or without three spines on the outer margin, with apical spines and a pair of spines on the inner edge near apex; femora with spines along inner and outer margins. Cerci with setae near the middle and an apical tuft of four setae.

Variety 1. Reddish-brown, head and thorax variegated brown and light brown. Three spines on outside of tibia.

Variety 2. Dorsal surface dark brown, ventral surface light grey, head capsule uniformly dark. Tibia bare of spines, also fewer spines on the outside of the femora than in var. 1.

Length, 10-12 mm. Head capsules last instar 1·58 mm. wide, 1·68 mm. long, second instar, ·99 mm. wide, 1·08 mm. long; first instar ·73 mm. wide, ·82 mm. long.

Larvae collected from a weedy creek at Williamstown, South Australia, October 1961 (var. 2); a weedy creek, Adelaide, December 1960 (var. 2); Hackham, South Australia (var. 1), October 1960; Mt. Compass, South Australia (var. 2), October 1960; a bare creek at Hobart (var. 1), August 1961; and a saline pool at Robe, South Australia, August 1961 (var. 2).

P. decempunctatus is a common, very variable and wide-spread species in which the adults can be divided into four more or less distinct forms. The two larval varieties described above differ markedly in their colouring. Only a very few individuals that are intermediate between the two varieties as far as colouring is concerned have been collected. The structural differences in the legs appear to be constant. A few specimens from Mt. Compass agree with var. 1, except that their setae are very much stouter. This difference is very noticeable and could indicate another variety. There is also a subtle difference in the shape of the head and neck between the forms, var. 1 having the hind angle of the head rounder and the neck more distinct than var. 2.

Genus Lancetes Sharp

Head squarish with a well-developed neck region. Temporal spines small and on a line that will pass through the ocelli. Underside of head with a few small spines. Maxillary stipe broad, with two hooks on anterior inner margin. Antenna and palpi slender, last segment of antenna about half the length of the third. Legs long with numerous fine spines and a row of very long setae on the femora, tibia and tarsi. Cerci long: more than twice the length of the last abdominal segment, and with many long setae. Main tracheal tubes narrow.

Lancetes lanceolatus, Clk.

(Figs. 22, 42, 35)

Colour light brown; head with the clypeus, and a large patch in front of each set of ocelli pale, the rest brown with numerous pale spots. Maxillary stipes wide and flat, their palpi long and thin, the second and third joints nearly equal in length and the first a bit longer. Labium broad, constricted in the middle with two rows of very short spines along the anterior edge. Its palpi long and thin, the second joint being about two-thirds the length of the first. Last abdominal segment cylindrical, truncate at apex. Cerci long, three times the length of the last abdominal segment.

Length, 15-16 mm. Head capsules, last instar 2·53 mm. wide, 2·64 mm. long; second instar 1·43 mm. wide, 1·66 mm. long.

The younger instars have rounder heads and longer appendages, especially the more distal joints.

Larvae collected from a saline pool, Robe, South Australia, August 1961; Eudunda, South Australia, August 1961; and Williamstown, South Australia, September 1960.

Genus Rhantus Lacord

Head squarish with well-marked neck region. Temporal spines short and strong. Underside of head with numerous short spines. Labium wide, maxillary stipes broad, their inner margins curved. Last joint of the antenna large, more than two-thirds the length of the third joint. Legs with a moderate number of spines which are mostly along the dorsal surface, a row of long setae on the femora, tibia and tarsi. Cerci short, about the length of the last abdominal segment, with numerous setae. Main tracheal tubes wide.

Rhantus pulverosus, Steph.

(Figs. 36, 41)

Compact, brown, upper surface variegated light and dark brown. Head square with numerous small spines on the underside which are arranged in four patches, the two largest near the base of the head on either side of the gulga and a smaller patch on each side of the head midway along the outer margins. There is also a line of spines running obliquely between the basal and lateral patches on each side of the head. The last abdominal segment is slightly less than twice the length of the second to last segment. The cerci are slightly longer than the last abdominal segment, and have about twenty-five setae on their inner sides.

Length, 17-19 mm. Head capsules, last instar 2·30 mm. wide, 2·57 mm. long, second instar 1·38 mm. wide, 1·47 mm. long.

There are two rows of light-coloured spots arranged in two whorls in the centre of the head. This same pattern occurs in *Lancetes lanceolatus* and in several other species. The arrangement of the spines on the underside of the head appears to be constant in this species.

Larvae collected from a sheep trough, Sheffield, Tasmania, January 1960; Williamstown, South Australia, October 1960; Canberra, January 1961.

Genus Copelatus Er.

Head with neck region well developed. Temporal spines strong. Labium wide, labial palpi very short. Maxillary stipe broad with two to three large hooks on their inner anterior margin. Maxillary palpi and antennae short. Last segment of antennae biramous. Mandibles with fine teeth on inner edge. Legs stout with a few spines. Cerci very short, less than the length of the last abdominal segment. Body covered with small, round, raised areas. Tergites with numerous short, strong spines, especially along the posterior margins.

The larvae of *Copelatus* have many characters not found in any other Colymbetinae; their bodies tend to be harder, more cylindrical, and to have more and much stronger spines especially along the posterior margins of the tergites; they have a biramous last joint to their antennae although the extra portion is often small and inconspicuous; their cerci are smaller and stouter than in other members of the group; their labial palpi are small and stout, whereas the rest of the group have rather long palpi; and their mandibles are toothed.

This last character is no doubt correlated with the fact that these larvae swallow their food whereas in all other Dytiscids digestion is partly external and feeding is done by sucking the digested body contents of the prey into the mouth through a partially closed groove in the mandibles. This method of feeding was first noticed by Williams, in the Hawaiian species *C. parvulus*, and has since been observed in all five Australian species that I have seen. Larvae of *C. extensus* have been observed in the field to swallow Chironomid larvae as long as themselves, the process taking about five minutes. With *Daphnia* as prey, *C. extensus* crushes the crustacean up against its mouth, holding it there with its mandibles. It then sucks the body contents of the *Daphnia* into its mouth.

Copelatus extensus, Sharp

(Figs. 26, 40, 31)

Uniformly dark brown. Tergites covered with numerous stout spines on raised areas, their posterior margins with stout blunt spines rather irregularly spaced but averaging about the width of their bases apart. Maxillary stipes with three hooks, galea greatly elongated and curved. Apical segment of antennae small and ventrally placed. Cerci short: 0·4 times the length of the last abdominal segment, with a few fine setae.

Length, 12-13 mm. Head capsules, last instar 1·88 mm. wide, 1·84 mm. long, second instar 1·31 mm. wide, 1·31 mm. long.

The body spines are well developed in this species as is the peculiar warting of the body surface. Larvae that I take to be those of *C. nigritulus* Sharp, but have not bred, greatly resemble those of *C. extensus*.

Larvae collected from the muddy bottom of a shallow tank, Mt. Lofty, South Australia, August 1960, and January 1961.

CYBISTRINAE

Genus Homoeodytes Reg.

Head anteriorly tri-lobed, middle lobe narrow and separated from lateral lobes by deep clefts, the lateral lobes wide and strongly dentate along their anterior margins. Antennae and maxillary palpi with nine segments, labial palpi with four, last segment of antennae biramous. Ligula very small. Cerci rudimentary.

Differs from *Cybister* in the greatly reduced ligula and in having the lobes on the head strongly dentate, each tooth with a dense tuft of short setae at its tip.

Homoeodytes scutellaris, Germ.

(Figs. 37, 38, 39)

Body grey-brown, head and thorax reddish-brown, black stripes on either side of the body being especially noticeable on the thorax. Teeth on front of head variable in number (thirteen to eighteen) often asymmetrically arranged. Last two abdominal segments with fringe of long setae, rest of body sparsely covered with long setae. There are two chitinous knobs in the middle of the dorsal side of the head. Cerci small and vestidual, placed about three times their length back from the tip of the last abdominal segment.

Length, 45-55 mm. Head capsules, last instar 6·1 mm. wide, 5·0 mm. long, second instar 3·8 mm. wide, 4·0 mm. long, first instar 2·4 mm. wide, 2·5 mm. long.

The younger instars are smaller and lack the black stripes on the thorax and the chitinous knobs on the head are more noticeable.

Larvae collected from a weedy creek, Canberra, January 1961; a weedy pool, Melbourne, December 1961; Lake Boga, Victoria, January 1961; and a swamp, Mannum, South Australia, September 1961.

APPENDIX

The following genera are all represented in Australia by species whose larvae I have not seen. But larvae of certain non-Australian species have been described and the following diagnosis (modified after Bertrand, 1928) are based on these descriptions.

Genus Laccophilus Leach

Larvae without frontal projection and without swimming hairs. Body elongate, legs long and slender. Sides of head, in older larvae, with only a few long strong spines (three-five).

Distribution in Australia: Queensland, Northern Territory, north-west Australia, northern Tasmania and southern Victoria.

Genus Eretes Laporte

Larvae without frontal projection. Last few abdominal segments provided with a lateral fringe of swimming hairs. Body elongated and humped. Clypeus complete, cerci without swimming hairs. Ligula small with four spines.

Distribution in Australia: throughout the inland areas.

Genus Rhantaticus Sharp

Larvae without frontal projection, last abdominal segments provided with a lateral fringe of swimming hairs. Body elongate, clypeus complete. Cerci without swimming hairs. Ligula simple, very long, nearly the length of the first joint of the labial palpi, with six spines.

Distribution in Australia: Queensland and Northern Territory.

Genus Hydaticus Leach

Larvae without frontal projection. Last few abdominal segments with lateral fringes of swimming hairs. Body elongate, not humped. Clypeus complete, cerci without swimming hairs. Ligula small, bilobed.

Distribution in Australia: Queensland, Northern Territory, South Australia (River Murray), and New South Wales.

Genus Cybister Curt.

Larvae without frontal projection. Last few abdominal segments with lateral fringe of swimming hairs. Body elongate, not humped. Clypeus divided into three lobes, lateral lobes not, or only slightly, dentate. Ligula simple, of moderate length. Cerci rudimentary.

Distribution in Australia: Queensland, Northern Territory, north-west Australia, New South Wales and South Australia.

Genus Hydrovatus Motsch.

Larvae with frontal projection. Body squat, very short and depressed; head with a long frontal projection which is slightly notched. Cerci very short (shorter than last abdominal segment in last instar). Siphon elongate. Labium short and subtriangular.

Distribution in Australia: Queensland, Northern Territory, New South Wales, Victoria and South Australia.

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BY J. N. JENNINGS

Summary

On the basis of further data provided by recent speleological parties, some of the geomorphological problems of the Nullarbor are rediscussed. The extremely flat surface of the Plain is regarded neither as a planation surface nor as a stripped structural surface but as an almost unmodified emerged sedimentary surf ace. Faulting along the coastline and the Harnpton Range remains unproven; the morphology is readily explicable in terms of costal erosion and subaerial weathering during the substantial Pleistocene-Recent changes in relative level of land and sea of which there is stratigraphical evidence. The shallow caves are primarily of vadose origin but are localised and still much influenced in their character by a zone of small-scale phreatic preparation of unusual intensity. The few deep caves die not considered to be phreatic in the proper sense of that term, but have developed along the lines of Glennie's theory of "master caves". They are unusually large caves for their lithological context and their coastal distribution is thought to be climatic in origin, rather than structural. King's views that cave destruction, rather than formation, is in progress today and that Pleistocene pluvials were important for the development of the Nullarbor caves. are supported. Nevertheless, changing relative level of land and sea is also thought to have been important in that it shifted the watertable and the level of phreatic solution. Although our knowledge remains small, on the whole it points to poverty, rather than richness, in caves in the Nullarbor and the underground as well as the surface morphology is indicative of a retarded, immature karst. This is thought to indicate that Pleistocene pluvials did not cause the climate to depart very much or very long from its present semi-arid to arid range.

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by J. N. JENNINGS*

(*Communicated by Dr. N. H. Ludbrook*)

[Read 9 August 1962]

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The extremely flat surface of the Plain is regarded neither as a planation surface nor as a stripped structural surface but as an almost unmodified emerged sedimentary surface. Faulting along the coastline and the Hampton Range remains unproven; the morphology is readily explicable in terms of coastal erosion and subaerial weathering during the substantial Pleistocene-Recent changes in relative level of land and sea of which there is stratigraphical evidence.

The shallow caves are primarily of vadose origin but are localised and still much influenced in their character by a zone of small-scale phreatic preparation of unusual intensity.

The few deep caves are not considered to be phreatic in the proper sense of that term, but have developed along the lines of Glennie's theory of "master caves". They are unusually large caves for their lithological context and their coastal distribution is thought to be climatic in origin, rather than structural.

King's views that cave destruction, rather than formation, is in progress today and that Pleistocene pluvials were important for the development of the Nullarbor caves, are supported. Nevertheless, changing relative level of land and sea is also thought to have been important in that it shifted the water-table and the level of phreatic solution.

Although our knowledge remains small, on the whole it points to poverty, rather than richness, in caves in the Nullarbor and the underground as well as the surface morphology is indicative of a retarded, immature karst. This is thought to indicate that Pleistocene pluvials did not cause the climate to depart very much or very long from its present semi-arid to arid range.

INTRODUCTION

Despite its simplicity of surface form, the Nullarbor Plain is of considerable interest as one of the world's largest karst regions, though as might be expected a good deal of that interest centres on the underground geomorphology. Incidental observations relevant to this theme are to be found in many of the early accounts of explorers and geologists but the first man to organise expeditions specifically in this connection was Captain J. M. Thomson from 1934 onwards. This long-continued effort culminated in his own and D. King's papers in this journal (Thomson, 1950; King, 1950) though he has led parties into the Nullarbor since then. In 1957 the Cave Exploration Group of South Australia organised an expedition to the Plain for the newly-founded Australian Speleological Federation. Over 60 members of the many caving societies which had sprung up in Australia since the war, participated in varied scientific work as well as

* Research School of Pacific Studies, Australian National University.

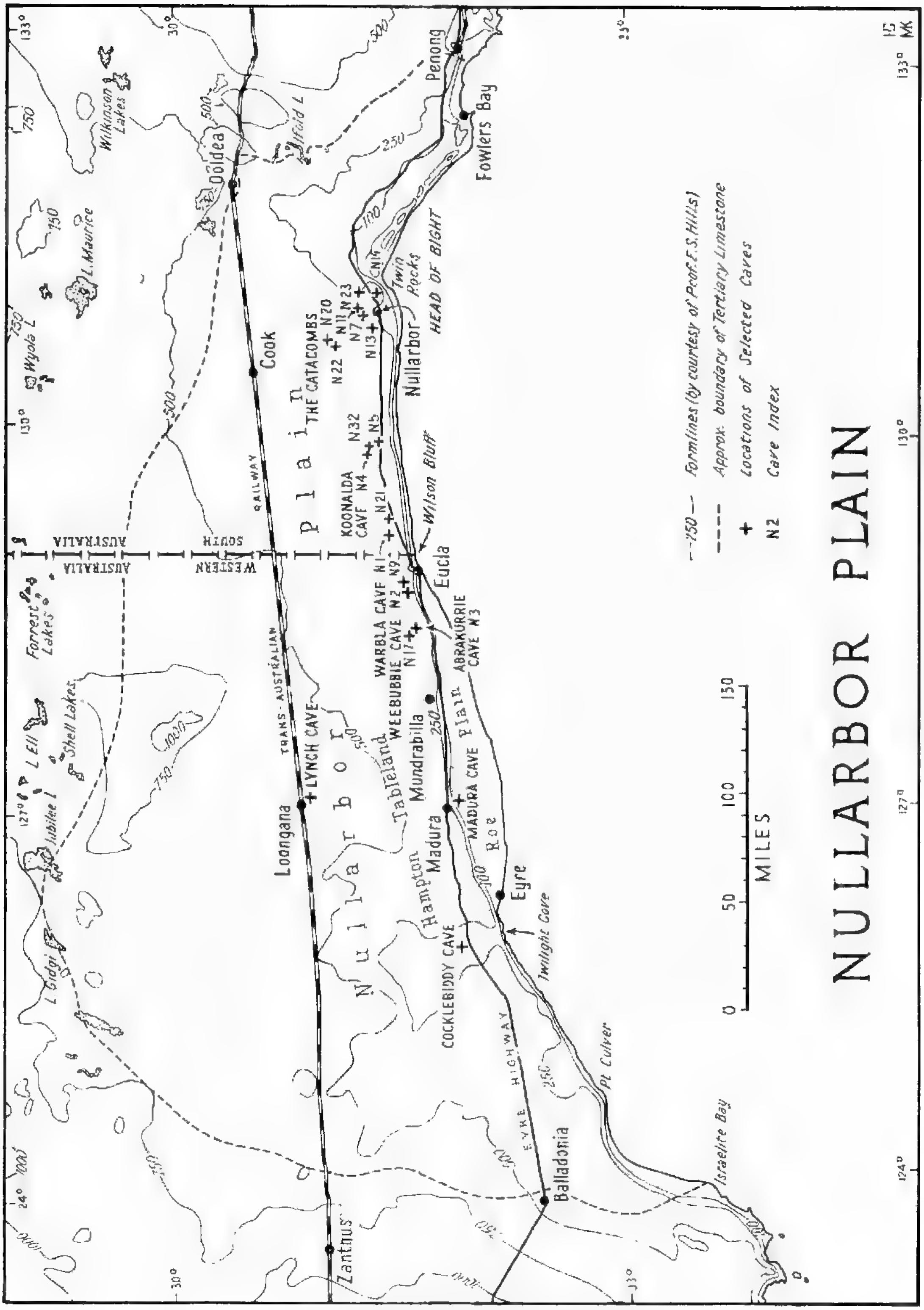

Fig. 1. Map of the Nullarbor Plain.

straightforward cave exploration. Three other parties have added to this knowledge since then.

The geomorphological report of the 1957 expedition, prepared by the writer, was first made available privately to subsequent expeditions and later given wider circulation by CEGSA (Jennings, 1961). Attention is centred in this paper on certain problems of interpretation. Though the views expressed differ significantly at certain points from those of King, it is not maintained that they approach definitiveness and conclusively displace earlier ideas. Our knowledge of the Nullarbor Plain remains very inadequate. Nevertheless, this account is based on much more detailed cave survey than was previously available. Many cavers are responsible but R. T. Sexton must be singled out for acknowledgment in this regard, not only for his own contribution but for the informed stimulus he has given to others. Opportunity is taken to illustrate this paper with previously unpublished or revised cave surveys.*

WHAT SORT OF GEOMORPHOLOGICAL SURFACE DOES THE PLAIN COMPRISE?

If the name is taken to connote not solely the treeless plains to which it strictly applies, but also the topographically similar yet scrub-covered extensions over the same Tertiary limestone, the Nullarbor forms one of the most extensively and uniformly plane bedrock surfaces of the world (Fig. 1). Yet its generic nature has so far occasioned little discussion.

The levelness of the Plain has always astonished travellers from Eyre onwards. Traversing its inner margin for the first time, Giles comments, "A bicycle could be ridden, I believe, over the whole extent of the plain". The uniformity of the relief could not be revealed more clearly than by the course of the Transcontinental Railway including as it does one absolutely straight reach of 300 miles.

The only widespread diversification of the surface is so minor that it could almost be termed "micro-relief". This consists of gentle undulations of an amplitude of about 10 feet and a wavelength of several miles. In some areas the local relief is rather greater than this but was never found to be more than 25-30 feet. Examination of a wartime run of trimetrogon air photographs along the coast supports Woolnough (1933) rather than Tate (1879) in the question of the presence or absence of structural control. Since the undulations are arranged along two trends at right angles to one another — NE-SW and NW-SE — and this seems on the ground to be the joint pattern of the Nullarbor Limestone, it is reasonable to attribute the features to differential solution.

There are also a very few shallow valleys. Only one of these, close to Koonalda homestead, was examined in the field for four miles though its full length is greater. Its flat floor, 15-20 feet below the Plain, has a continuous down gradient seawards. Though gentle and with only an occasional rock outcrop, its sides define it well and a similar slope cuts it off before it reaches the coast, turning it into a blind valley. From a northern part of the Plain, Jones (1880) writes of valleys 30 and 60 feet deep, but how continuous these are is not clear since he also writes of "valleys invariably broken by cross-ridges". Though there was no stream bed to be seen in the Koonalda example, valleys such as it must have been the product of concentrated runoff.

* The writer has revisited the Plain in 1963 and observations made then call for qualification of some factual detail of the present paper though not the conclusions. However, the printing of this volume had progressed too far for the fresh data to be incorporated.

More numerous than the valleys but still infrequent in relation to the area involved are "circular hollows" (Jones, 1880) or "dongas" (Gibson, 1909). These are smaller, more circular and better defined than the troughs of the undulations previously described. They commonly range from 50-60 feet to over 400 yards across and lie 10-20 feet below the Plain with flat floors which may be penetrated by blowholes. Bedrock outcrops rarely on their flanks, which are not very steeply inclined. These have been interpreted as solution dolines previously (Jennings, 1961). Even though the writer would not accept the generalisation by Coleman and Balchin (1959) that all dolines are of collapse origin, it must be admitted the Nullarbor "circular hollows" could have been derived from collapse dolines by degradation of their sides. Because of the small depth of the "circular hollows", only shallow caves would be involved if they are of collapse origin. Size is not a problem when the dimensions of shallow caves such as Jimmy's Cave N23* (Fig. 5) are borne in mind but shape is since the caves tend to an elongation not characteristic of the dolines under discussion.

Less frequent but unmistakeable in origin are the collapse dolines. These oblong or circular enclosed depressions are surrounded on all or most sides by vertical cliffs or steep broken rock slopes; they are deeper in relation to their area than the "circular hollows". The collapse doline of Murrawijinie Cave N7, 15-25 feet deep, is roughly trapezoidal in shape through joint control, 120 feet long and 35 feet across. Knowles Cave N22 is a cave remnant at the end of an elongated collapse doline, 15-30 feet deep, 60 feet across and 320 feet long. With no known cave development from it, Chowilla Landslip N17 is one of the largest collapse dolines, about 90 feet deep and roughly elliptical in plan, approximately 150 feet by 200 feet. The entrance valley to Abrakurrie Cave N3 is much larger still, being over 700 feet long and 200 feet across, but its floor falls gradually from 10 feet depth to nearly 100 feet at the cave entrance. So it partakes more of the nature of a blind valley; it may have begun as a collapse doline and have been extended later by spring sapping northwards.

All these karst features are few and far between; the Plain is in fact an incredibly featureless low plateau, rising imperceptibly to the eye from heights of 150-250 feet on the coast to 450-650 feet on its inland margin. This rise is compounded of a S-N element and an E-W one. Some causes of this lack of relief are obvious.

(a) There was virtually no initial tectonic relief. Possible exceptions to this are the escarpment of the Hampton Range to be discussed below and also three low scarps westward of Ooldea (Jones, 1880), which may be due to faulting. The rocks are almost horizontal; Ludbrook has suggested a slight southward and eastward tilting in accordance with the present relief.

(b) Nor has there been sufficient surface drainage to generate erosional topography of fluviatile origin; the purity of the limestones has virtually eliminated this factor.

(c) Moreover, the low annual rainfall of 12 to 5 inches has ensured that karst development has not proceeded far enough to diversify the surface in its own peculiar manner to any marked degree.

(d) Though it has been maintained that deflation of the calcareous desert soils of the Nullarbor has provided the materials for soils around the Lake Eyre region (Jessup, 1961; Stephens, 1961), the quantities involved do not bulk large in relation to the extent of the Plain.

* The caves of many Australian limestone areas have been indexed; the Nullarbor caves have the letter prefix N followed by numbers.

What sort of surface then is represented here? That it is not a planation surface due to any form of erosion whatever seems to be substantiated by the apparent occurrence over the whole surface of the Plain of a single and thin formation, the Lower Miocene Nullarbor Limestone (Ludbrook, in Glaessner and Parkin, 1958). At Pidinga its margin has been chatered back some little way (King, 1951) and north of Watson, Ludbrook (1961) indicates the possibility of some removal of Nullarbor Limestone again at the margin of the Plain. Within its vast extent, however, the Nullarbor Limestone outcrops everywhere as far as is known and if erosional planation were involved, older formations would surely be found over substantial areas. On the other hand, if it were a stripped structural surface, remnants of younger sedimentary covers would survive here and there and such have not yet come to light. Rather does the Plain appear to be the original sedimentary surface of Miocene age raised above sea-level, tilted slightly downward to the south and east in the process and preserved almost unmodified since. The useful term "sediplain" has been proposed by R. O. Brunnschweiler for this kind of surface, though to the writer's knowledge he has not applied the idea nor the term to this case.

This conclusion is relevant to the theory of karst erosion cycles since many authorities have taken the view that the initial stage in the evolution of a doline karst such as this must include the development of a surface valley system by runoff. Here the dolines, modest though they are in numbers, have been produced without such prior development of valleys. This initial stage has been elided because of the absence of any significant cover of later impervious rocks over the Nullarbor Limestone.

WHAT IS THE NATURE OF THE NULLARBOR COASTLINE?

Such long reaches of unbroken cliffs as constitute much of the coast of the Nullarbor Plain are rare in the world (Valentin, 1952) and it is little wonder that they aroused speculation from Flinders onwards. He postulated an inland valley parallel to the coast to explain the absence of any valleys interrupting the even crestline of the Bunda cliffs between Eucla and the Head of the Bight. However, Eyre showed there was no such valley. Since then the continuity and linearity of the cliffs has prompted geologists from time to time to postulate a fault origin for them (e.g. Woodward, 1890; Woolnough, 1933; David, ed. Browne, 1950). However, the danger of postulating faults solely on physiographic grounds is a well-known one and here there are perhaps optimal conditions for a regular cliffline without such a direct tectonic origin. The same combinations of almost horizontal pure limestones in a semi-arid to arid climate which accounts for the uniformity of the Plain also provides the waves with a uniform height of uniform rock on which to work.

Not all the coastline is cliffed. At the Head of the Bight, the Bunda cliffs pass inland and are buried under dunes. At their other extremity at Eucla they merge into the scarp which has been called the Hampton Range and which forms the inner boundary of the Roe Plain, a coastal lowland up to 25 miles wide. Beyond Eyre the coastal cliffs reappear even higher than in the Bunda cliffs and persist to beyond Point Culver. Once more the cliffs are transformed into a scarp behind a narrow coastal lowland extending to Israelite Bay, a remote area from which no scientific observations seem to have been gathered.

The Hampton Range and the Roe Plain provide the best opportunity for proving or disproving faulting along the coast. Frost (1958) has made the most recent case for considering the relief here as truly tectonic. But his evidence of jointing from the Roe Plain is too meagre for his argument from joint patterns of the area to be very convincing. Otherwise he depends on the lithological correlation of Madura No. 1 bore at the foot of the scarp with the bores on the plateau to the north. He maintains that the Nullarbor Limestone underlies the Roe Plain, thrown down 300 feet along the line of the scarp. Examining the same bores palaeontologically, Ludbrook (1958) came to the opposite view that

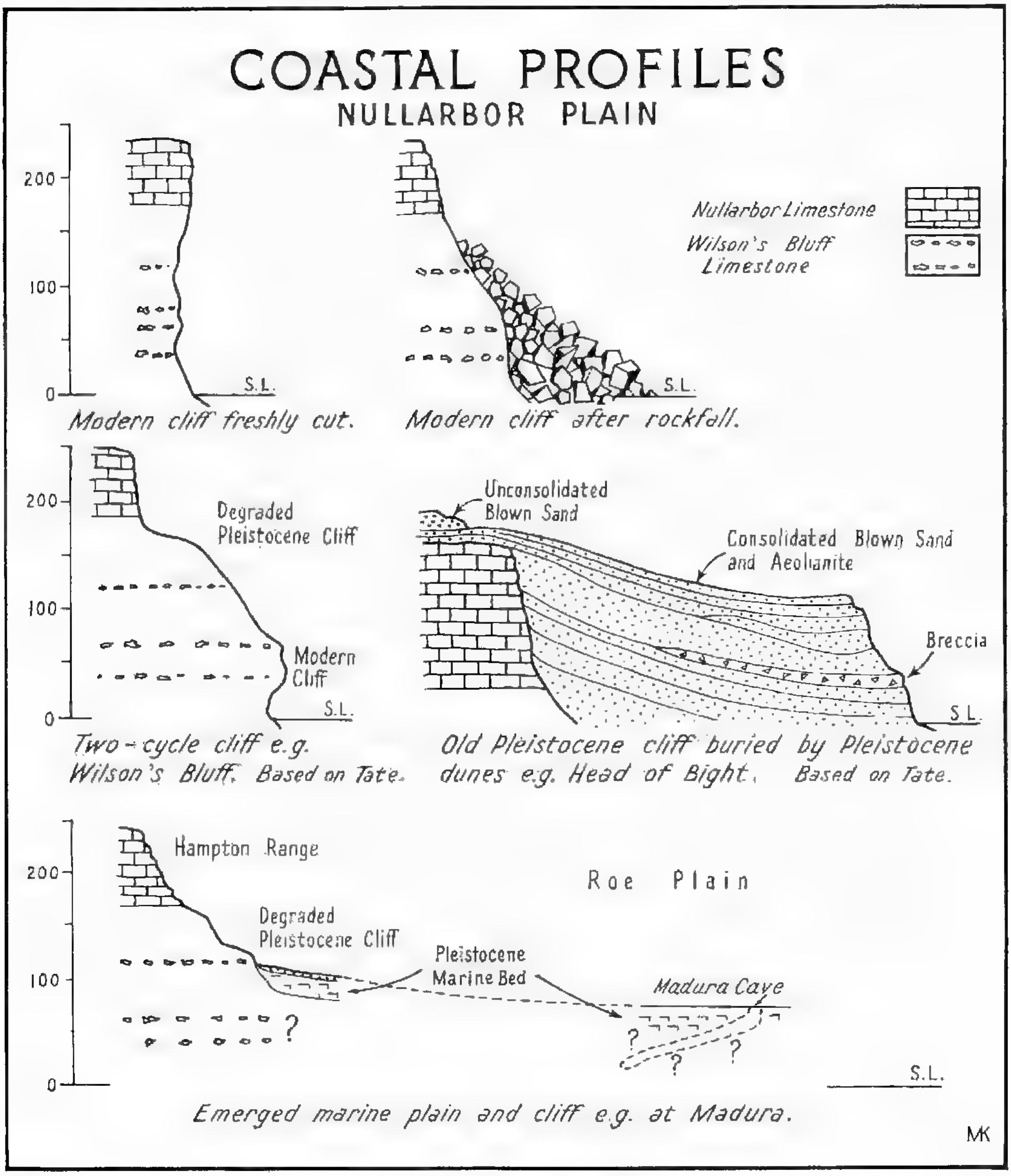

Fig. 2. Coastal profiles.

the Nullarbor Limestone has been removed by marine erosion and that it is the Eocene Wilson Bluff Limestone which underlies the coastal lowland. Unfortunately this divergence of interpretation depends on one sample since the Madura bore was sampled once only between 30 and 300 feet.*

Further stratigraphical evidence may be necessary before this issue can be finally decided; one thing seems certain, however, namely, that the Hampton Range has been subjected to marine erosion and is no longer a simple fault scarp. Air photographs show that the western part of the Hampton Range takes the form of a series of shallow, smooth curves in plan, best interpreted as the wave-cut bays of a former sea cliff. The varying vertical profiles support the same interpretation (Fig. 2). On the Hampton Range only the Nullarbor Limestone presents a free face; the Wilson Bluff Limestone below has a much less steep, though fairly constant slope, partly soil and rubble covered. At Wilson Bluff itself modern wave attack has fashioned a fresh cliff at the base of this incline in the weaker limestone. This composite profile is buried by the Merdayerrah Sandpatch but reappears to the east where the lower cliff grows in height gradually to eliminate the intervening bevel. Thus the typical vertical to overhanging profile of the Bunda cliffs is achieved, with the slight bulge of the overlying more resistant Nullarbor Limestone. At the far end of this cliffline the reverse succession is found, the bevel gradually reappearing before the dunes at the Head of the Bight bury everything. The bevelled cliffline has the appearance of a "two-cycle" cliff (Cotton, 1951), slightly complicated by the different resistance to erosion of the two limestones.

It is inferred then that during a former higher stand in the relative level of land and sea, the whole coast was cliffed; during a subsequent phase of lowered sea-level this cliff was degraded by subaerial weathering to produce the profile of the Hampton Range, which reflects the different responses of the two limestones. Since then wave action has destroyed this degraded cliffline along the Bunda cliffs. At the Head of the Bight, and near Eucla, the bevel in the Wilson Bluff Limestone is still being removed and the "two-cycle" profile persists temporarily. The sea caves well above sea-level near Twilight Cove, reported by Gibson (1909), probably relate to another event in the history of the relative level of land and sea in the region.

There is, of course, stratigraphical evidence for more than one high stand of sea-level relative to the land. Ludbrook (1958) reports Pleistocene shelly limestone of marine origin at + 80-102 feet in Madura No. 1 bore; similar limestone has been collected from the cave six miles south of Madura on the Roe Plain, of unknown height but at least − 65 feet (Ludbrook, pers. comm.). There is also Pleistocene marine calcareous sandstone at + 120 feet from the eastern end of the Plain (Ludbrook, in Glaessner and Parkin, 1958). All these could relate to the same phase on present knowledge. However, it is much less likely that the marine calcareous sandstone at + 12 feet at the eastern end of Roe Plain and the emerged shell beds at + 6 feet at Yalata Swamp near the Head of the Bight, both reported by Tate (1879) as having a Recent fauna, belong to this stand, rather than to a later one.

Tate also noted that Pleistocene aeolian calcarenite was plastered against an old cliffline at the Head of the Bight, at Merdayerrah and at Eucla. He maintained that this dune limestone extends below sea-level and implies a stand of sea-level below the present. Ludbrook (pers. comm.) confirms this with the information that the Twin Rocks, sea stacks near the Head of the Bight, are also

* Recent unpublished work by Ludbrook on Eyre No. 1 Oilwell, 15 miles south of Madura, confirms the absence of Nullarbor Limestone from the Roe Plain.

formed of this rock. Taking Tate's figure illustrating the relationship of the aeolian calcarenite to the old cliff literally, it must be inferred that the dunes were built up before the old cliff had been degraded by subaerial weathering.

A tentative sequence of these coastal events could be put together, but in view of the known complexity of sea-level changes elsewhere and the present meagre information from the region itself, there is no great advantage in doing this as yet. That there have been substantial changes in the relative level of land and sea in the area must, however, be noted because of its relevance to later discussion.

ARE THE SHALLOW CAVES VADOSE OR PHREATIC?

Thomson (1950) divided the caves of the Plain into a twofold scheme of shallow and deep; this was followed by King (1950) in interpreting their development. Further knowledge seems to underline this dichotomy as significant, though there are caves intermediate in level, e.g. the cave leading east from the Weebubbie doline, and lying between 60 and 120 feet below the Plain.

Reaching to depths between 15 and 80 feet, the shallow caves are confined to the Nullarbor Limestone, generally a hard, dense, well-jointed, crystalline limestone, grey or cream in colour. Usually small with one to two hundred

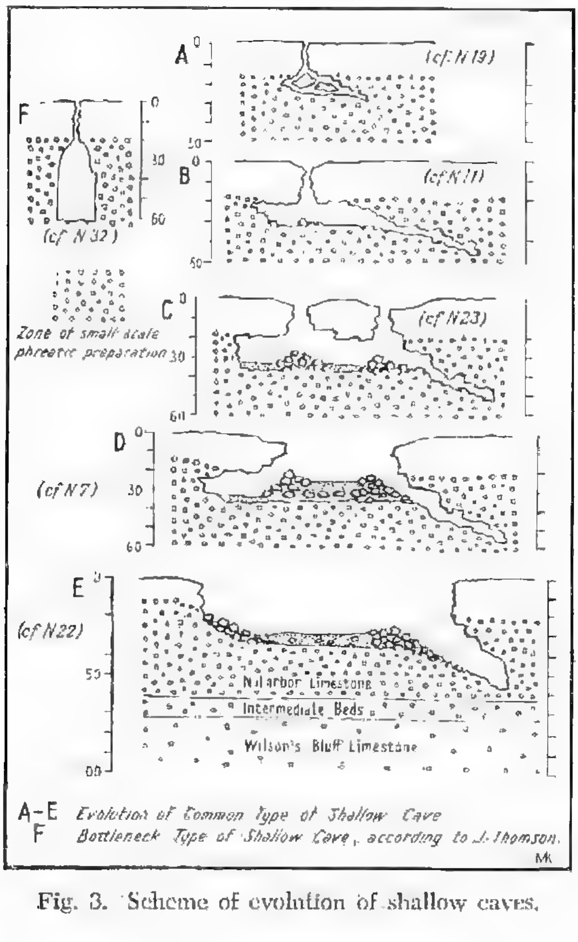

Fig. 3. Scheme of evolution of shallow caves.

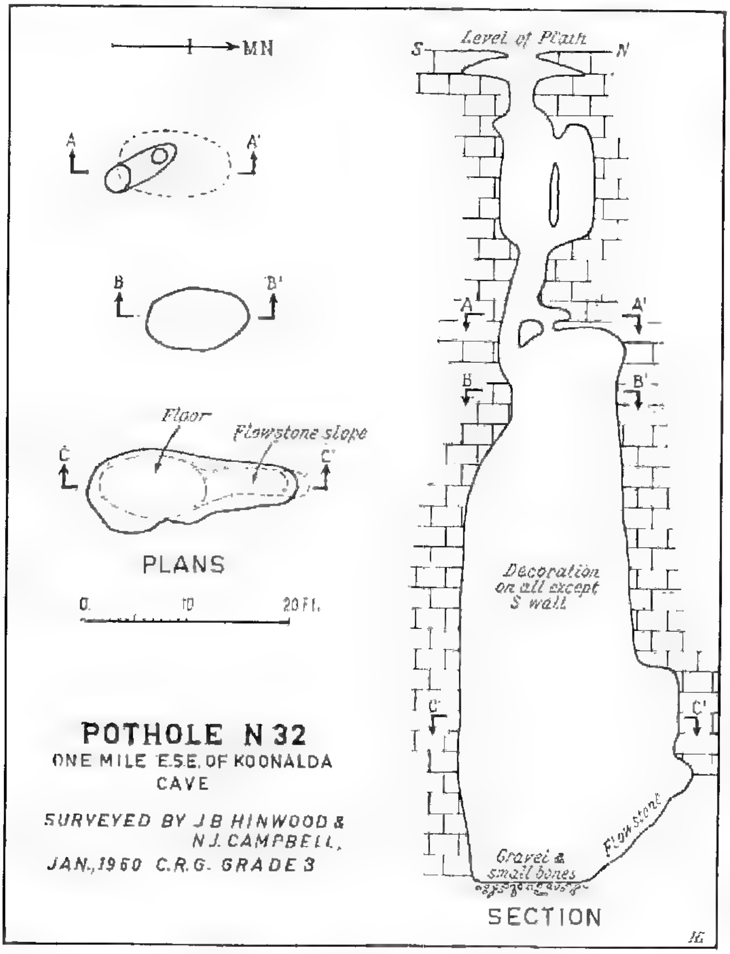

Fig. 4. N32 Pothole.

feet of passage, the shallow caves are known also to include quite large chambers and up to 600-700 feet of passages. They are widely distributed through the Plain, at least south of the Transcontinental Railway.

Thomson associates particular kinds of entrance with particular forms of shallow cave, but the relationships are more complex than that (Fig. 3). Four types of entrance have been observed by the writer:

(a) Vertical shafts or wells, roughly circular in cross-section, 2-4 feet in diameter and up to 15-20 feet deep, e.g. New Cave N11. Their surfaces are commonly marked by conchoidal hollowings, which may be attributed to turbulent water under gravity dissolving and possibly also abrading the rock. These are the typical "blowholes" of the Plain.

(b) Roof collapse windows. Enlargement of the chambers below can also lead to enlargement of the shafts by fracture along joint planes, e.g. White Wells Cave N14.

(c) Small oblique entries in the sides of dolines, usually in rock fall, e.g. The Catacombs N20.

(d) Large lateral entries in the sides of dolines. Extensive roof collapse may result in a steep-walled doline with wide entries at the base of the cliff rim leading into the remainder of the cave, e.g. Murrawijinie Cave N7.

The vertical solution shafts lead down into several types of cave. Simplest of all is the single bottle-shaped chamber, Thomson's "bottle-neck cave". Fig. 4 shows N32 Pothole near Koonalda homestead, which falls into this category of cave though the entrance shaft is not a simple one. Other shafts lead into complex arrangements of small passages, e.g. N19 Cave close to Weebubbie; much of this complexity is due to rock collapse, which is characteristic of even very small shallow caves. The shaft type of entry may still survive after large, flat-roofed chambers have developed, from which small passages branch off horizontally or downwards, maybe leading to smaller chambers at lower levels, e.g. New Cave N11. More usually the development of these large chambers close below the surface results in entrances of the second and third types being produced. Eventually collapse destroys most of such chambers and the remnants around the rim of the collapse doline have much more of the nature of rock shelters than of true caves, e.g. Knowles Cave N22.

King (1950) has argued that the shallow caves are of vadose origin, chiefly because they have a steep gradient, especially in the vertical shafts and because they possess dripstone decorations. The latter point is in no way conclusive since dripstone and flowstone features can form in caves of diverse genesis subsequent to their excavation. In fact, in comparison with the caves of most other parts of Australia known to the writer they are very poor in calcite decorations; by contrast gypsum flowers seem more frequent than elsewhere.

It is true, nevertheless, that the vertical shafts exhibit eversional sculpturing to be associated with descending vadose water. Moreover, not only are parts of the cave floors fairly level with water-laid accumulations of loamy earth, silt and rock debris, but intermittent watercourses of silt and angular gravel can be seen descending to lower levels through irregular masses of rock fall. No erosional channels in solid rock have yet been seen in the shallow caves though a cause will be mentioned later which casts no doubt on the view that vadose action has been very important in the fashioning of the shallow caves.

Nevertheless, many of the shallow caves, e.g. Jimmy's Cave N23 (Fig. 5), show pronounced horizontal development just below a massive surface crust of 10-20 feet thickness and in a zone of intense perforation by solution tubes a few inches in diameter. Not only do walls of chambers and passages show anastomosing networks of small half-tubes in exposed bedding- and joint-planes, but irregular fallen blocks show that the whole mass of the rock is penetrated in all directions by these tubes. In parts of White Wells Cave N14 the tubes have been filled with dark-coloured calcite and stand out clearly (Pl. 1). This zone of perforation can be seen excellently in the coastal cliffs south of Koonalda where it is seen to be confined to the Nullarbor Limestone.

Such anastomosing solution tubes have generally been regarded by British and American speleologists as due to true phreatic solution, i.e. by slowly circulating water beneath a watertable (Bretz, 1942; Glennie, 1954). But they are usually described as restricted to joint- and bedding-planes; here there is no such restriction. This intense zone of phreatic preparation has not only localised the level of development of the shallow caves, it is responsible also for the prevalence of cave breakdown in them and for the typical irregularity of walls and floors. The flat roofs are often a reflection of the unperforated surface layer of limestone. The lack of bedrock erosional channels can also be attributed to this weakening of the limestone. Breakdown due to the weakness of the riddled limestone is apparently still quite active today; Thomson has reported collapse in The Catacombs N20 and in Ivy Cave N13 between visits separated by only a few years.

Caves are not usually due to one phase of excavation only, be it vadose or phreatic; indeed nearly all caves must begin by something closely akin to phreatic solution. The problem is to assess the relative importance of the different phases in producing the present morphology. It is clear that an early phase of intense, small-scale phreatic preparation has remained important in governing the character of the present-day shallow caves of the Plain.

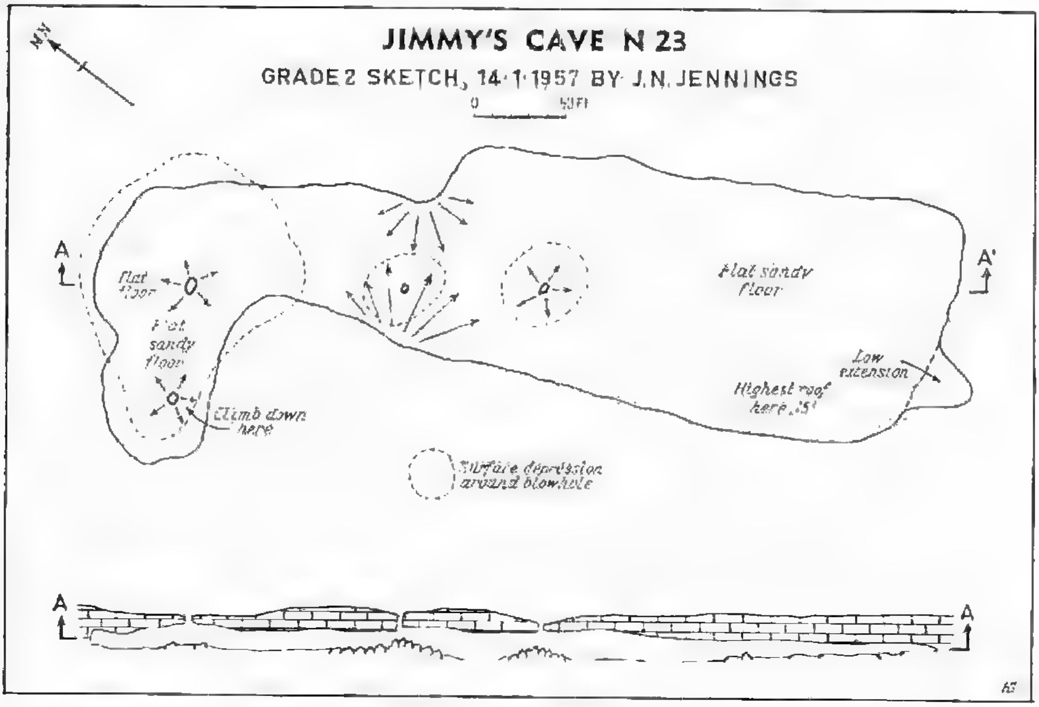

Fig. 5. Jimmy's Cave N23.

ARE THE DEEP CAVES PHREATIC?

The known deep caves of the Nullarbor — from west to east, Cocklebiddy, Abrakurrie N3, Weebubbie N2, Warbla N1, Koonalda N4 — have entrances leading from the bottoms of collapse dolines at 80-100 feet down, except for Abrakurrie into which the blind valley already mentioned leads at 90-100 feet below the Plain. As a result they are almost entirely developed in the Wilson Bluff Limestone of Upper Eocene age. This pure bryozoal calcarenite is friable and chalky, though somewhat harder than a typical chalk; joints are few, but King reports it to have a porosity of 26 p.c. The deep caves are substantial in size (Figs. 6 and 7; Pls. 2 and 3) and are therefore of interest in this lithological context since until very recently only very small caves have been found in the Cretaceous Chalk of N.W. Europe and the longer caves found latterly apparently do not possess the large dimensions in other directions of the Nullarbor examples.

From the entrances, steep slopes lead down to levels of 150-300 feet below the Plain where fairly horizontal levels are found made up of large halls, 40-60 feet high and 80-120 feet wide. Warbla is the shortest in length with 800 feet and Koonalda the longest with an overall length of 2,700 feet, together with another 1,000 feet in branches. However, these lengths are a much less satisfactory indication of their size than their floor area or, even better, their volume would be. Indeed, they are very impressive caves because of their bold, spacious, simple forms — flat roofs, smoothly arching walls and apse-like ends — and because of the whiteness of their chalk. Here and there the roofs rise in well-rounded domepits, beneath which the fairly level floors are broken by debris piles. The largest example is found in Koonalda, where a dome rises about 225 feet between Second and Third Lakes and the rockfall piles 115 feet high beneath its almost perfect cupola. Width usually increases to 150-200 feet at these domepits.

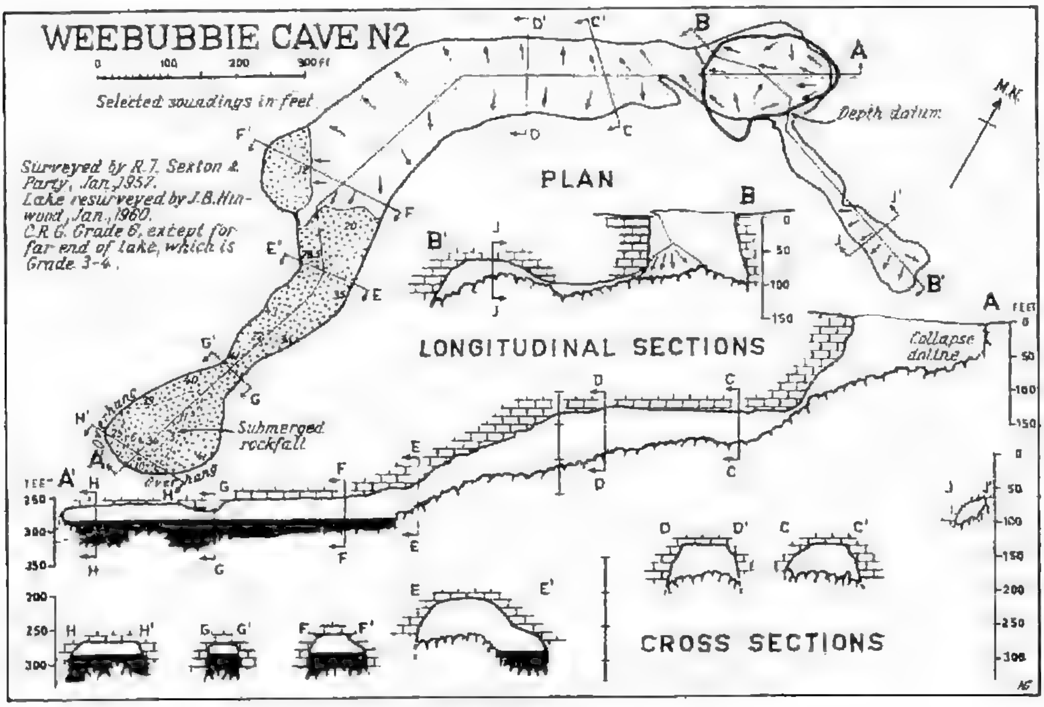

Fig. 6. Weebubbie Cave N2.

The plans of the deep caves are also simple, consisting of long, straight halls which are probably joint-controlled, linked by rounded bends. In trend they are directed coastwards in a broad sense but the alignments vary between NW-SE and NE-SW. Only Koonalda has branches.

The floors are mainly formed of angular blocks and chalk dust on the one hand and brackish lakes on the other. Some earth and clay is also encountered, e.g. in the main passage of Koonalda. The lakes may be shallow measured in a few inches or a foot or two, e.g. First Lake, Koonalda, or else they are deep, clear lakes, such as Third Lake in Koonalda and the lakes in Weebubbie and Cocklebiddy. Soundings in January 1960 by J. B. Hinwood and his party showed the first two to be between 20 and 40 feet deep for the most part. Water levels can vary quite substantially over intervals of several years, e.g. at least 16 feet in the case of First and Second Lakes, Koonalda, but they can also stay unchanged for a year or two. Thus between January, 1957, and January, 1960, the level of Weebubbie Lake was unchanged. The bottoms of the lakes consist in parts of mud and in parts of angular blocks.

Ward (1946) has contoured a regional watertable in the South Australian part of the Plain on the evidence from bores and the lakes of the deep caves appear to lie in this watertable. "Karst watertables" are not accepted by many European authorities, who insist that limestone drainage takes the form of independent underground streams which do not conform to a single watertable (cf. Lehmann, 1932). Nevertheless, the idea of a continuous watertable is probably acceptable in this context of a level plateau in horizontally-bedded, lithologically-uniform limestone of high porosity.

Abrakurrie differs from the others in several respects. Waterworn boulders comprise much of the material on the steep initial descent and the nearly level floor below is almost entirely alluviated with gravel and silt, the finer material being found at the lower end. Intermittent watercourses traverse the fill, finally running along and slightly eroding the sidewalls, before entering small holes in the alluvium. These differences can be linked to the fact that a blind valley with a stream bed leads into this particular deep cave. Also Abrakurrie lacks permanent water bodies though a few inches of water may stand for short periods on the floor at the northern end of the main hall.

Warbla also differs from the others in having no large lakes. Beyond the main, more or less horizontal, level between 150 and 200 feet down, there is a further descent over steep talus, becoming confined where two small but deep pools are reached with their surfaces at 307 feet below the Plain (January, 1957).

The five caves are restricted to the coastal zone of mallee, myall and mulga scrub. King explained this distribution structurally, namely, that there is a greater thickness of limestone near the coast. There is, however, more than enough to accommodate the deepest known caves as far north as the Trans-continental Railway; moreover, the watertable lies low enough for deep caves. Possibly the coastal localisation is more apparent than real; the coastal belt is the best known and deep caves may be discovered well inland. If not, climate may be the responsible factor; the deep caves lie in the better watered part and four of them examined in 1957 lay on the margin of fairly large shallow depressions in the surface of the Plain. The deep caves may be due to greater concentrations of surface runoff in the climatically more favoured belt.

Phreatic formation is attributed to the deep caves by King but his discussion suggests a confusion of distinctly different views on cave origins, those of Davis (1930) and Bretz (1942) on the one hand and of Swinnerton (1932) on the other. Davis and Bretz apply the term "phreatic" to solution by nearly static water and reaching to considerable depths beneath a watertable. By contrast, Swinnerton stresses the importance of solution by rapidly moving water close to the watertable and in the zone of oscillation of level of the watertable. How divergent these views are is shown by the fact that Warwick (1953), when presenting a general survey of theories of cave formation under a threefold division of "vadose", "phreatic" and "compromise" theories, thought it most appropriate to discuss Swinnerton's views under the heading of "vadose" theory.

There has been much discussion of terminology in these matters (Glennie, 1957, 1958; Little, 1957; Tratman, 1957) and it is at least clear that "phreatic" should be restricted to still or slowly moving water below the watertable, whether or not some such term as "epi-phreatic" be introduced to apply to Swinnerton's watertable streams.

The five grounds given by King for considering the deep caves as phreatic will now be discussed.

(a) "The cavern floors show little or no gradient."

Allowing for rock piles beneath collapse domes, this seems to be substantially true for the deep caves. More than half of Weebubbie has a steep gradient, however, and Warbla has a long steep descent below its level section.

However, this attribute is not characteristic of phreatic origins in the Davisian sense. Solution well below a watertable will not be controlled by it; a truly phreatic system is likely to be irregular in profile. In fact, slight gradient is taken by authorities such as Birot (1954) to be typical of well-developed vadose cave systems. This criterion does not help much to distinguish between mature vadose caves and those due to Swinnerton's watertable streams, but it does argue against phreatic formation *sensu stricto*.

(b) "The general direction of the caverns (north-south) corresponds with the direction of watertable drainage."

Abrakurrie, Weebubbie and Warbla do indicate drainage towards the coast influenced by the major joint systems.

Koonalda presents some difficulty in that, although the main passage is aligned roughly N-S, the deepest part is at the bottom of Third Lake at the northern end. This on its own suggests drainage against the gradient of the watertable. However, the profile could be due to irregular cave breakdown. Thus if the high domepit, between Second and Third Lakes, which reaches within 50 feet of the surface already, were to cause surface collapse, the floor profile would be drastically modified very quickly. There is other evidence that drainage may have been seawards when there was active flow in the cave. The branching pattern of the system is directed seaward and the current marking in the flat passage linking West Passage with North-west Passage indicates a southward flow. Koonalda is therefore regarded as compatible with King's generalisation. The 1960 survey indicates that Third Lake is about 5 feet higher than Second and First Lakes so what seepage there is today is in the seaward direction.

Again, however, the interpretation of this generalisation favours Swinnerton's ideas and classical vadose theory rather than true phreatic solution. With the former theories underground drainage will tend to be dominated by streams directed towards the coast. A phreatic pattern will be controlled much more by structural conditions and elongation down the surface of the watertable may not be very strongly evident.

One additional fact possibly points to Swinnerton's watertable streams rather than to completely free-surface gravity streams of simple vadose theory. At the top of the steep talus slope in North-west Passage, Koonalda, there are large, rounded chalk boulders implying rapid and turbulent flow, but they are 40 feet higher than the current markings in the squeeze at the far end of this passage. This seems to imply uphill flow under hydrostatic pressure ("conduits à eau forcée" of the French, e.g. Chevalier, 1944).

(c) "The occurrence of calcite crystals and calcite encrustation on the walls and ceilings, in contrast to the absence of dripstones. . . ."

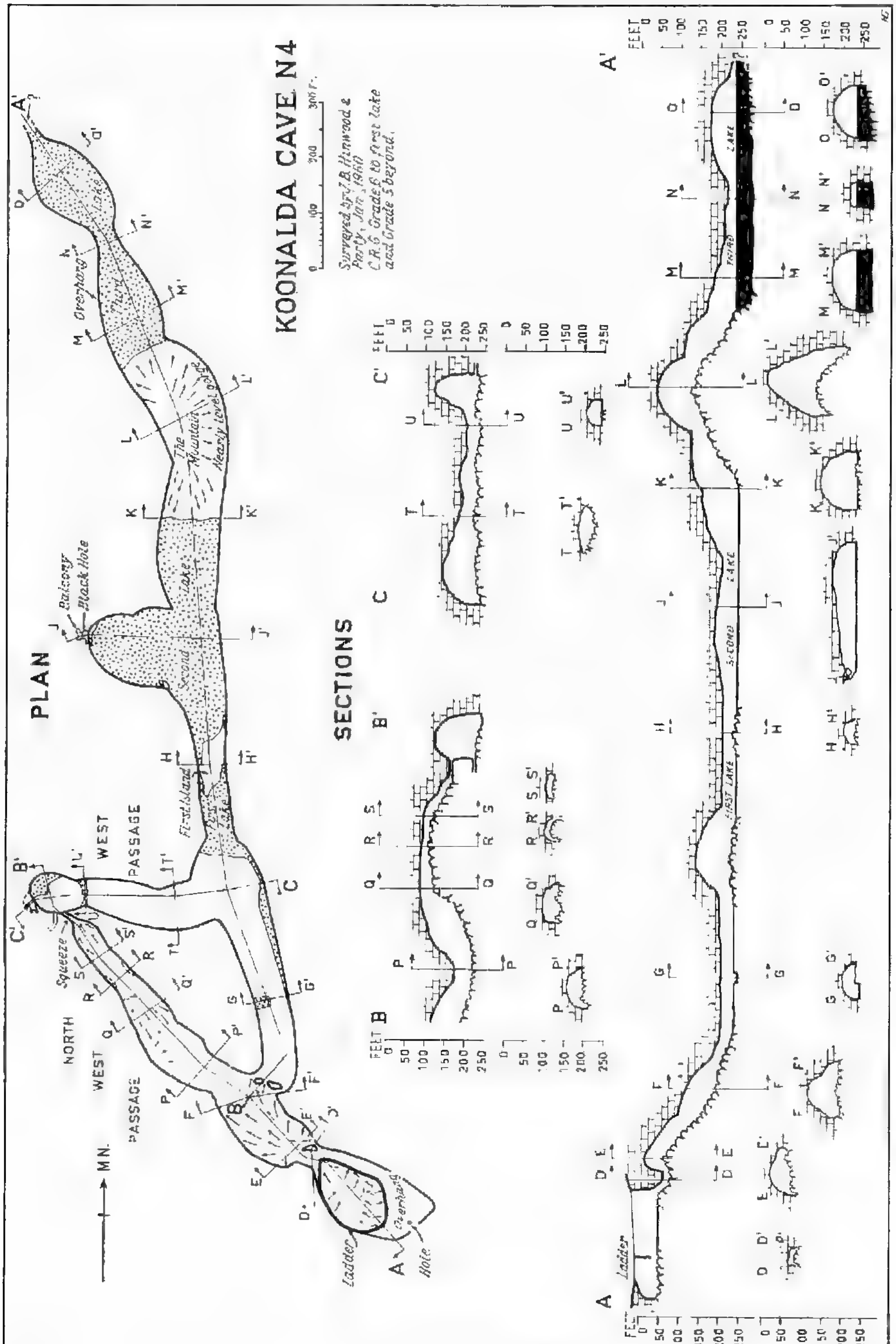

Fig. 7. Koonalda Cave N4.

The absence of dripstones is no ground for phreatic origin of a cave. Not all inactive vadose caves have dripstone decoration and conversely many caves interpreted as phreatic have much ornamentation (Bretz, 1949). The difference between the two types of cave in this respect is that stalactites and stalagmites can develop in some degree during the active development of a vadose cave, but not during that of a phreatic one. However, a great deal of dripstone forms after caves of both types have ceased being excavated and conditions have changed.

The explanation of the absence of dripstones must be sought elsewhere. It may rest in the high porosity and sparse jointing of the Wilson Bluff Limestone; water may soak through the body of the rock and is insufficiently concentrated in joint planes to break out in drips. Moreover, as has already been noted, dripstone features are by no means plentiful in the shallow caves also, the total amount of water seeping downwards is small at all levels.

Calcite with external crystalline form is generally regarded as forming under still water, but the occurrence of such crystals on helictites, which there is no reason to think have been submerged in the course of their deposition, makes this association far from invariable. "Crystal caves" are, nevertheless, usually associated with Davisian phreatic excavation. However, in his examination of Abrakurrie, Koonalda and Weebubbie, the writer was only able to find calcite crystals close to present lake levels, e.g. in West Passage, Koonalda. Oscillations of lake level such as are known today from this cave could explain them.

(d) "The caverns have rounded cross-section and, in general, there is no line of demarcation of roof and wall. The smooth and undulating surfaces of both roof and walls are diagnostic of solution effects."

The four detailed deep cave surveys available today — i.e. of all except Cocklebiddy — show that flat roofs in bedding planes are found more widely than the curved type and with them the line of meeting of roof and arched wall is usually well defined. Moreover, the wall arches often show keels along bedding planes.

As has been mentioned above, the floors and lake bottoms are often covered with angular rockfall. If the walls and roofs are due to solution, why hasn't this talus been dissolved also? Instead it is simpler to explain the forms as due to weathering and breakdown under gravity as King himself suggests at another point in his paper. The successively curved and keeled walls, the flat roofs and the domes constitute the equilibrium forms of mechanical breakdown in this structural context of weak, uniform lithology in massive beds of horizontal attitude. Freshly detached blocks indicate adjustment is continuing slowly, as does the powdery outer surface of the walls and the presence of chalk dust on ledges and floors. A further evidence of the readiness of Wilson Bluff Limestone to weather is found in the large taloni seen just in front of the Lake in Weebubbie Cave (Pl. 4) and, not so well developed, close to the junction of the North-west and the main passages of Koonalda.

However, at a few points on the walls some rather weak current markings of large dimensions are discernible; these, however, support vadose or Swinnerton's theory rather than phreatic conditions.

(e) "The ends of the caverns are as sudden as their commencement as sinkholes and are rounded out perfectly in continuity with the roofs and walls. Such a phenomenon is not in accordance with the habits of vadose streams."

The actual form of the apses would seem best attributed to the lithology and structure of the rocks. Whether the apses definitely end the caves needs discussion. Abrupt closure is certainly evident at both ends of the long hall of Abrakurrie. Beyond the apse at Warbla, there is the steeply descending passage mentioned earlier; collapse may have blocked a continuation here. There is a water-filled continuation at the north end of Third Lake, Koonalda, which has still to be explored to its limit. Nor has the possibility of underwater passages leading on from the end of Weebubbie Lake been eliminated as yet. At Christmas, 1961, a West Australian party dived at the far end of the Lake and thirty feet beyond the roof seemed to be rising into a further chamber. Insufficient equipment prevented further exploration. Diving at Cocklebiddy Lake, the same party extended the known part of this cave. It is not impossible that at Abrakurrie alluviation has buried former continuation.

Despite these qualifications the fact remains that very rapid changes in the size of the underground cavities are present even if there are prolongations of these caves yet to be penetrated. Such changes fit most readily into phreatic solution although the previous discussion has not favoured such an origin. Resort cannot be had to variations in rock strength to explain the rapid changes since the horizontal uniformity of the rock is marked.

As a whole, the discussion favours most of all Swinnerton's theory of watertable streams and Glennie's adaptation of this theory to his more general theory of cave development (Glennie, 1954) appears to overcome the remaining difficulty better than any other. Caves start by the preparation through phreatic solution of small, interconnecting cavities but large caves are not generally produced in this way. The next development is the enlargement of rising stream passages under hydrostatic pressure at the outlets from the karst. This improved outflow has the effect of draining the small anastomosing solution tubes in the upper part of the system: vadose stream action and cave breakdown proceed to enlarge these upper parts. However, according to Glennie, the most substantial cave excavation now takes place where these upper vadose passages meet the water-filled and tight phreatic elements still separating them from the "artesian" final passages. Rains will cause much water to back up here and water levels will oscillate greatly. This is the locus of maximum solution and produces the "master caves" as they are termed in Britain, the "big, level railway tunnels", a description very apt for the Nullarbor deep caves also. Glennie approximates this phase to Swinnerton's theory and his modification of it provides a possible explanation of the sudden tightening up of the deep caves.

There are difficulties, however. Solution tubes in the Wilson Bluff Limestone are few, although there are some examples which have been known to spout water. The major joint planes, which appear to be responsible for the straightness of some of the halls of the deep caves, may have induced more phreatic tubes, however. Pinchemel's views on the hydrological system of the Chalk of N. France and S. Britain are relevant here (Pinchemel, 1954). He believes that there is a karst watertable in the chalk but that beneath it localised currents also occur, following joint systems. Such could have produced the phreatic beginnings of the deep caves. Secondly, the distance to present or former outlets on the coast or the Hampton Range is great and no such outlets have yet been identified with certainty. Caves in the cliffs have been mentioned but not described. Outlets are likely to be submarine, of course, and H. Y. L. Brown (1885) has described what he regarded as submarine springs offshore at the Head of the Bight, Wilson Bluff and Merdayerrah. All that can be claimed, nevertheless, is that Glennie's theory provides the most likely working hypothesis for the formation of the deep caves.

ARE THE CAVES DUE TO PLEISTOCENE PLUVIALS?

In King's view little cave development is taking place today and therefore the caves must be attributed largely to greater solution during a Pleistocene pluvial period.

As has been seen already, the morphology of the caves testifies to cave breakdown being the chief process in operation today; such stream courses as occur give evidence of intermittent transport and deposition and little of deepening and widening of floors or walls. Cave excavation is clearly on a small scale.

As further evidence of this, King cited low lime content of the cave waters. His three analyses can be supplemented by four more from samples collected in 1957.

Weebubbie Lake	105 mg./l.	$CaCO_3$
First Lake, Koonalda	105 mg./l.	
Drip, Murrawijinie N7	233 mg./l.	
Drip, The Catacombs N20	237 mg./l.	

These values fall well within the range associated with active cave formation in many Irish karst areas for example. However, in arid areas the concentration of solutes by evaporation must be allowed for. Thus do Corbel's high values from Saharan limestone areas of over 500 mg./l. find their explanation (Corbel, 1957). Corbel also stated that "free CO_2" is absent from Saharan waters. The 1957 samples from the Nullarbor showed substantial "free CO_2" contents. However, subsequent investigation casts doubt on the validity of this determination as a measure of the capacity of natural waters for further solutional work. If the Nullarbor lakes are saturated at about 100 mg./l., this would lend some support to the morphological evidence but it remains to be substantiated that this is the case.

King gives low rainfall as an argument for very limited cave excavation today. This is indisputable and other factors intensify this effect. Rainfall effectiveness is reduced by high temperatures experienced in much of the year and low relative humidities at most times. Vegetation cover is sparse even in the coastal scrubland and this minimises the supply of carbon dioxide to rainwater as it percolates through the soil. Limestone solution depends on carbon dioxide in solution in the water and the chief source of it is biological, from surface trash and soils. Moreover, with the high temperature of underground water here, the saturation equilibrium in water of carbon dioxide, and so of the carbonate ion, is lower than in colder climates. These reasons combine to render hot, dry lands most unfavourable to cave development. On the other hand, it must be admitted that meagre plant cover permits quicker runoff to cave entrances. In this connection a quotation from T. Brown (1919) is relevant, "I have known a hundred acres of water 2 feet deep disappear in 6 hours and next day when listening down a blowhole I heard water rushing through the country below like a river". Nevertheless, the overall picture is one of inactivity in the caves today.

There is some evidence from areas close to the Nullarbor of a wetter period (or periods) probably in the Pleistocene. King (1956) has described Pleistocene-Recent lacustrine deposits, rising 36 feet above the present bed of Lake Eyre. It is possible that the shift within these deposits from fresher conditions below to more saline conditions above is the result of marine incursion rather than a reflection of desiccation (Ludbrook, 1956). Nevertheless, the basal deposits support the idea of a bigger, fresher "L. Dieri" associated with more pluvial climatic conditions. Soils evidence (Jessup, 1960) also points to alternating wetter and drier conditions. Closer still, at Pidinga on the eastern margin of the Plain, a chain of saline lakes linked by depressions blocked by wind-blown sands is regarded by King (1951) as relict from an ancient river system and north-west of the Plain in Western Australia are chains of salt lakes similarly thought formerly to be rivers draining down to it. From the Plain itself there is little evidence, however. Lundelius (1957) has recently described finds from cave floor surfaces in the Nullarbor, which extend greatly the range of certain small marsupials restricted now within Western Australia to the wetter south-west. Though climatic change could be the cause, Lundelius recognised that other explanations were possible also. More certain perhaps is the older evidence (Glauert, 1912) from Balladonia Soak on the western margin of the Plain where fossil giant marsupials such as *Diprotodon* sp. and *Sthenurus* sp. were found in superficial deposits of Pleistocene-Recent age. It is difficult to believe that these large animals could live off the very limited food supply growing there nowadays. Even this is not conclusive, however. Despite this lack of definite internal evidence, the presumption of a wetter phase or phases is a reasonable one and much of the cave development can be associated with them.

However, the zone of intense perforation close to the surface of the Plain, if correctly interpreted as phreatic, implies a rise in the watertable as much as 200-300 feet near the coast. In causing such a lowering, climatic change could have been supplemented by coastal recession in some degree, but not substantially, because the coastal evidence already cited suggests that recession has not been very rapid. This big drop in water level seems too much to be attributed to these factors.

King rejected changes in the relative level of land and sea as a contributory cause in the development of the caves. But interglacial high sea levels as part of the eustatic oscillations of the Pleistocene (Flint, 1957) can be scarcely denied though the very great eustatic oscillations claimed by some workers may be. Moreover, there is the direct evidence from the Nullarbor coast of higher stands in the relative level of land and sea up to +120 feet. These would seem to be a more adequate cause of raised watertables in the Plain than climatic changes of the order usually envisaged for the Pleistocene. Phreatic preparation can therefore be associated with the interglacial high sea levels. The intervening phases of lowered sea level during glacial periods would then be periods of lowered watertables; however, with higher rainfalls, vadose stream passages could be fashioned and master cave enlargement in accordance with Glennie's theory could take place then.

On this basis the shallow caves would involve one high stand of sea level and of watertable. Another may be the cause of the more or less horizontal levels of the deep caves which stand high above the present watertable, i.e. that of Warbla Cave and the North-west passage of Koonalda; possibly also this applies to Abrakurrie, which seems to lie well above the present watertable (Jennings, 1961). The other horizontal levels of the deep caves, which contain the lakes, may need little or no change in sea-level to explain them and it is possible that climatic change alone explains their present inactivity.

No correlations with the coastal evidence of sea-level changes are possible as yet, but it is evident that these changes are of the same order of importance in understanding the development of the Nullarbor caves as is the changing climate of the Pleistocene.

IS THE NULLARBOR RICH IN CAVES?

Many writers have maintained that the Nullarbor is rich in caves. With the Plain as little explored speleologically as it is, it is not easy to make a reliable assessment of this. Obviously a distinction must be made between absolute numbers and the frequency of caves in relation to area. The numbers of all caves known at present probably does not amount to one hundred, certainly not to two hundred, and this total comes from a limestone area of some 65,000 square miles, i.e. roughly two and a half times the area of Switzerland. Only a small proportion of Switzerland is of limestone, yet it has many more caves than that, including very much larger ones than any in the Nullarbor, such as the Hölloch. There are only five substantial caves known from the Nullarbor at present; the small area of about three square miles of limestone at Yarrongobilly, New South Wales, can match this. It is true that further exploration in the Nullarbor will reveal many more caves. Yet certain parts such as that around Nullarbor homestead are by now fairly well known and it must be admitted that the caves are few and far between.

There is a strong likelihood then that the underground karst of the Nullarbor is as weakly developed as its surface development discussed above. One further aspect not previously mentioned is also congruent. Though the Plain is a covered karst, i.e. it is mainly soil-sovered, there are rock outcrops, particularly around the collapse dolines and cave entrances. These outcrops are poor in minor surface solution features. There is little widening of joints into solution slots or grikes; vertical or steeply sloping faces fail to carry the characteristic solution fluting (*Rillenkarren*) or solution grooves (*Rinnenkarren*). The forms which occur are tiny pittings and solution pans (*Kamenitsa*) of small to moderate size on flat slabs or gently inclined blocks. The fact that the flat bottoms of the pans are horizontal on unstably inclined blocks indicate that this surface solution is proceeding at the present time. The net effect, however, has been meagre. This contrasts drastically with the highly developed surface solution features of the Limestone Ranges of the Fitzroy Basin (Jennings and Sweeting, in press); the latter receive rather more rainfall, 18-28 inches, but evaporation loss is much greater.

The surface and the underground morphology converge to support the conclusion that here is a doline karst in an early stage of development despite the long period of subaerial exposure suggested by the absence of marine rocks later than the Lower Miocene. This is in agreement with the ideas of Birot (1954) and Corbel (1956) on the slow development of karst in semi-arid and arid climates, particularly in subtropical and tropical latitudes. Though Pleistocene pluvial conditions appear to have ameliorated conditions and promoted cave development, climate does not seem to have been very much wetter for very long periods. The Nullarbor remains an immature, retarded karst.

ACKNOWLEDGMENTS

I am indebted to Dr. N. H. Ludbrook for a valuable discussion of the stratigraphy of the area before visiting it. As mentioned in the introduction, the work of the surveyors of the 1957 and the 1960 expeditions has provided much of the factual basis for this paper. They are too numerous to acknowledge individually, but for the surveys on which the accompanying figures are based, Mr. R. T. Sexton and Mr. J. B. Hinwood must be specially thanked. Mr H. Berry, Australian National University, analysed the water samples recorded here and he has many times advised me on chemical matters. I must also thank Mr. H. Fairlie-Cuninghame for allowing his photographs to be used for Plates 2 and 3.

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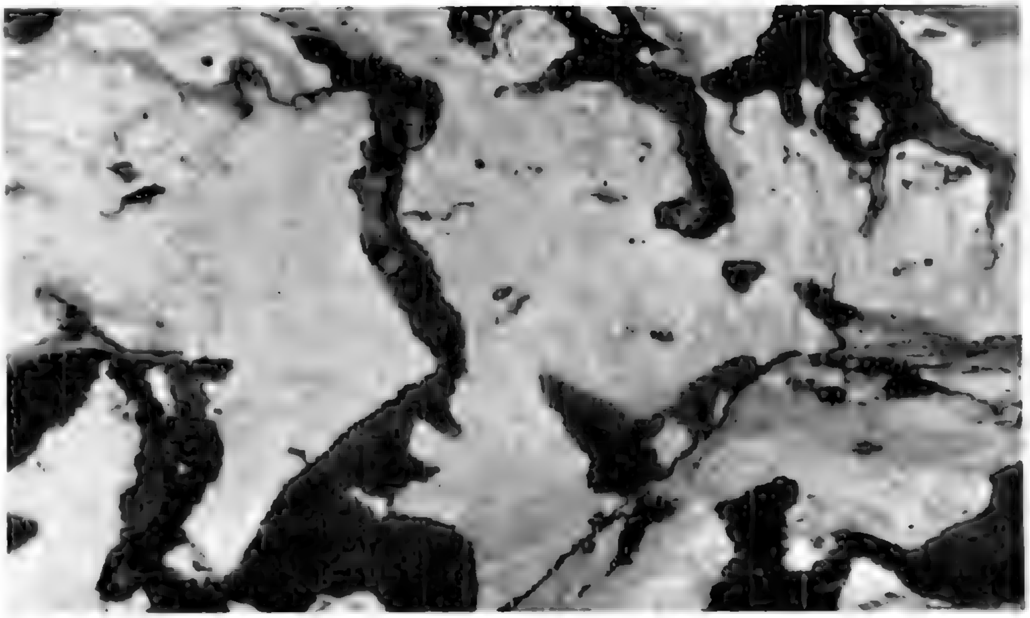

Fig. 1. Black calcite infilling anastomosing solution tubes in the Nullarbor Limestone in White Wells Cave N14. The left of the photograph comprises about 3 feet vertically of rock face.

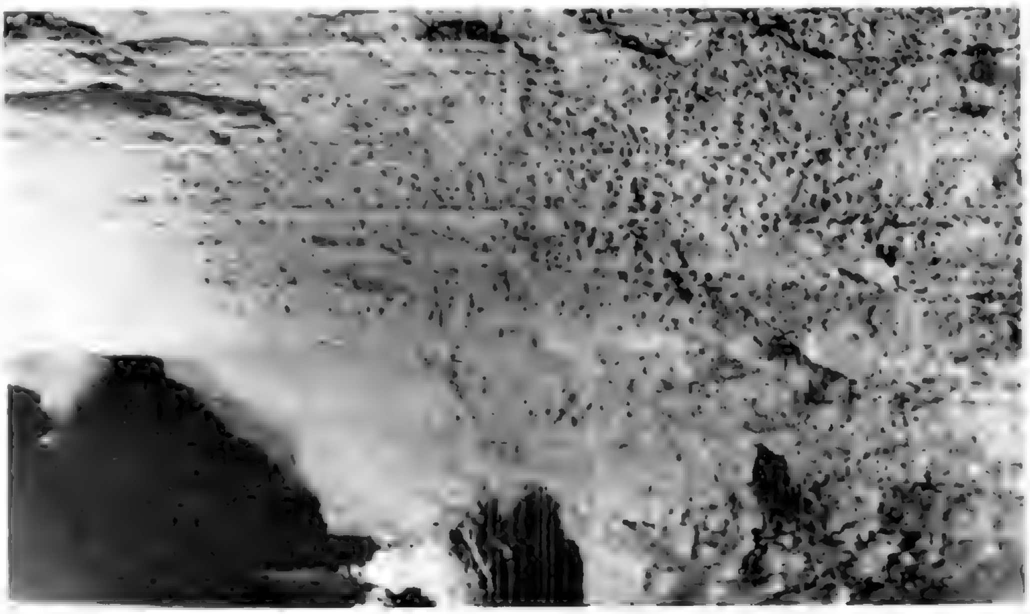

Fig. 2. Tafoni on the wall above the lake of Weebubbie Cave. About 70 feet vertically of rock face is visible and the tafoni go up to 3 feet across in size.

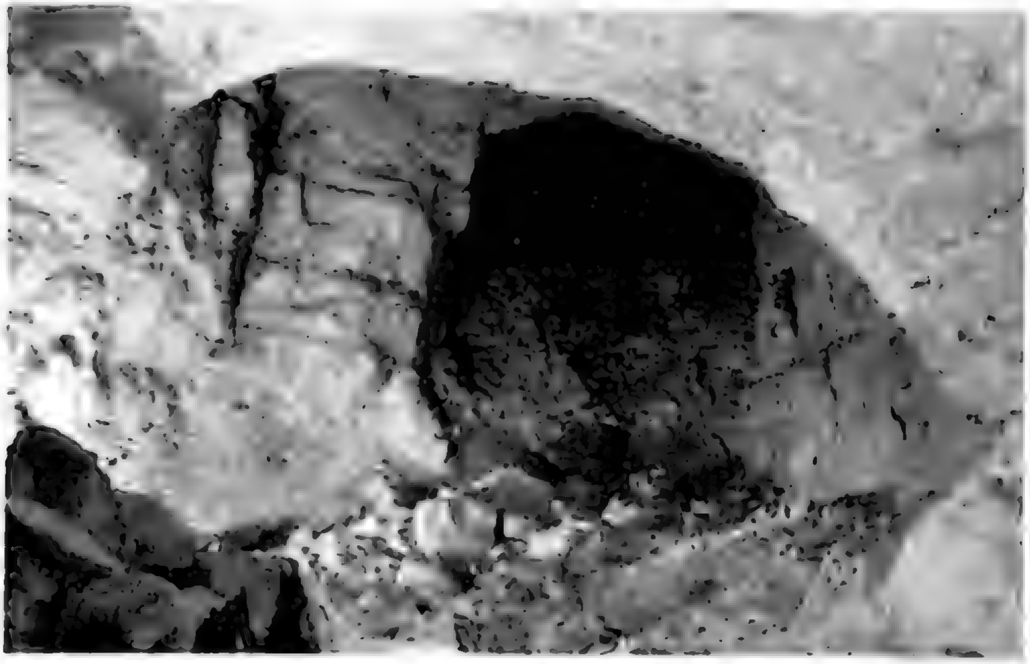

Fig. 1. View along the North-West Passage of Koonalda Cave N4. Behind the figures there is the steep rise of 70 feet to the upper level of this passage. The angular rockfall and chalk dust covering the floor are typical of the deep caves of the Nullarbor.
Photo by H. Fairlie Coninghame.

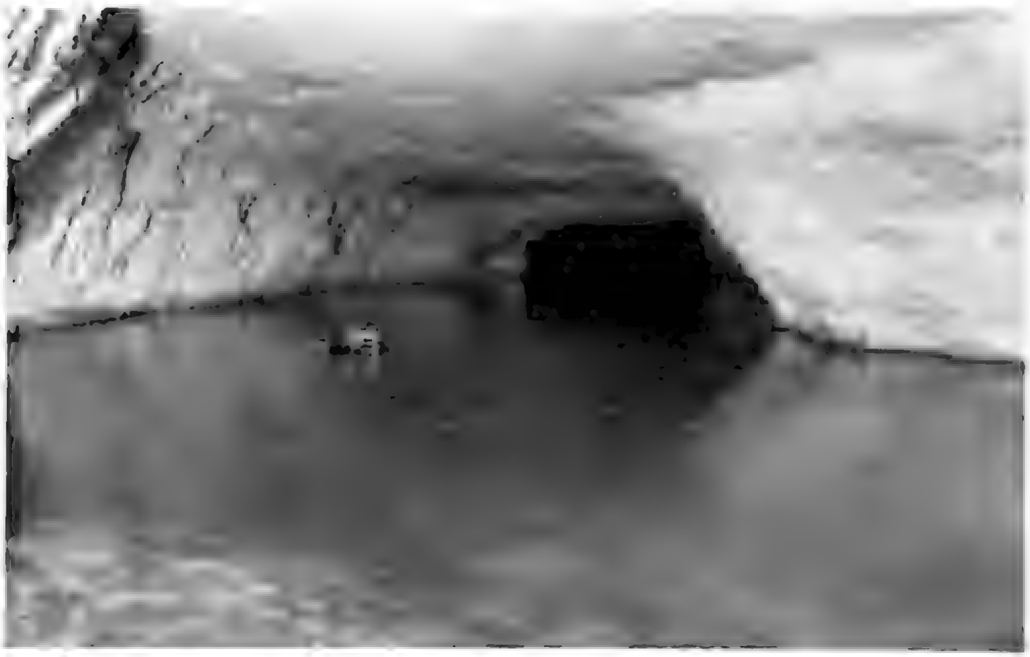

Fig. 2. The lake in Weebubbie Cave N2. It is 20 to 40 feet deep and crystal clear. Flat roofs and arched walls are common in the deep caves.
Photo by H. Fairlie Coninghame.

FLORA CONSERVATION IN SOUTH AUSTRALIA
PT. 11. THE PRESERVATION OF SPECIES RECORDED IN SOUTH AUSTRALIA

BY R. L. SPECHT

Summary

A list of plant species recorded in the flora and fauna reserves in South Australia is given. This information is examined against the total flora of the State. 42 p.c. of the 2,255 native species and 4.3 p.c. of the *557* introduced species are found on the present reserves, The distribution of the species, not conserved, is examined to pinpoint the sites of future reserves,, Sites in the Musgrave, Everard, Mann, Birksgate, Gawler or Northern Flinders Ranges would enable almost 50 p.c. of the remaining flora to be conserved. Small areas on the adjacent, more uniform plains would enable appropriate plant formations to be preserved. Sites along the River Murray would conserve up to 8 p.c. of the remaining flora. While sites in the Southern Flinders Ranges, Burrs Hills, foot of Yorke Peninsula, Fleurieu Peninsula and north of Mt. Gambier are suggested to conserve a considerable number of the other species as well as plant formations. The problem of introduced species is again discussed.

FLORA CONSERVATION IN SOUTH AUSTRALIA

PT. II. THE PRESERVATION OF SPECIES RECORDED IN SOUTH AUSTRALIA

by R. L. Specht*

(with Collaboration from J. B. Cleland)†

[Read 13th September 1962]

SUMMARY

A list of plant species recorded in the flora and fauna reserves in South Australia is given. This information is examined against the total flora of the State. 42 p.c. of the 2,255 native species and 43 p.c. of the 557 introduced species are found on the present reserves

The distribution of the species, not conserved, is examined to pinpoint the sites of future reserves.

Sites in the Musgrave, Everard, Mann, Birksgate, Gawler or Northern Flinders Ranges would enable almost 50 p.c. of the remaining flora to be conserved. Small areas on the adjacent, more uniform plains would enable appropriate plant formations to be preserved.

Sites along the River Murray would conserve up to 8 p.c. of the remaining flora. While sites in the Southern Flinders Ranges, Burra Hills, foot of Yorke Peninsula, Fleurieu Peninsula and north of Mt. Gambier are suggested to conserve a considerable number of the other species as well as plant formations.

The problem of introduced species is again discussed.

INTRODUCTION

In the previous volume of these Transactions the authors (1961) discussed the preservation of the various plant formations and associations which had been recorded in South Australia. Glaring deficiencies were indicated.

In this paper an attempt has been made to tabulate the plant species (Ferns, Gymnosperms, and Angiosperms only) which may be found in the Reserves established in South Australia up to this date (Table 1). For some of the Reserves the list is by no means complete, but it serves to highlight major discrepancies in flora conservation in this State.

The records thus tabulated were compared with the list of species recorded for South Australia by Black (1943-57) and subsequent workers (Williams, 1953; Ising, 1955, 1958 and 1961; Aellen, 1955; Garden, 1956; Melville, 1957 and 1960; Eichler, 1958; Forde and Ising, 1958; Stauffer, 1959; Wilson, 1960 and 1961; Symon, 1961; Burbidge, 1953, 1958 and 1960; Willis, 1957 and 1958; Carolin, 1958 and 1961).

In each family the number of native and introduced species recorded in the Reserves was compared with the total listed for the State. The distribution of any species not, as yet, recorded in any reserve was then examined on a regional basis; these data, compiled for each family and for the whole flora of the State, are presented in Table 2.

* Formerly Department of Botany, University of Adelaide. Present address, Department of Botany, University of Melbourne.

† Chairman of the Commissioners of the National Park and Wild Life Reserves, South Australia.

TABLE 1

In the table given below the presence of each species recorded in any Reserve is indicated by +; the fact that it has, as yet not been recorded in a Reserve is indicated by –. In most cases, the specimens collected to verify the presence of a species in a Reserve have been deposited either in the State Herbarium of South Australia (AD) or in the Herbarium, Waite Agricultural Research Institute, Adelaide (ADW). The nomenclature follows Black (1943-57) unless indicated by a footnote. An asterisk before the species indicates that the species is introduced to South Australia.

LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA

The names of the Reserves are indicated at the top of each column by the following numerals:

1. Reserves of Mount Lofty Ranges. Data from Cleland and Goldsack (1953).
2. Flinders Chase, Kangaroo Island. Data from Cleland and Black (1927, 1941, 1952).
3. Wilpena Pound, Flinders Ranges. Data from Mr. D. E. Symon, Herbarium, Waite Agricultural Research Institute, Adelaide.
4. Pearson Islands, Great Australian Bight. Data from Osborn (1923) and Specht (unpublished).
5. Hd. Flinders, Eyre Peninsula. Data collected by Flora and Fauna Reserves Investigation Committee, November, 1960.
6. Hd. Lake Wangary (Coffin Bay), Eyre Peninsula. Data collected by Flora and Fauna Reserves Investigation Committee, November, 1960.
7. Hds. Hincks, Murlong, Nicholls and Section 365, Out of Hundreds, Eyre Peninsula. Data collected by (1) Cleland, J. B., Sharman, G. B., and Specht, R. L., December, 1959. (2) Flora and Fauna Reserves Investigation Committee, November, 1960.
8. Hds. Hambidge, and Section 364, Out of Hundreds, Eyre Peninsula. Data collected by Flora and Fauna Reserves Investigation Committee, November, 1960.
9. Chauncey's Line, near Monarto South, and adjacent roadsides. Data from Cleland (1955).
10. Fairview, north-east of Lucindale, South East. Data collected by J. B. Cleland.
11. Hds. Archibald and Makin, near Keith. Data from Coaldrake (1951), Litchfield (1956), Specht and Rayson (1957), and Specht (1963).
12. Hd. Peebinga, near Peebinga. Data collected by Flora and Fauna Reserves Investigation Committee, October, 1960.
13. Hd. Billiatt, south east of Wanbi. Data collected by Flora and Fauna Reserves Investigation Committee, October, 1960.
14. Koonamore Vegetation Reserve, north of Yunta. Data from Wood (1936) and Miss C. M. Eardley, Botany Department, University of Adelaide.

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Polypodiaceae														
Adiantum aethiopicum	+	+	—		—	—	—	—	—	—	—		—	—
Anogramme leptophylla	+	—	—	—	—	—	—	—	—	—	—	—		
Asplenium flabellifolium	+	+			—	—	—	—			—	—		
Blechnum capense	+	—	—	—	—	—	—	—				—	—	—
B. discolor	+	—	—	—	—			—	—	—	—	—	—	—
Cheilanthes tenuifolia	+	—	+	+		—	—		—	—	—	—	—	—
Lindsaea linearis	+	+	—	—	—	—	—	—	—				—	—
Notholaena brownii	—	—	+	—	—	—	—	—	—	—				—
Pleurosorus rutaefolius	+	—	+	—	—	—	—		—	—	—	—	—	—
Pteridium aquilinum	+	+	—	—	—		—	—	—	+	—	—		—
F. Gleicheniaceae														
Gleichenia circinata	+	+					—	—	—	—	—	—	—	—
F. Schizaeaceae														
Schizaea fistulosa	+	—		—	—	—	—	—						
F. Osmundaceae														
Todea barbara	+	+	—	—	—	—	—	—		—	—	—	—	—
F. Ophioglossaceae														
Ophioglossum coriaceum	+	—	+	—	—	—	—	—	—	—	—	—	—	—
F. Marsileaceae														
Marsilea hirsuta	+	—	—	—	—	—	—	—	—	—			—	—
F. Lycopodiaceae														
Lycopodium densum	+				—	—	—			—	—	—	—	—
L. laterale	—	—	—	—	—	—					—	—	—	
Phylloglossum drummondii	+	+	—	—			—	—	—		—	—	—	—
F. Selaginellaceae														
Selaginella preissiana		+		—	—	—	—	—	—	—	—	—		—
F. Isoetaceae														
Isoetes drummondii	+	+	—	—	—	—	—	—	—			—	—	—

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Pinaceae														
Callitris† *canescens*	—	—		—	—		+	+	+	—	—		+	—
C. preissii ssp. *verrucosa*	—		—	—	—	—	+	+	+	—	—	+	+	—
C. rhomboidea		+	—	—			—	—	—	—	—	—	—	—
F. Typhaceae														
Typha angustifolia	+	—	—	—		—	—	—	—	—	—	—	—	—
F. Potamogetonaceae														
Potamogeton aff. *sulcatus/tepperi*	—	—	+	—	—	—	—	—	—	—	—	—		—
F. Scheuchzeriaceae														
Triglochin calcitrapa	—	—	+	—	—	—	—	—	—	—	—	—	—	—
T. centrocarpa	+	—	—	—	—	—	+	—	—	—	—	—		—
T. muelleri	—	—	—	+		—	—	—	—	—	—	—	—	
T. procera	+	—		—	—				—	—	—	—	—	—
T. striata	—	+	—	—	—		—	—	—	—	—	—	—	—
F. Hydrocharitaceae														
Ottelia ovalifolia		+	—		—	—	—	—	—		—	—		—
F. Gramineae														
Agropyron scabrum	+	—	+	+	—	—	—		—	—			—	—
Agrostis aemula	+	+	—	—	—		—	—	—	—	—		—	—
A. avenacea	+	+	—	+	—		—	—	—	+	+	—	—	—
A. billardieri	—	+	—		—	—	—	—	—	—	—	—		—
**A. semiverticillata*	+	—	—	—	—	—	—	—	—	—	—	—		—
**A. tenuis*	+	—	—	—	—	—	—	—	—	—		—	—	—
**Aira caryophyllea*	—	+	—	—	+	—	—	—	—	—	—	—	—	
Amphibromus archeri	—	—	—	—	—	—	—	—	—	—	—	—	—	
A. neesii	—	—	+	—	—	—	—	—	—	—	—	—	—	—
Amphipogon caricinus‡ (syn. *A. strictus*)	+	—	—	—	—			—	—	—	+	—	—	—
**Anthoxanthum odoratum*	+	—			—	—	—	—	—	—	—		—	
Aristida behriana	+		—	—	—	—		—	—		—	—	—	—
**Aveltinia michelii* (syn. *Koeleria michelii*)	—	—	—	—	—	—	—	—	—	—	+	—	—	

† Garden, 1956; Blake, 1959. ‡ Williams, 1953.

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
**Avena barbata*	—	—	—	—	—	—	—	—	—	—		—	—	
**A. fatua*	+	—	—	—	—	—	—	—	—	—	—		—	—
**Brachypodium distachyon*	+	—	—	—	—	—		—	—	—	—	—		—
**Briza maxima*	+	—	—	—		—	—	—	—	—	—	—		—
**B. minor*	+	+	—		—	—	—	—	—	—	—	—	—	—
**Bromus catharticus*	+	—	—	—	—	—		—	—	—	—	—	—	—
**B. hordeaceus*	+		—	—	—	—	—	—		—	—		—	—
**B. madritensis*	+	—		—	—	—	—		—	—	—	—		—
**B. mollis*	+	—	—	—	—	—	—	—	—	—	—	—	—	
**B. rigidus*	+	—	—	—	—	—	—	—	—		—	—	—	—
Cymbopogon bombycinus	+	—	—	—	—		—	—	—	—	—	—	—	—
Cynodon dactylon	+	+	—	—	—	—	—		+	—	—	—	—	—
**Cynosurus echinatus*	+	—	—	—		—	—	—	—	—	—	—	—	
**Dactylis glomerata*	+	—	—	—	—	—	—	—	—		—	—	—	—
Danthonia auriculata	+	—	—	—	—			—	—	—	—	—	—	—
D. caespitosa	+		+	—	—	—	—	—	—	—	—	—	—	
D. clelandii	+	—	—	—	—	—	—	—	—		—	—	—	—
D. eriantha	—	—	+	—	—		—	—	—	—		—	—	—
D. geniculata	—	+	—	—	—	—		—	—	—	+		—	—
D. laevis	+	—	—	—	—	—	—		—	—	—	—		—
D. minutiflora	+	—	—	—	—	—	—			—	—	—	—	—
D. penicillata	—	—	—	+	—	—	—	—		—	—	—	—	+
D. pilosa var. *paleacea*	+	—	—	—	—	—		—	—		—	—	—	—
D. racemosa	+		—	—	—	—	—		—	—	—	—	—	—
D. semiannularis	—	—	—	—	—	—	+		—	—	—	—	—	—
D. setacea	+	+	—	—	—	—	—	—	—	—	+	—	—	—
Deyeuxia densa	+	—	—	—	—	—	—	—	—	—	—		—	—
D. minor	—	+	—	—	—	—	—	—	—	—	—	—	—	—
D. quadriseta	+	+		—	—	—	—	—		—	—	—	—	—
Dichelachne crinita	—	—	+	—	—	—	—	—	—	—	—	—	—	—
D. sciurea	+	+	—	—	—	—	—	—	—	—	—	—	—	—
Digitaria sanguinalis	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Distichlis distichophylla	—	+	—	—	—	—	—		—	+	—	—	—	—

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
**Echinochloa crus-galli*	+	—		—	—	—	—	—	—	—	—	—	—	—
Echinopogon ovatus	+	+	—	—		—	—	—	—	—	—	—		
**Ehrharta longiflora*	+	—	—	—	—	—	—	—	—	—		—	—	
Enneapogon nigricans	+	—	—		—	—			—	—			—	+
Eragrostis brownii	+	—	—	—		—	—	—	—	—	+	—	—	—
**Gastridium ventricosum*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Glyceria fluitans	+	—		—	—	—	—	—	—	—	—	—	—	—
**Holcus lanatus*	+	—	—		—	—	—	—	—	—	—	—	—	—
**Hordeum maritimum*	+	—	—	—		—	—	—	—	—	—	—	—	—
**H. murinum*	+	+	—	—	—	—	—	—	—	—	—	—	—	—
Imperata cylindrica var. *major*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Koeleria phleoides*	+	—	+	—	—	—	+	—	—	—	+	—		—
**Lagurus ovatus*	—	+	—	—	—	—	—	—	—	—	—	—		
**Lepturus cylindricus*	+	—	—	—	—	—		—	—	—	—	—	—	—
**Lolium perenne*	+		—	—	—	—	—	—	—	—	—	—	—	—
**L. subulatum*	+	—	—	—	—	—	—	—	—	—	—	—		—
**L. temulentum*	+	—	—	—	—	—	—	—	—		—	—	—	—
Microlaena stipoides	+	+	—	—	—	—		—	—	—	—	—	—	—
**Molineria minuta*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Neurachne alopecuroides	+	—	—		—	—	+	+	+	—	+	—	—	—
Paspalum distichum	+	—	—	—		—	—	—	—	—	—	—	—	—
**Pennisetum villosum*	+		—	—	—	—	—	—	—	—	—	—	—	—
**Pentaschistis airoides*	+	—	—	—	—	—	—	—	+	—	+	—	—	—
**P. thunbergii*	+	—	—	—	—	—	—	—		—	—	—	—	—
**Phalaris minor*	+	—	—	—	—	—		—	—	—	—	—	—	—
**Pholiurus incurvus*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Phragmites	+	—	—	—	—	—	—	—	—	—	—	—	—	—
communis	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Poa annua*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
P. australis	+	—	—	—	?	—	+	—	—	—	—	—	—	—
**P. bulbosa*	+			—	—	—		—	—	—	—	—	—	—
P. drummondiana	—	—		—	—	—	+	—	—	—	—	—		—

TABLE 1 —LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
P. poaeformis	—	—	+	+	—	—	—		—	—	—	—	—	—
P. tenera	—	+	—	—	—	—	—	—	—	—	—	—	—	—
**Polypogon monspeliensis*	—	+	—	—	—	—	—	—	—	—	—	—	—	—
**Schismus barbatus*	—	—	—	—	—	—	—	—	—	—	—	—	+	+
**Scleropoa rigida*	+	—	—	—	+	—	—	—	—	—	—	—	—	
Spinifex hirsutus	—	+	—	—	—	—	—	—	—		—	—	—	—
Sporobolus virginicus	—	+	—	—	—	—	—	—	—	—	—	—	—	—
**Stenotaphrum secundatum*	+	+	—	—	—	—	—	—	—	—	—	—	—	—
Stipa aristiglumis	+	—	—	—	—	—	—	—	—	—	—	—		—
S. congesta	+	—	—	—	—	—	—	—	—	—	—	—	—	—
S. elegantissima	+	—	—	—	—	—	—	—	+	—	—	—	—	—
S. eremophila	—	—	—	—	?	—	—	—	—	—	—	—	—	—
S. falcata	—	—	+	—	—	—	?		—	—	—	—	—	
S. indeprensa	—	—	—	—	—	—	—	?	—	—	—	—	?	—
S. mcalpinei	—	+	—	—	—	—	+	—	—	—	+	—	—	
S. nitida	—	—	—	—	—	—	—	—	—	—	—	—	—	+
S. plagiopogon	—	—	+	—	—	—	—	—	—	—	—	—	—	—
S. pubescens	+	—	—	—	—	—								
S. semibarbata	+	—	—	—	—	—	—	—	+	—	+	—		—
S. setacea	+	—	—	—	—	—	—	—	—	—	—	—	—	—
S. tenuiglumis	—	—	—	—	?	—	—	—	—	—	—	—	—	—
S. teretifolia	—	+	—	—	+	—	—	—	—	—	—	—	—	—
Themeda australis	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Triodia irritans	—	—	+	—	—	+	+	+	—	—	+	+	+	—
**Trisetum pumilum*	—	—	—	—	—	+	—	—	—	—	—	—	—	+
**Vulpia bromoides*	+	—	+	+	—	—	+	—	—	—	+	—	—	—
**V. ciliata*	+	—	—	—	—	—	—	—	—	—	+	—	—	
**V. myuros*	+	—	—	—	—	—	+	—	+	—	+			—
Zoisia matrella	—	+	—	—	—	—	—	—	—	—	—	—		—
F. Cyperaceae														
Carex appressa	+	+	—	—	—	—	—	—	—	—	—	—	—	—
C. bichenoviana	+		—	—	—	—	—	—	—	—	—	—	—	—
C. breviculmis	+	+	—	—	—	—	—	—	—	—	—	—	—	
C. chlorantha	+	—	—	—	—	—	—	—	—	—	—	—		—
C. fascicularis	+	—	—	—	—	—	—	—		—		—	—	—
C. gunniana	+	—	—	—	—	—	—	—	—	—	—	—	—	—
C. hebes	+	—	—	—	—	—	—	—	—	—	—	—	—	—
C. inversa	+	—	—	—	—	—	—	—	—	—	—	—	—	—
C. pumila	+	—	—	—	—	—	—	—	—	—	—	—		
C. tereticaulis	+	—	—	—	—	—	—	—	—	—	—		—	
Caustis pentandra	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Chorizandra enodis	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Cladium acutum		+	—	—	—	—	—	—	—	—	—	—	—	—
C. filum	—	—			+	+		—	—	+	—	—	—	—
C. glomeratum	—	+	—	—	—	—	—	—	—	—	—	—	—	—
C. gunnii	+	—	—	—	—	—	—	—	—	—	—	—	—	—
C. junceum	+	+	—	—	+	—	—	—	—	—	—	—	—	—
C. laxum	—	+	—	—			—	—				—	—	—
C. mariscus	+	—	—	—	—	—				—	—	—	—	—
C. tetragonum	+	—	—	—	—	—	—	—	—	—	—	—	—	
**Cyperus flabelliformis*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
C. gunnii	—	—	+	—	—	—	—	—			—	—	—	—
C. tenellus	+		—	—	—	—	—	—				—	—	—
C. vaginatus	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Eleocharis acicularis	—	+	—	—	—	—	—	—	—	—	—	—	—	—
E. acuta	+	—	+	—	—	—	—	—	—	—	—	—	—	—
E. gracilis	+	—	—	—	—	—	—	—		—	—	—	—	—
E. sphacelata	—	+	+	—	—	—	—	—		—	—	—	—	—
Gahnia deusta	—	+	—	—	+	—	+	—	+	—	+	—	—	—
G. hystrix	—	+	—	—	—	—	—	—	—	—	—	—	—	—
G. lanigera	—	—	—	—	—	—	+	—	+	—	—	—	—	—
G. tetragonocarpa	+	+	—	—	—		—	—	—	—	—	—	—	—
G. trifida	+	+	—	—	+	+	—	—	—	—	—	—	—	—
Lepidosperma canescens	—	+	—	—	—	—	—	—	—	—	—	—		
L. carphoides	+	+	—	—	—	—	+	—	+	—	+	—	—	—
L. congestum	—		—	—	—	—	—	—	—	+	+	—	—	—
L. gladiatum	—	—	—	—	+	—	—	—	—	—	—	—	—	—
L. laterale	+	—		—	—	—	+	—	—	—	+	—	+	
L. lineare	+	+	—	—	—	—	—	—	—	—	—	—	—	—
L. longitudinale	—	+	—	—	—	—	—	—	—	—	—	—	—	—
L. semiteres	+	+	—		—	—	—	—	—	—	—	—	—	—
L. viscidum	+				—	—	—	+	+	—	—	+	+	—
Schoenus apogon	+		—	—	—	—	—	—	—	—	—	—	—	—

TABLE I—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA *continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
S. breviculmis (syn. *S. tepperi*)	+	+	—	—	—	—	+	—	—	—	+	—	—	—
S. carsei	—	+	—	—	—	—	—	—		—		—	—	
S. maschalinus	+	+	—	—	—	—	—				—	—		
S. nitens	—	+	—	—	+	—	—	—	—	—	—	—	—	—
S. racemosus	—	—			—		+	—	+	—	—	—	—	—
S. subaphyllus	—							—					+	
Scirpus antarcticus	+	—	+	—	—	—	+	—	—	—	—	+	+	—
S. calocarpus	+	—	—	—	—	—	—	—	—	—	—	—	—	—
S. cernuus	+	—	—	—	—	—	—	—	—	—	—	—	—	—
S. fluitans	+				—			—			—	—	—	—
S. inundatus	+	+	+	—	—	—		—	—	—	—	—	—	—
S. nodosus	—	+	—	—	+	—	—	—	—	+	—	—	—	—
S. platycarpus	+	—	—	—	—	—	—	—	—	—	—		—	—
S. stellatus	—	+	—	—	—	—	—	—	—	—	—	—	—	—
S. validus		—	+		—		—				—			—
Tetraria halmaturina		+				—					—	—	—	—
F. Araceae														
**Zantedeschia aethiopica*	+	—	—	—	—	—	—	—	—	—	—	—		
F. Restionaceae														
Hypolaena fastigiata	—	+					—		+	+	+	—	—	—
H. lateriflora	+				—				—	—			—	—
Lepidobolus drapetocoleus	—	—	—	—	—	—	—	—	—	—	+	—	—	—
Leptocarpus tenax	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Loxocarya fasciculata	—	—	—	—	—	—	+	—	—			—	—	
Restio complanatus	—	+	—	—	—	—	—		—	—	—	—	—	—
F. Centrolepidaceae														
Aphelia gracilis	+										—	—	—	—
A. pumilio	+	—			—	—	—		—	—	—	—	—	—
Centrolepis aristata	+	—	—	—	—	—	—	—	—	—	—	—	—	
C. murrayi	—	—	+	+	—	—	—		—	—				
C. polygyna	—	—	+	—	—	+	+	—	—	—	—	—	—	—
C. strigosa	+	+	+	+		—	—			—	—	—	—	—
F. Xyridaceae														
Xyris operculata	—	+		—	—	—	—	—	—	—	—	—	—	—

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Juncaceae														
Juncus articulatus	+	—	—	—	—			—	—	—		—		—
J. bufonius	+	+	—	—	—	—		—	—	—	—	—	—	
J. caespiticius	+	+	—		—	—	—		—		—	—	—	
**J. capitatus*	+	—	—	—		—	—	—	—	—		—	—	—
J. maritimus var. *australiensis*	+	+	—				—	—	—	—				—
J. pallidus	+	+	—	—	—	—		—	—	—	+	—		—
J. pauciflorus	+	+	+		—	—	—	—		—	—	—	—	—
J. planifolius	+	+	—	—	—	—	—	—	—	—	—	—	—	—
J. polyanthemos	+				—	—	—	—	—	—	—	—		—
J. prismatocarpus	—	—	+	—	—	—	—			—	—	—	—	—
J. vaginatus	+	—	—	—	—	—	—		—		—	—	—	—
Luzula campestris	+	—	—	—	—	—	—	—	—	—	—	—	—	—
F. Liliaceae														
**Allium triquetrum*	+		—		—	—	—	—	—	—	—	—	—	
Anguillaria dioica	+	—	+	—	—	—	+	—		—	—	—	—	
**Asparagus asparagoides*	+	+	—	—	+	—	—			—	—	—	—	—
**A. officinalis*	+	—	—	—	—	—	—	—	—	—		—	—	—
**Asphodelus fistulosus*	+	—	—		—	—	—	—	—	—	—	—	—	
Bulbine bulbosa	+	—	—	—	—	—	—	—		—	—	—	—	—
Bulbinopsis semibarbata		+	+	+	—	—	+	—	—	—	—	+	+	—
Caesia vittata	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dianella laevis	+	—	+	—	—	—			—			—	—	—
D. revoluta	+		+	+	+	—	+	+	+	—	+	+	+	—
Dichopogon fimbriatus	—	—	—	—	—	—	—	—	—	—	—	—	—	—
D. strictus	—	—	+	—	—	—	—		—		—	—	—	—
Laxmannia sessiliflora					—	—	—	—	—		+			—
Lomandra caespitosa	+	—	—	—		—		—	—	—	—	—	—	—
L. densiflora	+	—	—	—	—	—	—	—				—	—	—
L. dura	+	—	—	—		—	—	—	+	—	—	—		—
L. fibrata	+	—	—	—					—	—	—			—
L. glauca	+	—	—	—	—	—	+		—	—	+	—	—	—
L. juncea	+	—	—	—	—	—	+		—	—	+	—	+	—

TABLE 1. LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
L. leucocephala	—	—	—	—	—	—	—	—	+	—	+	—	+	—
L. micrantha	+	—	—	—	—	—	—	—	+	+	+	—	—	—
**Ornithogalum thyrsoides*	+	—	—	—	—	—	—	—	—		—	—	—	—
Reya umbellata	—	+	—	—	—	—	—			—	—	—	—	—
Thysanotus baueri	—	—	—	—	—		+	—	—	—	—	—	—	—
T. dichotomus	—	+					+	—	—	—	+			—
T. patersonii	+	—	+	—	+	—	+	—	—	—	+	?		—
Tricoryne elatior	+	+	—		—	—	—	+	+		+	—	—	—
Xanthorrhoea australis		—	—	—	—	—	—	—	—	+	+	—	—	—
X. quadrangulata	+	—	+	—	—	—	—				—	—	—	—
X. semiplana	+										—			
X. tateana	—	+	—	—	—		—	—	—	—			—	—
F. Amaryllidaceae														
Calostemma purpureum	—		—	—	—	—	—	—	—	—	—	—	—	—
Hypoxis glabella	—	—	—	—	—	—	—	—	—	—	—	—	—	—
H. pusilla	—	—	+	—	—		—	—	+	—	—	—	—	—
F. Iridaceae														
**Anthelyza aethiopica*	—	—	—	—	—	—	—		—	—	—	—	—	—
**Gynandriris setifolia*	+	—		—	—	—	—	—	+	—		—	—	
**Homeria collina*	+	—	—	—	—			—	—	—	—	—	—	—
Patersonia longiscapa	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Orthrosanthus multiflorus	—	+			—	—	—	—	—	—	—	—	—	—
**Romulea columnae*	+	—	—	—	—	—	—	—	+		—	—	—	—
**R. cruciata*	+	—	—	—	—	—	—		—	—	—	—	—	—
**Sparaxis bulbifera*	+	—	—	—	—	—		—	—	—	—	—	—	—
**Watsonia meriana*	+	+			—	—	—	—	—	—	—	—	—	—
F. Orchidaceae														
Acianthus exsertus	+	—	—	—	—	—	—	—	+	—		—	—	—
A. reniformis	+	—	—	—	—	—	—	—	+	—	—	—	—	—
Caladenia cardiochila	+	—	—	—	—	—	—	—	+	—	—	—	—	—
C. carnea	+	+	—	—			—	—	—	—	—	—	—	—

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
C. coerulea	—	+	—	—	—	—	—	—	—	—	—	—		—
C. deformis	+	+	—	—	—	—	—	—	+	—	+	—	—	
C. dilatata	+	+	—	—	—		—	—	+			—	—	—
C. filamentosa	—	—	+		—	—	—	—	+	—	—		—	—
C. latifolia	+	+	—								—	—	—	—
C. leptochila	+		—	—	—	—	—	—	—			—	—	—
C. menziesii	+	+			—	—	—	—	—	—	—	—	—	—
C. patersonii	+	—	—	—	—	—	—	—		—	—	—	—	
C. reticulata	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Calochilus robertsonii	+	+	—	—	—	—		—	—	—		—		
Corybas diemenicus	+	—	—	—		—	—	—	—	—	—	—	—	—
C. dilatatus	+		—	—	—	—	—				—	—	—	—
C. pruinosa		+	—	—	—	—	—		—	—	—	—		—
Cyrtostylis reniformis	—	—	—	—	—				—	—	—			—
Dipodium punctatum	+	—	—	—	—		—	—	—		—	—	—	—
Diuris brevifolia	—	+	—		—	—	—	—	—	—	—	—		
D. maculata	+	—	—		—	—			—	—	+	—	—	—
D. longifolia	—	—	—	—			—	—	—	—	—			
D. palachila	+	—	—	—	—		—	—	—		—	—	—	—
D. palustris	+	—				—	—	—	+			—	—	—
D. pedunculata	+	—		—	—	—	—		—	—	—	—		—
Eriochilus cucullatus	+	—	—	—	—		—	—	—	—	—		—	—
Gastrodia sesamoides	—	+	—	—		—	—	—	—	—	—		—	—
Glossodia major	+	—		—			—	—		—		—	—	—
Leptoceras fimbriatum		+		—	—	—	—		—	—	—	—		
Lyperanthus nigricans	+	—	—	—	—	—	—		—	—	+			—
Microtis atrata	+	—	—	—	—		—	—	—	—	—	—	—	—
M. parviflora	+		—	—	—	—	—	—	—	—	—	—	—	—
M. unifolia	+		—	—	+	+	—	—	+	—	—	—	—	—
Orthoceras strictum	—	—	—	—	—				—	—			—	—
Prasophyllum australe	+	—	—	—		—	—	—	—	—	—	—	—	—
P. elatum	+	+				—	—	—	—	—	—	—	—	—
P. fitzgeraldii	+	—	—	—	—	—	—	—	—	—	—	—	—	—
P. gracile	+	—	—	—	—	—		—	—	—	—	—	—	—

TABLE I LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
P. nigricans	+	—	—	—	—	—	—	—	—	—	—	—	—	—
P. occidentale	+		—	—	—		—	—	—	—	—	—	—	—
P. odoratum	+	—	—	—	—	—	?	—	—		—	—	—	—
P. pallidum	—	—	—	—	—	—	—	—		—	—	—	—	—
P. patens	+	—	—		—	—	—	—	—	—	+		—	—
Pterostylis alata	—	+	—	—	—	—	—	—	—	—	—	—	—	
P. barbata	+	—	—	—	—	—	—	—	+	—	—	—	—	—
P. cucullata	+	—	—	—	—	—	—	—	—	—	—	—	—	—
P. curta	+	—	—	—	—	—	—	—	—		—	—	—	—
P. cycnocephala	—	—	—	—	—	—	—	—	+	—	—	—	—	—
P. furcata	—	+	—	—		—	—	—	—	—	—	—	—	—
P. longifolia	+	—	—	—	—	—	—	—	—	—	—	—	—	—
P. mutica	—	—	+	—	—	—	—	—	+		—	—	—	—
P. nana	+	—	+	—	—	—	—	—	+		—	—	—	—
P. nutans	—	+	—	—	—	—	—	—	—	—	—	—		—
P. obtusa	—	+	—	—	—				—	—	—	—	—	—
P. pedunculata	—	+	—	—	—	—	—	—	—	—	—	—	—	—
P. pusilla	+	—	—	—	—	—	—	—	+	—	—	—	—	—
P. robusta	+	+		—		—	—	—	—		—	—	—	—
P. rufa	+	—	—	—	—	—	—	—	—	—	—	—		—
P. vittata	+	—	—	—	—	—	—	—	+	—	—	—	—	—
Thelymitra antennifera	+	—	—	—	—	—	—	—	+	—	+	—	—	—
T. aristata	+	—	+	—	—	—	—	—	+		—	—	—	—
T. flexuosa	+	—	—	—	—	—	—	—	—	—	—	—		—
T. floribunda	—	—	+	—	—	—	—	—	—	—	—	—	—	—
T. fuscolutea	+	+	—	—	—	—	—	—	—	—	—	—	—	—
T. grandiflora	+	—	—	—	—	—	—	—	—	—		—	—	—
T. ixioides	+	+	—	—	—	—	—	—	—	—	—	—	—	—
T. longifolia	+	—	—	—	—	—	—	—	—	—	—	—	—	—
T. luteocilium	+	+	—	—	—	—	—	—	—	—	—	—		—
T. macmillanii	+	—	—		—	—	—	—		—	—	—	—	—
T. pauciflora	+	+	—	—	—	—	—	—	—	—	—		—	—
T. rubra	+	—	—	—	—	—	—	—	—	—	—		—	—
T. urnalis	+			—	—	—		—		—	—	—	—	—
F. Casuarinaceae														
Casuarina cristata	—	—	—	—	—	—		—	—	—	—	—		+
Casuarina muelleriana	—	+	+	—	—	—	+	—	—		+	+	+	—

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
C. pusilla	—		—	—	—	—	—	—	+	—	+	—	+	—
C. striata	+		—	—	—	—	—	—	—		—	—	—	—
C. stricta	+	+	+	+	+	—	—	—	—	—	+	—	—	—
F. Urticaceae														
Parietaria debilis	+	—	+	—	+	—	—	—	—	—	—	—		+
Urtica incisa	—	+	—	—	—	—	—	—	—		—	—		—
**Urtica urens*	+	+	—	—		—	—	—	+	—	—	—	—	—
F. Proteaceae														
Adenanthos sericea var. *brevifolia*	—	+	—	—	—	—		—	—	—	—	—	—	—
A. terminalis	—	+	—	—		—	+	—	+	+	+	—	—	—
Banksia marginata	+	+	—		—	—	—	—	—	+	+	—	—	—
B. ornata	—	+	—	—	—	—		—	+	—	+	—	—	—
Conospermum patens		+	—	—	—	—	+	—	—	—	+	—	—	—
Grevillea aspera		—	+	—	—	—	—	—	—	—	—	—	—	—
G. huegelii	—		—	—		—	+	+	—	—	+	—	—	—
G. ilicifolia	—	+	—			—	+	+	+	—	—	—	—	—
G. ilicifolia var. *lobata*	—	—	—	—	—	—	—	—	—	—	—	+	+	—
G. lavandulacea	+	—	+	—	—	—	—	—	+	—	—	—	—	—
G. parviflora var. *acuaria*	—	+	—		—	—	—	—	—	—	—	—	—	—
G. pauciflora	—	+	—	—	—	—	—	—	—	—	—	—	—	—
G. pterosperma	—	—	—	—	—	—	—	+	—	—	—	+	+	—
G. quinquenervis		+	—	—	—	—	—	—	—		—	—	—	—
G. rogersi	—	+	—	—		—	—	—	—	—	—	—	—	—
Hakea cycloptera	—	—	—	—	—	—	+	+	—	—	—		—	—
H. rostrata	+	+	—	—	—	—	—	—	—	—	+		—	—
H. rugosa	+	+	—	—	—	—	—	—	—	+	+	—	—	
H. ulicina	+	+		—	—	—	—	—	—			—	—	—
H. ulicina var. *latifolia*	—	—	—	—	—	—	—	—	—	—	+	—		—
H. vittata	—	+	—	—	—	—	—	—	—	—	+	—	—	
Isopogon ceratophyllus	+	+	—	—	—	—	—	—	—	+	+	—	—	—
Persoonia juniperina	+	—	—	—	—	—		—	—	—	+	—	—	—
Petrophila multisecta	—	+	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Santalaceae														
Choretrum glomeratum	—	+	—	—	—	—	+	+	+	—	—	—		—
C. glomeratum var. *chrysanthum*	—	—			—	—	+	+	—	—	—	—	—	—
C. spicatum	—	+	—	—				—	—	—	—	—	—	—
Eucarya acuminata	—	—	+	—	—	—	+	+	+	—	+	+	—	+
E. murrayana	—	—	—	—	—	—	+	+	—	—	+	+		
E. spicata	—	—	—	—	—	—	—	—	—		—	—	—	+
Exocarpos† *aphyllus*	—	—	—	—	+	—	+	+	—	—	—	—	—	+
E. cupressiformis	+	+	—	—	—	—	—	—	—	—	—	—	—	—
E. sparteus	—	—	—	—	—	—	+	+	+	—	+	—	—	—
E. syrticolus‡	—	—	—	—	+	—				—	—	—	—	—
Leptomeria aphylla	—	+	—	—	—	—	—	—	—	—	—	—	—	—
F. Olacaceae														
Olax benthamiana	—	+	—	—	—	—	—	—	—	—	—	—	—	—
F. Loranthaceae														
Loranthus exocarpi	+	—	—	—	—	—	—	—	—	—	—	—	—	+
L. maidenii	—	—	—	—	—	—	—	—	—	—			—	+
L. miraculosus var. *melaleucae*	—	—	—	—	—	—	—	—	—	+	—	—	—	—
L. miquelii	+	—	—	—	—	—	—	—	+	—	—	—	—	—
L. pendulus	+	—	—	—	—	—	—	—	—	—	—	—	—	+
L. preissii	—	—	—	—	—	—	—	—	—	—	—	—	—	+
F. Polygonaceae														
**Emex australis*	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Muehlenbeckia adpressa	—	+	—	—	—	—	+	—	+	—	—	—	—	—
M. adpressa var. *hastifolia*	—	—	—	—	+	—			—		—	—	—	—
M. diclina	—	—	—	—	—	—	—	—	—	—	—	—	+	—
**Polygonum aviculare*	+	+	—	—	—	—	—	—	—	—	—	—	—	—
P. minus	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Rumex acetosella*	+	+	—	—	—	—	—	—	—	—	—	—	—	—
R. brownii	+	+	—	—	—	—	—	—	—	—	—	—	—	—
**R. conglomeratus*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**R. obtusifolius*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**R. pulcher*	+	—	—	—	—	—	—	—		—	—	—		—
**R. roseus* (possibly *R. vesicarius*)	—	—	—	—	—	—	—	—	—	—	—	—		+
F. Chenopodiaceae														
Arthrocnemum halocnemoides var. *pergranulatum*	—	—		+	—	—	—	—	—	—	—	—	—	—
Atriplex cinerea	—	—	—	+		—	—	—	—	—	—	—	—	—
A. eardleyae	—	—	—	—	—	—	—	—	—	—	—	—	—	+
A. paludosa	—	—	—	+	—	—	—	—	—	—	—	—	—	—
A. spongiosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—
A. stipitata	—	—	—			—	—	—	—	—	—	—	—	—
A. velutinella	—	—	—	—	—		—	—			—	—	—	—
A. vesicaria	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Babbagia acroptera	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bassia diacantha†	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B. obliquicuspis	—		—		—	—	—	—	—	—	—	—	—	—
B. paradoxa	—		—	—	—	—	—	—	—	—	—	—	—	+
B. patenticuspis	—	—	—	—	—	—	—	—	—	—	—	—	—	+
B. sclerolaenoides	—	—	—	—						—		—	—	+
**Chenopodium album*	+	+	—	—	—	—	—	—	—	—	—	—	—	—
C. cristatum	—		—	—	—	—	—	—	—	—	—	—	—	+
C. desertorum	—	—	—	+	—	—	—	—	—	—	—	—	—	—
C. insulare	—	—		+				—						
**C. murale*	+	—	—	—	—	—	—	—		—	—	—	—	—
C. aff. *pseudomicrophyllum*	—	—	—	+	—	—	—	—	—	—	—	—	—	—
C. pumilio	+	—	—	—	—	—	—	—	—	—	—	—		—
Enchylaena tomentosa	—	—	—	+	—	—	—	—	—	—	—	—	—	+
Kochia aphylla	—	—	—	—		—	—	—	—	—	—	—	—	+
K. excavata	—	—	—	—	—	—	—	—	—	—	—	—	—	+
K. georgei	—	—	—	—	—	—	—	—	—	—	—	—	—	+
K. astrotricha‡ (formerly *K. planifolia*		—	—	—	—	—	—	—	—	—	—	—	—	+

† Labillardiere, 1799. ‡ Stauffer, 1959.

† Ising, 1961, ‡ Johnson, 1950.

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
K. pyramidata		—	—	—	—	—	—	—	—	—	—	—	—	+
K. sedifolia			—	—	—	—	—	—	—	—	—	—	—	+
K. triptera var. *erioclada*	—	—	—	—	—	—	—	—	—	—	—			+
Rhagodia baccata	—	—	—	+		—	—							
R. crassifolia		+	—	+	—	—	—	—	—	—	—	—	—	—
R. gaudichaudiana	—	—	—	—	—	—	—	—	—	—	—	—	—	+
R. nutans	+	—	—	—	—	—	—	—	—	—	—	—	—	—
R. preissii	—	—	—	—	—	—		+						—
R. spinescens var. *deltophylla*	—	—	—	—	—	—	—	—	—		—			+
Salicornia australis			—	+	—	—	—	—	—	—	—	—	—	—
S. blackiana		+	—	—	—	—	—	—	—	—	—	—	—	—
Salsola kali	—	—	—	—	—	—	—					—	—	+
Suaeda australis	—	—	—	+	—	—	—	—	—		—	—	—	
Threlkeldia diffusa	—	+	—	+	—	—		—	—	—			—	—
F. Amaranthaceae														
Alternanthera denticulata	+	—	—			—	—	—	—	—	—	—	—	—
**Amaranthus albus*	—	+	—	—	—	—	—	—	—	—	—	—	—	—
**A. patulus*	+	—	—	—	—	—	—	—	—	—	—	—	—	
**A. viridis*	+	—			—	—		—	—	—	—	—	—	—
Ptilotus erubescens	+	—	—	—			—	—	—	—	—	—		—
P. spathulatus	—	—	+	—	—	—	—	+	+	—	—	—	—	
F. Nyctaginaceae														
Boerhavia diffusa	—	—	—	—	—	—	—	—	—	—	—	—	—	+
F. Phytolaccaceae														
Didymotheca thesioides	—	+		—		—	—	—	—	—	—	—	+	
Gyrostemon australasicus	—	—	—	—	—	—	+	—	—	—	+		—	
F. Aizoaceae														
Carpobrotus aequilaterus	+	—		+	+		—	—	—	—	—	—	—	—
C. modestus†	—	—	—	—	—	—	—	—	+	—	+	+	+	
Disphyma australe	—	+	—	+	—	—	—	—	—	—	—	—	—	
Sarcozona (*nov. sp.* ?)	—		—		—	—	+	—	—	—	—	—	—	—

† Blake, S. T., in press.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Tetragonia eremaea	—	—	—	—									—	+
T. implexicoma	—	—	—	+	—	—	—	—	—	—	—	—	—	—
Trianthema turgidifolia	—	—	—	+	—	—	—	—	—	—	—	—	—	—
F. Portulacaceae														
Calandrinia calyptrata	+	—	—	—	—	—	—	—	—		—	—	—	—
C. corrigioloides	—	—	—	—	—	—	—	—	+	—	—	—	+	—
C. pygmaea	—	—	—	—	—	—	—	—	+	—	—	+	+	—
C. sphaerophylla	—	—	—	?	—	—	—	—	—	—	—	—	—	—
C. volubilis (probably *C. eremaea*)	+	—	+	—	—	—	—	—	—	—	—	+	+	+
**Claytonia perfoliata*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Portulaca oleracea	+	—	—	—	—	—	—	—	—	—	—	—	—	—
F. Caryophyllaceae														
**Cerastium viscosum*	+			—	+	—		—		—	—	—	—	—
**Gypsophila tubulosa*	—	—	+	—	—	—	+	—	—	—	—	—	—	—
**Herniaria hirsuta*	—	—	+	—	—	—	—	—	—	—	—	—	—	
**Moenchia erecta*	+	—	—		—							—		—
Polycarpon tetraphyllum	+			—	—	—	—	—	—	—	—	—	—	—
Sagina apetala	+		—	—	—	—	—	—	—	—	—	—		—
S. procumbens	—	—	—	—	+	—	—	—	—	—	—	—	—	
Scleranthus pungens	—	—	—	+	+	—	—	—	—	—	—	—	—	—
**Silene gallica*	+	+	—	—	—	—	—	—	—	—	—	—	—	—
**S. nocturna*	+	—	+	—	—	—	—	—	+	—	—	—	—	—
**Spergularia rubra*	+	—	—	—	—	—	—	—	—	—	—	—	+	—
Stellaria filiformis	—	—	+	—	—	—	—	—	—	—	—	—	—	—
**S. media*	+	—	—		—	—	—	—	—	—		—		—
S. palustris	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Tunica prolifera*	—	+	—	—	—	—	—	—	—	—	—	—	—	—
**T. velutina*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
F. Ranunculaceae†														
Clematis microphylla	—	—	+	—	+	—	—	—			+		—	—
Ranunculus hamatosetosus			+			—	—		—	—	—	—	—	—

† Eichler, 1958.

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
R. lappaceus	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**R. muricatus*	+	—	—	—	—	—	—	—	—	—	—	—		
R. rivularis	—	+	+	—	—	—	—	—	—	—	—	—	—	—
R. sessiliflorus	—	—	+	—	—	—	—	—	—	—	—	—	—	—
R. trichophyllus	+	+									—	—	—	—
F. Lauraceae														
Cassytha glabella	+	+	—	—	—	—	—	—	+	—	+	+	—	—
C. melantha	—	—	—	—	+	—	+	+	+	—	—	—	—	—
C. pubescens	—	+	—	—	—	—	+	+	—	—	+	—	—	—
F. Papaveraceae														
**Fumaria capreolata*	+				—			—	—				—	
**F. micrantha*	+													
**F. muralis*	+	+	—	—	—	—	—	—	—	—	—	—	—	—
**F. parviflora*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Papaver dubium*	+	—	—	—	—	—	—	—	—	—	—	—		
**P. hybridum*	+	+	—	—	—	—	—	—	—	—	—	—	—	
**P. rhoeas*	+		—	—	—	—	—	—	—	—	—	—		—
F. Cruciferae														
Blennodia brevipes	—	—	+	—	—	—	—	—	—	—	—	—		—
B. canescens	—	—	—	—	—	—	—	—	—	—	—	—	—	+
B. nasturtioides	—	—	—	—	—	—	—	—	—	—	—	—	—	+
**B. trisecta*	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Brassica tournefortii	—	—	—	—	—		—	—	+		—	—	—	
**Capsella bursa-pastoris*	+	—	+	—	—	—	—	—	—	—	—	—	—	—
Cardamine hirsuta	—	+	—	—	—	—	—	—	—	—	—	—	—	—
**Coronopus didymus*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
**Diplotaxis muralis*	—	+	—	—	—	—	—	—	—	—	—	—	—	
**D. tenuifolia*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Geococcus pusillus	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Lepidium foliosum	—	+	—	—	—	—	—	—	—	—	—	—	—	—
L. halmaturinum	—	+	—	—	—	—	—	—	—	—	—	—	—	
L. hyssopifolium	+	—	—	—	—	—	—	—	+	—	—	—	—	—
L. papillosum	—	—	+	—	—	—	—	—		—	—	—		—
**Nasturtium officinale*	+	—		—	—	—	—		—	—	—	—	—	—
**Raphanus raphanistrum*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Rapistrum rugosum*	+	—	—	—	—	—	—	—	—	—	—	—	—	—

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
**Synapis arvensis*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Sisymbrium erysimoides*		—	+	—			—	—	—			—	—	—
**S. officinale*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**S. orientale*	+	+	—	—	—	—	—	—	—	—	—	—	—	—
Stenopetalum lineare			+	—		—	+	—	+		+	+	+	—
S. sphaerocarpum	—	—	+	—	—	—	—	—	—	—	—	—	—	—
Stenopetalum sp.	—	+	—	—	—	—	—	—	—	—	—	—	—	—
F. Resedaceae														
**Reseda luteola*		—			—	—			—	+	—	—	—	—
F. Droseraceae														
Drosera auriculata	+	+							—					
D. binata	+	+	—	—	—	—	—	—	—	—	—	—	—	—
D. glandulifera	+	—	+	—	—	—	—	—	—	—	—	—	—	—
D. peltata	+	—	—	—	—	—	—	—	—	—	—	—	—	—
D. planchonii	+	—	+	—	—	—	+	—	—	—	+	—	—	—
D. pygmaea	—	+	—	—	—	—	—	—	—		—	—	—	—
D. whittakeri	+	—	—	—	—	—	—	—	+	—	+	—	—	—
F. Crassulaceae														
Crassula bonariensis	+	+	—	—	—	—	—	—	—	—	—	—	—	—
C. colorata	—	—	+	—	—	—	+	+	—	—	—	+	+	+
C. macrantha	+	—	—	—	—	—	—	—	—	—			—	
C. pedicellosa	+	—	—	—	—	—		—	—	—	+	+	—	—
C. recurva	+		—	—	—	—		—	—	—	—	—	—	—
C. sieberiana	+	—	+	+	—	—	—	+	—	—	+	—	—	+
F. Saxifragaceae														
Bauera rubioides		+	—	—	—	—	—	—	—	—	—	—	—	—
F. Pittosporaceae														
Billardiera cymosa	—	—	+	—	—	—	+	—	+	—	+	+	—	—
B. scandens	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Bursaria spinosa	+	+	+	—	—	—	+	—	+	—	+			—
Cheiranthera linearis	+						+	—	+	—	—	—	—	—
C. volubilis	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Marianthus bignoniaceus	+	+	—	—	—	—	—	—	—	—	—	—	—	—
Pittosporum phillyraeoides	—	—	+	—	—	—	—	—	—	—	—	—	—	+

TABLE 1 LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Rosaceae														
Acaena anserinifolia	+	+	—	—	—	—	—	—	—	—			—	—
A. ovina	+	—	+	—	—	—	—	—	—	—	—	—	—	—
**Crataegus monogyna*	+			—		—	—	—	—	—	—	—	—	—
**Rosa canina*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**R. rubiginosa*	+	—	—		—	—	—	—	—	—	—	—	—	—
F. Leguminosae—Mimosoideae														
Acacia acanthoclada	—	—	—	—	—	—	—	—	—	—	—	—	+	—
A. acinacea	—	—	—	—	+	—	—	+	—	—	—	—	—	—
A. anceps	—	—	—	—	+	—	+	—	—	—	—	—	—	—
A. aneura	—	—	—	—	—	—	—	—	—	—	—	—	—	+
A. armata	+	+	—	—	—	—	—	—	—	—	—	—	—	—
A. brachybotrya	—	—	—	—	—	—	—	+	—	—	—	+	—	—
A. burkittii	—	—	—	—	—	—	—	—	—	—	—	—	—	+
A. calamifolia	—	—	—	—	+	—	—	+	+	—	—	+	—	—
A. colletioides	—	—	—	—	—	—	—	—	—	—	+	—	—	—
A. continua	+	—	+	—	—	—	—	—	—	—	—	—	—	—
A. farinosa	—	—	—	—	—	—	+	+	—	—	+	—	—	
A. hakeoides	—	—	—	—	—	—	—	—	—	—	+	—	—	—
A. havilandii	—	—	+	—	—	—	—	—	—	—	—	—	—	—
A. ligulata	—	+	+	—	—	—	+	—	—	—	—	—	—	—
A. melanoxylon	+	—	—	—	—	—	—	—	—	—	—	—	—	—
A. microcarpa	—	—	—	—	—	—	—	—	—	—	—	—	—	
A. myrtifolia	+	+	—	—	—	—	—	—	—	—	+	—	—	—
A. notabilis	—	—	+	—	—	—	—	—	—	—	—	—	—	—
A. obliqua	+	—	—	—	—	—	—	—	—	+	—	—	—	—
A. oswaldii	—	—	—	—	—	—	—	—	—	—	—	—	—	+
A. pycnantha	+	+	+	—	—	—	—	—	—	—	+	—	—	—
A. retinodes	+	+	—	—	—	—	—	—	—	+	—	—	—	—
A. rigens	—	—	+	—	—		+	+			+		+	—
A. rivalis	—	—	—	—	—	—	+				—	—	—	—
A. rupicola	+	—	—	—	+	—	+	—	—	—	+	—	—	—
A. salicina	—		+		—	—	—	—	—	—	—	—	—	—
A. sclerophylla	—		—	—	—	—	—	+	—	—	—	—	+	—
A. sophorae	—	—	—	—	+	—	—	—	—	+			—	—
A. spinescens	+	+	—	—	+	—	+	+		—	+	+	+	—
A. verticillata	+	+	—	—	—	—	—	—	—	—	—	—	—	—
A. vomeriformis	+			—	—	—	—	—	—	—	—	—	—	—
Albizzia lophantha	+	—	—	—	—	—	—	—	—	—	—	—	—	—

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Leguminosae—Caesalpinioideae														
Cassia artemisioides	—	—	+	—	—	—	—	—	—	—	—	—	—	+
C. nemophila	—	—	—	—	—	—	—	—	—	—	—	—		+
C. sturtii	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Petalostylis labicheoides	—	—	+	—	—	—	—	—	—	—	—	—	—	—
F. Leguminosae—Papilionatae														
Aotus villosa	—	—	—	—	—	—	+	—	—	—	—	+	+	—
Bossiaea prostrata	+	—		—	—	—	—	—	—		—	—	—	—
B. aff. *walkeri*	—	—	—	—	—	—	+	—	—	—	—	—	—	—
Clianthus speciosus	—	—	—	—	—	—	—	—	—	—	—		—	+
**Cytisus canariensis*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**C. proliferus*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**C. scoparius*	+	—	—	—	—	—	—	—		—	—	—	—	—
Daviesia brevifolia	—	—	—	—	—	—	—	+	—	—	+	—	—	—
D. corymbosa	+	—	—	—	—	—	—	—	—	+	—	—	—	—
D. genistifolia	—	+	+	—	—	—	+	—	—	—	—	—		—
D. pectinata	—	+	—	—	—	—	+	—	—	—	—	—	—	—
D. ulicina	+	+		—	—	—	—	—	—	—	—	—	—	—
Dillwynia floribunda	—	+	—	—	—	—	—	—	—	—	—	—	—	—
D. hispida	+	+	—	—	—	—	—	—	—	—	+	—	—	—
D. uncinata	—	—	—	—	—	—	+	+	+	—	—	+	+	—
Eutaxia microphylla	+	+	+	—	—	—	+	+	+	—	+	—	+	—
Glycine clandestina	+	—	—	—	—	—	—	—	—	—	—	—	—	—
G. latrobeana	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Gompholobium minus	+	+	—	—	—	—	—	—	—	—	+	—	—	—
Goodia lotifolia	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Hardenbergia violacea	+	+	—	—	—	—	—	—	—	—	—	—	—	—
Indigofera australis	+	—	+			—				—	—	—	—	—
Kennedya prostrata	+	—	—	—	—	—	+	—	+	—	+	—	—	—
**Lathyrus latifolius*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**L. sphaericus*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Lotus australis	+	—	—	—	—	—	—	—	—	—	—		—	—
L. coccineus				—	—			—		—	—	—	—	+
**Medicago apiculata*	+	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
**M. arabica*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**M. confinis* (?)	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**M. denticulata*	+	—	—	—	—	—	—		+	—	—	—	—	+
**M. lupulina*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**M. minima*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**M. sativa*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**M. tribuloides*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**M. truncatula*	—	+	—	—		—	—	—	—	—	—	—	—	—
**Melilotus indica*	+	+	+	—	—	—	—	—	—	—	—	—	—	—
Phyllota pleurandroides	—	+	—	—	—	—	—			—	+	—	—	—
P. remota†	—	—	—	—	—	—	+	—	—	—	+	—	—	—
Platylobium obtusangulum	+	—	—	—	—	—	—	—	—	—	—	—	—	
Psoralea patens	+	—	—	—				—	—	—	—	—	—	—
Pultenaea acerosa var. acicularis	+	—	—	—	—	—	—	—	—	—	—	—	—	—
P. daphnoides	+	+	—	—	—	—	—		—		—	—	—	—
P. densifolia		—	—	—	—	—	—	+				—	—	—
P. involucrata	—	—	—		—	—	—	—	—	—	+	—	—	—
P. largiflorens	+	—	+	—	—	—	—	—	—	—	—	—	—	—
P. pedunculata	+	—	—	—	—	—	—		—	—	+	—	—	—
P. rigida	—	+	—	—	—	—			—	—		—	—	—
P. scabra	—	+		—	—	—	—	—	—	—	—	—	—	—
P. tenuifolia	—	+	—	—	—	—	+	+	—	—	—	—	—	—
P. villifera var. *glabrescens*	—	+	—	—	—	—	—	—	—	—	—	—		
P. viscidula		+	—	—	—	—			—		—	—	—	—
Swainsona behriana	+			—	—	—	—	—	—	—	—	—	—	—
S. lessertiifolia	—	—				—	—	—	—	—	—	—	—	—
Templetonia egena	—	—	—	—	—	—	—	—	—			—	—	+
T. retusa	—	—	—	—	+	—	+	—	—	—	—	—	—	—
T. sulcata	—	—	—	—	—	—	—	+	—	—	—	—	—	—
**Trifolium angustifolium*	+	—		—	—	—	—		—	—	—	—	—	—
**T. arvense*	+			—			—	—	+	—	+	—		—
**T. dubium*	+	+	—			—	—	—	—	—	—	—	—	—

† Willis, 1957

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
**T. glomeratum*	+	+	—		—	—	—	—	—				—	—
**T. incarnatum*	+		—		—	—	—	—	—	—	—	—	—	—
**T. procumbens*	+	—	—	—	—		—	—	+	—	+	—	—	—
**T. repens*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**T. scabrum*	+	—	—	—	—	—	—		—	—	—	—	—	—
**T. striatum*	+	—	—	—	—		—	—	—	—	—	—	—	—
**T. subterraneum*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**T. tomentosum*	+	+	+	—	—	—	—	—	—	—	—	—	—	—
**Trigonella ornithopodioides*	+	—	—	—	—	—	—	—	—	—	—		—	—
T. suavissima	—	—	—	—	—	—	—	—	—	—	—	—		+
**Ulex europaeus*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Vicia angustifolia*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**V. hirsuta*	+	—	—	—	—	—	—	—			—	—	—	—
**V. sativa*	+	—	—	—	—	—	—			—		—	—	—
**V. tetrasperma*	+	—		—	—	—	—	—	—	—	—		—	—
Viminaria denudata	—	+	—	—	—	—	—	—	—	—	—	—	—	—
F. Geraniaceae†														
**Erodium botrys*	+	—	—	—	—		—		+	—	—	—	—	—
E. crinitum		—	+	—	—	—	+	—	—	—	—	—	+	+
**E. cicutarium*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**E. cicutarium* var. *stellatum*	—	—	—	—	—	—	—	—	+	—	—	—		—
E. cygnorum var. *glandulosum*	+	—	—	—		—	—		—	—	—	—	—	+
**E. moschatum*	+	+	+	—	—	—	—	—	—	—	—	—	—	—
**Geranium molle*	+	+	—	—	—	—	—	—	—	—	—	—		—
G. pilosum	+	—	+	—		—	—	—	—	—	—		—	—
Pelargonium australe	—	+	—	+		—	+		—	—	—	—	+	—
**P. graveolens*	+		—	—	—	—	—	—	—	—	—	—	—	—
P. littorale	—	+	—	—	—	—	+	—	—	—	—		+	—
F. Oxalidaceae‡														
**Oxalis bowiei*	—	—	+	—	—	—	—	—	—	—	—	—	—	—
O. corniculata	+	+	+	—	—	+	—	—	—	—	—	—	—	+
**O. pes-caprae*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**O. variabilis*	+		—	—	—	—	—	—	—	—			—	—

† Carolin, 1958, 1961 ‡ Symon, 1961.

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Linaceae														
**Linum gallicum*	+	—	—	—	—	—	—	—						
**L. marginale*	+	—					—		+	—	—	—	—	—
F. Zygophyllaceae														
Nitraria schoberi	—			+			—	—	+	—				+
Tribulus terrestris	—	—	—	—	—	—	—	—	—	—		—		+
Zygophyllum ammophilum	—	—	—	—	—	—	—	—		—	—	—	—	+
Z. apiculatum	—	+	—	—	—		+	+	—	—	—	—	—	—
Z. aurantiacum	—		—	—	—				—	—	—	—		+
Z. billardieri	—	+	—	—	—	—	—	—	—	—		—	—	+
Z. crenatum					—	—	+	—	—		—	—	—	—
Z. glaucescens	—	—	—	—	—	—	—	+	—				—	—
Z. iodocarpum	—	—	—	—	—	—	—	—		—	—	—	—	—
Z. ovatum	—	—	—	—	+		+	—	—	—	—	—		+
Z. prismatotheca	—	—	—	—	—	—	—	—	—	—	—	—	—	+
F. Rutaceae														
Boronia caerulescens			—	—	—		+	+	+		+	—	+	—
B. edwardsii	—	+	—	—	—	—		—		—	—	—	—	—
B. filifolia	—	+	—	—	—	—		—	—	—	—	—	—	—
B. inornata	—	—	—	—	—	—	+	—	+	—	—			—
B. palustris		+	—	—		—	—	—	—	—	—	—		—
B. polygalifolia	—	+		—	—	—	—	—				—	—	—
Correa† *aemula*	—	+	—	—	—	—						—	—	—
C. decumbens	+	+	—	—	—		—	—	—	—	—	—	—	—
C. glabra	+	—	—	—	—	—	—	—	—	—	—			
C. pulchella		+	—	—	—	—	—	—	—	—	—	—		—
C. reflexa var. *reflexa*	+	+	—	—	—	—	+			—	+	—	—	—
C. reflexa var. *coriacea*	—	—	—	+	+	—	—	—	—	—		—	—	—
C. reflexa var. *nummulariiflora*		+	—	—	—	—	—	—						
C. schlechtendalii	—	—	—	—	—			—	+				—	—
Eriostemon brevifolius	—	—	+				—	—	—	—	—	—	—	—
Microcybe multiflora		—	—	—	—	—	+	+	—	—	—	—	—	—

† Wilson, 1961

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
M. pauciflora	—				+	—	+	+	+	—	—	—	—	—
Phebalium bilobum	+	—	—	—	—	—			—				—	—
P. brachyphyllum	—	—	—	—				—	—	—	?	—	—	
P. bullatum	—	—					+	+	—	—	—	+	+	
P. pungens	+	—	—	—	—	—	—	—	+	—	—	—	—	
Zieria veronicea	—	—			—	—	—	—			+	—	—	—
F. Tremandraceae														
Tetratheca ericifolia	—	+	—	—	—	—	—	—	—	—	—	—	—	—
T. halmaturina	—	+	—	—	—			—	—	—	—	—	—	—
T. pilosa	—			—	—	—	—	—	—	—	—	—	—	
F. Polygalaceae														
Comesperma calymega		+	—	—	—	—	+	—	—	—	—	—	—	—
C. scoparium	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. volubile	—	+	—				—	—	+	—	—	—	—	—
**Muraltia heisteria*	+	—	—		—		—	—	—	—	—			—
F. Euphorbiaceae														
Adriana klotzschii	+	+	—	—	—	—	—	—	+		—	—	—	—
Bertya mitchellii	—	—	—	—	—	—	—		—	—	—	+	—	—
Beyeria leschenaultii	—	+	—	—	+		—	—	+	—	—	—	—	—
Euphorbia drummondii				—	—	—	—	—	—	—	—	—		+
E. paralias	—	+	—	—	—	—	—	—	—	—	—	—	—	—
**E. peplus*	+	—	—	—	—			—	—	—	—	—	—	—
Micrantheum demissum var. *microphyllum*	—	+	—	—	—	—		—	—	—	—	—	—	—
Phyllanthus australis	—	+	—	—	—	—	—	—	—		—	—	—	—
P. saxosus	—	—	+	—	—			—	—	—	—	—	—	—
Poranthera ericoides		+	—		—	—	—	—	—	—	—			
P. microphylla	+	+	+	—	—	—	—			—	+	—	+	—
P. triandra	—	—	—	—	—	—	+			—	—	—	—	—
F. Callitrichaceae														
Callitriche verna	—	—	—	—	—			—	—	—		—	—	—
F. Stackhousiaceae														
Stackhousia monogyna	+	+	+	—		—	+	—	+	—	+	—	+	—
S. spathulata		+	—	—		—		—	—	—	—		—	

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA *continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Sapindaceae														
Dodonaea attenuata	—	+	+	—	—	—	—	—	—	—	—			—
D. baueri	—	—	+	—	—	—	—	—						—
D. bursariifolia	—	+	—	—	—		+	+	+			+	+	—
D. hexandra	—	—	—	—	—	—	+	—	+	—	—	—	—	—
D. humilis		+				—	+	—	+	—		—	—	—
D. lobulata			+				+	+	—	—	—	—	—	—
D. stenozyga	—	—	—	—	—	—	—	—	+	—	—	—	—	—
D. viscosa	—	—	—	+	—	—	—	—	—	—	—	—	—	—
Heterodendrum oleifolium	—	—	+	—	—	—	—	—	—	—	—	—	—	+
F. Rhamnaceae														
Cryptandra amara (syn. *C. tomentosa*)	—	—	—	—	—	—	+	—	+	—	+	+	—	—
C. hispidula	—	+	—	—	—	—	—	—	—	—	—	—	—	—
C. leucophracta	—	—	—	—	—	—	+	+	+	—	+	—	+	—
C. waterhousei	—	+	—	—	—	—	—	—	—	—	—	—		—
Pomaderris obcordata	—	+	—	—	+	—	+	—	+	—	—	—	—	—
P. oraria (syn. *P. racemosa*)	+	+	—	—	—	—	+	—	+	—	—	—	—	—
**Rhamnus alaternus*	+	—	—	—	—	—	—	—	—	—	—	—		
Spyridium bifidum	—	—	—	—	—	—	+	—	—	—	—	—	—	—
S. bifidum var. *integrifolium*	—		—	—	—	—	+	—	—	—	—	—	—	—
S. eriocephalum	—	—	—	—	—	—	—	—	+	—	—	—	—	—
S. halmaturinum	—	+	—	—	—	—	—	—	—	—	—	—	—	—
S. parvifolium	+	—	—	—	—	—	—	—	—	—	—	—	—	—
S. phlebophyllum	—	—	+	—	—	—	—	—	—	—	—	—	—	—
S. phylicoides		+	—	+	—	—	—	—	—	—	—	—	—	—
S. spathulatum	+	—	—	—	—	—	—	—	—	—	—	—	—	—
S. subochreatum	—	—		—	—		+		+			+	—	
S. tridentatum (new record for S. Aust.)	—	—	—	—	—	—		—	—	—	—	—	—	
S. vexilliferum	+	—	—	—	—	—	+	—	—	—	—	—	—	—
Trymalium wayi	—	—	—	—	—	—	—	—	—	—	?	—	—	—
F. Malvaceae														
Abutilon fraseri	—	—	—	—	—	—		—			—		—	+
Hibiscus huegelii	—				+		+						—	

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lavatera plebeja	+	+		+	—	—	—	—	—	—	—	—	—	+
**Malva nicaeensis*								—	—	—	—		—	
**M. parviflora*	—	+	—	—		—	—	—	—	—	—	—	—	—
Plagianthus spicatus	—	—	—	—	+	—	?	—	—	—	—	—	—	—
Sida corrugata	—	—	+	—	—	—	—	—	—	—	—	—	—	+
S. intricata	—	—	—	—	—	—	—	—	—	—	—	—	—	+
F. Sterculiaceae														
Commersonia tatei						—	—	+	—	—	—	—	—	—
C. (*nov. sp.?*)	—	—	—	—	—	—	+	—				—	—	—
Lasiopetalum baueri	—	—	—	—	+			—	+					
L. behrii	—	—	—	—	—	—	+	+	+	—	+	+	—	—
L. discolor	—	+	—	—	+	+	+		—		—			—
L. schulzenii	—	+			—	—	—	—	—	—		—	—	—
Thomasia petalocalyx	—	+					—	—	—	—	+	—	—	—
F. Dilleniaceae														
Hibbertia acicularis var. *sessiliflora*	—	—	+	—	—	—	—	—	—	—	—	—	—	—
H. billardieri		+	—		—	—	—						—	—
H. fasciculata	—	+	—	—	—	—	—	—	—	—	—	—	—	—
H. sericea	—	+	—	—	—	—	—	—	—	—	—	—	—	—
H. sericea var. *cinerea*	—	—	—	—	+	—	—	—	—	—	—	—	—	—
H. sericea var. *major*		—	—	—	—	—	+	—	—		—	—	—	—
H. sericea var. *scabrifolia*	—	+	—	—	—		—	—	—	—	+	—	—	—
H. stricta	+	+	+		+	—	—	—	+	+		+	+	—
H. stricta var. *glabriuscula*							+							
H. stricta var. *oblonga*		+	—	—	—		—	—	—	—	—	—	—	—
H. virgata	—	+	—	—	—	—	+	+	+		+	—		
H. virgata var. *crassifolia*	—	—	—	—	—	—	—	—	—	—	—	+		—
F. Guttiferae														
Hypericum gramineum	+	+												

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
H. japonicum	+	—	—	—	—	—	—	—	—	—		—	—	—
**H. perforatum*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
F. Elatinaceae														
Elatine gratioloides	—	—	+	—	—	—	—	—	—	—	—	—	—	—
F. Frankeniaceae														
Frankenia pauciflora	—	+	—	+	+	—					—	—	—	—
F. Violaceae														
Clelandia convallis	—	—	+	—	—	—	—	—	—	—	—	—	—	—
Hybanthus floribundus	+	—	+	—	—	—	+			—	+	—	—	—
H. tatei	—	—	+	—	—	—	—	—	—	—	—	—	—	—
Viola hederacea	+	—	—	—		—	—	—	—	—	—	—	—	—
V. sieberiana	+	+	—	—	—	—	—	—	—	—	—	—	—	—
F. Thymelaeaceae														
Pimelea curviflora	+	—	—	—	—	—	—	—	—	—	—	—	—	—
P. dichotoma	—	+	—	—	—	—	—	+	—	—	—	—	—	
P. flava	—	+	—	—	—	—	—	—	—	—	—	—	—	—
P. glauca		+		—	—	—	—	—	—	—	—	—	—	—
P. humilis	+	—	—	—	—	—	—	—	—	—	—	—	—	—
P. octophylla	+	—	—	—	—	—	+	—	+	—	+	—	—	—
P. petraea	—	—	—	—	—	—	+	—	—	—	—	—		
P. petrophila	—	—	+	—	—	—	—	—	—	—	—	—	—	—
P. phylicoides		+	—	—	—	—	—	—	—	—	+	—	—	—
P. serpyllifolia	—	+	—	+	+	—	—	—	+	—	—	—	—	—
P. spathulata	+	—	—	—	—	—	—	—	—	—	—	—	—	—
P. stricta	+	—	—	—	—	—	—	—	—	—	—	+	—	
F. Lythraceae														
Lythrum hyssopifolia	+		—	—	—	—	—	—	—	—	—	—	—	—
F. Myrtaceae														
Baeckea behrii	—	—	—	—	—		+		+	—	+	+	+	
B. crassifolia	—	—	—	—	—	—	+	+	+	—	+	—	+	—
B. ericaea	—	—	—	—	—	—	—	—	+	—	+	—	—	—
B. ramosissima		+	—	—	—	—	—	—	—	—	—	—	—	—
Callistemon rugulosus	—	+	—	—	—	—	—	—	+		+		—	—
C. teretifolius	—	—	+	—	—	—	—	—	—	—	—	—	—	—
C. salignus var. *australis*	+	—	—	—	—	—	—	—	—	—	—		—	
Calytrix† *alpestris* (syn. *Lhotzkya alpestris*)		—	—	—	—	—	—	—	—	—	+	—	—	—
C. involucrata	—	—	—	—			—	+	—				—	—
C. tetragona	+	+	+	+	+	—	+	+	+	+	+	+	+	—
Darwinia micropetala	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Eucalyptus anceps		+	—	—	—	—	+	+	—	—	—	+	+	
E. angulosa	—	+		—		—				—	—			—
E. baxteri	+	+	—	—	—	—	—	—	—	—	+	—	—	—
E. calcicultrix	+	—	—	—	—	—	—	—	—	—	—	—	—	—
E. calycogona		—	—	—	—	—	+	?	—	—	—	+	+	—
E. camaldulensis	+	—	+					—	—	—	—	—	—	—
E. cladocalyx	—	+	—	—	—				—	—		—	—	
E. conglobata	—	—	—	—	+	—	—	—	—	—	—	—	—	—
E. cosmophylla	+	+	—	—	—	—	—	—	—	—	—	—	—	—
E. diversifolia		+	—	—	+	—	+	—	—	—	+	—	—	—
E. dumosa	—	—	—		—	—	+	—	—	—	—	+	—	—
E. elaeophora	+		—	—	—	—	—	—	—			—	—	—
E. fasciculosa	+	+	—	—	—	—	—	—	+	—	+	—		—
E. flocktoniae	—	—	—	—	—	—	+	+	—	—	—	—	—	—
E. gracilis	—	—	+	—	—	—	+	+	—	—	—	—	?	—
E. incrassata var. *costata*	—				—	—	+	+	—	—	+	+	+	—
E. intertexta	—	—	+	—	—	—	—	—	—	—	—	—	—	—
E. leptophylla	—	—	—	—	—	—	+	+	—	—	+	+	+	—
E. leucoxylon	+	—	—	—	—	—	—	—	—	+	+	—	—	—
E. macrorrhyncha‡	—	—	—			—	—	—	—	—	—	—		—
E. morrisii			+	—	—	—	—	—	—		—	—	—	
E. obliqua	+	+	—	—		—	—	—	—	+	—	—	—	—
E. odorata	+	—	—	—	—	—	—	—	—	—	—	—	—	—
E. oleosa		—	+	—	—	—	+	+	+	—	—	+	+	+
E. ovata	—	+	—					—			—			—
E. pileata	—	—	—	—	—		+	—	—	—		—	—	
E. rubida	+	—	—	—	—	—	—	—	—	—	—	—	—	—
E. rugosa	—	—	—	—	+	—	+	+	—	—	+	—	—	—
E. transcontinentalis	—		—	—	—	—	—	+	—	—	—	+	?	—
E. viminalis	+	+		—		—		—	—		—	—		—

† Court, 1957. ‡ Found on Reserve at Seven Hills, near Clare.

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA *continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Kunzea pomifera	—	—	—	—	—		—	—	+	—	+	—		—
Leptospermum coriaceum	—	—	—	—	—	—	+	+	+	—	+	+	+	
L. juniperinum	+		—	—	—	—	—		—	+	—	—		—
L. myrsinoides	+	—		—	—	—		—	+	—	+	—	—	
L. pubescens	+		—		—	—	—	—	—	—	—	—	—	—
Lhotzkya glaberrima var. *magnisepala*	—	+	—	—		—	—	—	—	—		—	—	—
L. smeatoniana	—	+	—	—	—		—	—	—	—		—		—
Melaleuca acuminata	—	—	—	—	—	—	+	+	+	—	+	+	+	
M. decussata	—	—		—	+	—	+				—	—		
M. gibbosa		+	—		—	—	—	—	—		—	—	—	—
M. halmaturorum	—	—	—	+	+	—	—	—	—					—
M. lanceolata (syn. *M. pubescens*)	—	+	—	+	+	—	+	+	+	+	+	+	+	—
M. oraria	—	+	—	—	+	—	—		—	+	—	—	—	
M. pauperiflora	—	—			—	—	—	+	—	—	—	—	—	
M. squamea var. *glabra*	—	+	—	—	—	—	—	—		—	—	—	—	—
M. uncinata	—	—	—	—	—		+	+	+	+	+	+	+	—
Thryptomene miqueliana		—	—	—	—		+	+	—	—	—	—	—	
Verticordia wilhelmii	—	—	—		—	—	+	+	—	—	—	—	—	—
F. Oenotheraceae														
Epilobium glabellum	+					—	—	—	—	—	—	—	—	—
E. junceum	+	+		—		—	—	—	—		—	—	—	—
E. pallidiflorum	?	—	—			—		—	—		—		—	—
**Oenothera stricta*	+	+	—	—	—		—		—	—	—	—		—
F. Haloragaceae														
Haloragis acutangula	—	+	—	—	—	—	—	—	—	—	—	—	—	—
H. brownii	+		—	—	—	—	—	—	—	—	—	—	—	—
H. elata	+	+	+	—	—	—	—	—		—	—	—		—
H. heterophylla	+	+	—			—	—	+			—	—	—	—
H. micrantha	+	—	—		—			—	—	—		—	—	—
H. tetragyna	+	+	—	—	—	—	—	—	—		+		—	—
H. teucrioides	+	+	—	—	—		+		—	—	—	—	—	
Loudonia aurea		—	+	—	—	—	—	—		—	—	—		—
L. behrii	+	+	—		—	—	+	+	+	—	+	+	+	—
Myriophyllum amphibium	—	+		—	—	—	—	—	—	—	—	—	—	—
M. elatinoides	—	+	—	—	—	—	—	—	—		—	—	—	—
M. muelleri		+	—	—	—		—			—		—	—	—
M. propinquum		+	—	—		—	—	—	—	—	—	—	—	—
F. Umbelliferae														
Apium australe	—	+		+	+	—	—	—	—	—	—	—		—
**A. graveolens*	—	—		—	—	—	—	—	—	—	—	—	—	—
**Bupleurum semicompositum*	—	—			+	—	—	—	+	—	—	—	—	
Daucus glochidiatus	+	—	+	—	—	—	+	+	+	—		+	+	+
Eryngium rostratum	+		—	—	—			—	—	—	—	—		—
**Foeniculum vulgare*	+	—	—	—	—	—	—		—	—	—	—	—	—
Hydrocotyle callicarpa	+	+	—		—	—	—	—		—	—	—	—	—
H. comocarpa	—	+	—	—	—	—	—	—		—	—	—	—	—
H. crassiuscula		+	—	—		—		—	—	—	—	—	—	—
H. hirta	+	—	—	—	—	—	—	—	—	—		—		—
H. laxiflora	+	+		—	—	—			—	—	—	—	—	—
H. trachycarpa	—	—	—	—	—	—	—	—		—	—	—	—	—
H. tripartita	—	+	—	—		—	—	—		—	—	—	—	—
H. vulgaris		—	+	—	—	—	—	—	—	—	—	—		—
Lilaeopsis australica		+	—	—	—	—	—	—	—	—	—		—	
Platysace heterophylla (syn. *Trachymene heterophylla*)	—	+	—	—	—	—	+	+		—	—	—	—	—
**Scandix pecten-veneris*	+	—	—	—	—	—	—		—	—	—	—		—
Sium latifolium var. *univittatum*	+	—	—		—	—	—			—	—	—	—	—
**Torilis nodosa*	+	—	—	—			—	—			—	—	—	—
Trachymene cyanopetala (syn. *Didiscus cyanopetalus*)		—	—	—		—	—	—	—	—	—	+		—

TABLE 1 LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
T. eriocarpa (syn. *Didiscus ornatus*)	—		+	—		—	—	—	—	—	—		—	—
T. pilosa (syn. *Didiscus pusillus*)	—	—	—	+	+	—	+	—		—	—	—	—	
Xanthosia dissecta	—	+	—	—	—	—	—	—	—	—		—	—	—
X. pusilla	—	+	—	—	—	—	—	—	—	—			—	—
F. Epacridaceae														
Acrotriche affinis		+	—	—	—	—		—	—	+	+	—	—	—
A. cordata	—	+	—	—	—	—	+		—	—	—			—
A. depressa	—	+	—	—		—	—	—	+	—	—			
A. fasciculiflora	+	—	—	—		—	—	—	—	—	—	—	—	—
A. halmaturina	—	+	—	—	—	—	—		—		—	—	—	—
A. patula	—	+	—	—	+	+	+	—	—	—	—	—	—	—
A. serrulata	+	—	—	—	—	—			—	—	—		—	
Astroloma conostephioides	+	+	—	—	—	—	+	+	—	+	+	—		
A. humifusum	+		+	—	—	—	—	—		—	+	—	+	—
Brachyloma ericoides		+		—	—	—			+		+	+	+	—
Brachyloma nov. sp.	—	+	—	—	—	—	—			—	—	—		—
Epacris impressa	+	+	—	—		—	—	—	—	—	—	—		—
Leucopogon australis	+	+	—	—	—		—	—	—				—	—
L. clelandii	—	—			—	—	—		—	—	+	—	—	—
L. concurvus	—	—	—	—	—	—	—		—	—	—	—		
L. cordifolius	—	—	—	—	—	—	+	+	—	—	—	+	—	—
L. costatus	—	—		—			—	—	—		+	—	—	—
L. ericoides	—		—	—	—	—	—	—	—	—	+	—	—	—
L. parviflorus	—	—		—	+	—	—		—	—	—	—	—	—
L. rufus	—	—	—	—	—	—	—		—	—	—	—		
L. virgatus	—	—	—	—			—	—	—	—	—	—		—
L. woodsii	—	—				—	+	—			+	—	—	—
Lissanthe strigosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sprengelia incarnata	+	+	—	—	—	—		—	—	—	—	—	—	—
Styphelia exarrhena	—	—	—	—	—	—	—		—	—	+		—	—
F. Primulaceae														
**Anagallis arvensis*	+	—	—	—	+	—	—	—	—	+		—	—	—
**A. femina*	+		+	—	—	—	—		+	—	—	—	—	—
Samolus repens	+	+	—	—	+	—	—	—		—	—	—		

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Oleaceae														
**Olea europaea*	+	—	—	—	—	—	—		—	—	—	—		—
F. Loganiaceae														
Logania crassifolia	—	+	—			—	—	—	—	—	—	—	—	
L. insularis	—	+	—	—		—	—	—			—	—	—	—
L. linifolia	—			—	—	—	—		+		—	—	—	—
L. ovata		+		—	—	—	—	+	—	—	—	—	—	
L. recurva	+	—	—	—	—	—	—	—	—	—	—	—		—
L. vaginalis	+	—	+	—	—		—	—	—	—	—	—		
Mitrasacme distylis	+	—	—	—	—		—	—	—			—	—	—
M. paradoxa	+	—	—	—	—	—	—	—	+	—			—	—
F. Gentianaceae														
**Cicendia quadrangularis*	+	—	—	—	—	—	—	—		—	—	—	—	—
Erythraea australis	—	+	—	—	—	—		—	—	—	—	—		—
**E. centaurium*	+	+	—	—	+	—		—	—	+		—	—	—
Sebaea ovata	—	+				+	—	—	—	—	—	—	—	—
Villarsia exaltata	—	+				—	—	—		—	—	—	—	—
F. Apocynaceae														
Alyxia buxifolia			—	—	+	—	—	—	—	—	—	—	—	—
**Vinca major*	+	—	—	—	—	—	—	—	—		—	—	—	—
F. Asclepiadaceae														
**Asclepias fruticosus*	+		—	—	—	—		—	—	—	—	—		
**A. rotundifolia*	+	—	—	—	—	—	—	—	—	—		—	—	—
F. Convolvulaceae														
Convolvulus erubescens	+	—	—	—	—	—	—			—	—	—	—	+
Dichondra repens	+	—	—	—		—	—	—	—	—			—	—
F. Boraginaceae														
Cynoglossum australe	+	—	—	—	—	—	—	—	—	+	—	—		—
C. suaveolens	+	—	—	—	—		—	—	—	—		—	—	—
**Echium lycopsis*	+	+	—	—	—	—	—	—	—	+		—	—	+
Halgania cyanea	—	—	—		—	—	+		+	—	—	—	+	
H. lavandulacea		+	—	—	—	—	—	+	—	—	—	—		
**Heliotropium amplexicaule*	+		—	—	—	—	—	—	—	—	—	—	—	
**H. europaeum*	+	—	—		—	—	—	—	—	—	—		—	+

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
**Lithospermum arvense*	+	—	+	—	—	—	—	—	—	—	—	—	—	—
Myosotis australis	+	—	—	—	—	—	—	—	—	—	—	—	—	—
M. sylvatica	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Omphalolappula concava	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Plagiobothrys plurisepalus	—	—	+	—	—	—	—	—	—	—	—	—	—	+
F. Verbenaceae														
**Verbena bonariensis*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
V. officinalis	—	—	—	—	—	—	—	—	—	—	—	—	—	—
**V. rigida*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
F. Labiatae														
Ajuga australis	—	—	—	—	—	—	—	—	—	—	—	—	—	—
**Lavandula stoechas*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Lycopus australis	—	—	—	—	—	—	—	—	—	—	—	—	—	—
**Marrubium vulgare*	—	—	—	—	—	—	—	—	+	—	—	—	—	—
**Melissa officinalis*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Mentha piperita*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**M. pulegium*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
M. saturejoides	—	—	+	—	—	—	—	—	—	—	—	—	—	—
**M. spicata*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Prostanthera aspalathoides	—	—	—	—	—	—	—	—	+	—	—	—	+	—
P. baxteri var. *crassifolia*	—	—	—	—	—	—	—	+	—	—	—	—	—	—
P. behriana	+	—	—	—	—	—	—	—	—	—	—	—	—	—
P. microphylla	—	—	—	—	—	—	+	+	—	—	—	—	—	—
P. serpyllifolia	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P. spinosa	—	+	+	—	—	—	—	—	—	—	—	—	—	—
**Salvia verbenaca*	+	+	—	—	—	—	—	—	—	—	—	—	—	—
**Stachys arvensis*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Teucrium corymbosum	—	—	+	—	—	—	—	—	—	—	—	—	—	—
T. sessiliflorum	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Westringia eremicola	—	—	—	—	—	—	—	—	+	—	—	—	—	—
W. rigida	—	—	—	+	—	—	+	+	+	—				

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Solanaceae														
Anthocercis angustifolia	+	—	—	—	—	—	—	—	—	—	—	—	—	—
A. myosotidea	—	—	—	—	—	—	—	—	—	—	—	—	+	—
Lycium australe	—	—	—	—	—	—	—	—	—	—	—	—	—	+
**L. ferocissimum*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Nicotiana glauca*	+	—	—	—	—	—	—	—	+	—	—	—	—	+
N. maritima	+	—	—	+	—	+	—	—	—	—	—	—	—	—
N. goodspeedii	—	—	—	—	—	—	—	—	—	—	—	—	—	+
**Physalis peruviana*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Solanum aviculare	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**S. giganteum*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
S. nigrum	+	—	—	—	—	—	—	—	—	—	—	—	—	+
S. simile	—	+	—	—	+	—	—	—	—	—	—	—	—	—
**S. sodomaeum*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
F. Scrophulariaceae														
**Antirrhinum orontium*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Euphrasia collina	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gratiola peruviana	+	+	—	—	—	—	—	—	—	—	—	—	—	—
**Kickxia elatine*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Mimulus moschatus*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Parentucellia latifolia*	+	—	—	—	—	+	—	—	—	—	—	—	—	—
**Verbascum virgatum*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Veronica arvensis*	+	—	—	—	—	—	—	—	—	—	—	—		
V. derwentia	—	+	—	—	—	—	—	—	—	—	—	—	—	—
V. distans	+	+	—	—	—	—	—	—	+	—	—	—	—	—
**V. persica*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
F. Lentibulariaceae														
Utricularia dichotoma	+	+	—	—	—	—	—	—	—	—	—	—	—	—
U. flexuosa	—	—	+	—	—	—	—	—	—	—	—	—	—	—
U. lateriflora	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Polypompholyx tenella	+	—	—	—	—	—	—	—	—	—	—	—	—	—
F. Myoporaceae														
Eremophila behriana	—	—	—	—	—	—	+			—	—	—		—

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
E. crassifolia	—	—	—	—	—	—	+	+	+	—		?	+	—
E. glabra	—	—	—	—	—	—	—	+	+	—	—	—	—	—
E. longifolia	—	—	—	—	—	—	—		—	—	—	—	—	+
E. scoparia	—	—	—	—	—				—	—	—		—	+
E. sturtii	—	—	—	—	—	—	—	—	—	—	—	—	—	+
E. weldii		—	—	—	—	—	—	+	—	—	—	—	—	—
Myoporum deserti	—		—	+	+			—	—	—	—	—	—	—
M. insulare	—	+	—	+	—				—	—	—	—	—	—
M. parvifolium	—	—	—	—	+			—	—	—	—	—	—	—
M. platycarpum	—	—	—	—	—	—	—	—	+	—	+	+	+	+
M. viscosum	+	+	—	—	—	—	—	—	—	—	—	—		
F. Plantaginaceae														
**Plantago coronopus*	—	+	—	—			—	—	—	—	—	—	—	—
**P. lanceolata*	+			—	—	—	—	—	—	—	—	—	—	—
**P. major*	+	—	—	—	—	—	—	—	—	—		—		
P. varia	+	—	—	+	—	—	—	—	—		—	+	+	
F. Rubiaceae														
Asperula conferta			—		—	—	—	—	—	—	—	—	—	—
A. euryphylla var. *tetraphylla*		+		—	—		—	—	—	—	—	—	—	—
A. scoparia	+	+	+	—	—	—				—	—	—	—	
**Galium divaricatum*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
G. gaudichaudii	+	+	+	+	—	—	—	—	—	—	—	—	—	—
G. gaudichaudii var. *muriculatum*		+	—	—	—	—	—	—	—	—	—	—	—	—
**G. murale*	+	+	—	—	—		—		—	—	—	—	—	—
**G. tenerum*	—	—	+	—	—	—	—	—	—	—	—	—	—	—
**G. tricorne*	+		—	—	—	—	—	—	—	—	—	—	—	—
Pomax umbellata	—		—			—		—	—	—	—	—	—	—
Opercularia ovata	+	—	—	—	—	—		—					—	—
O. scabrida	+	+	—	—			+		—		+	—	—	—
O. varia	+	+	—	—	—	—	—	—	+	—	—	—	—	—
**Sherardia arvensis*	—					—	—	—	—	—	—	—	—	—
F. Valerianaceae														
**Centranthus ruber*	+	—	—	—						—	—	—	—	—
**Fedia cornucopiae*	+	—	—	—		—		—		—	—	—	—	—
**Valerianella discoidea*	+	—	—		—	—	—	—	—	—	—	—	—	—
**V. eriocarpa*	—	—	—			—	—	—	—	—	—	—	—	—
**V. truncata*	+	—		—			—	—	—	—	—	—	—	—

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Dipsacaceae														
**Scabiosa atropurpurea*	+	—	—		—	—	—	—	—	—				—
F. Cucurbitaceae														
**Citrullus lanatus*	—	—	—	—	—	—	—	—	+			—	—	+
**Cucumis myriocarpus*	—	—	—	—	—	—	—	—	—	—	—	—	—	+
**Ecballium elaterium*	+	—			—	—				—	—	—	—	—
F. Campanulaceae														
Laurentia petraea	—	+	+	—	—	—	—	—	—			—		—
Lobelia alata	+	+			—	—	—	—	—	—	—	—	—	—
L. gibbosa	+	+	—	—	—	—	—	—	—	—	+	—	—	—
L. rhombifolia	—	+				—	—	—	—	—	—	—	—	—
Wahlenbergia bicolor	—	+	—	—	—	—	—	—	—	—	—	—	—	—
W. gracilenta	+	—	+	—	—	—	+	—	—	—	+	—	+	—
W. quadrifida	—	+	—	—		—	—	—	—	—	—	—	—	—
W. trichogyna	+	—	+		+	—	+	—	—	—	—	—	—	—
W. sieberi or *W. trichogyna*	—	—	—	—	—	—	—	—					—	+
F. Goodeniaceae														
Dampiera marifolia	—	—	—	—	—	—	—	—	—	—	+	—	—	—
D. rosmarinifolia	—	—	—	—	—	—	+	—	+	—	—	—	+	—
Goodenia affinis			—	—	—			+	—	—	—	—	—	—
G. albiflora	+	—	—	—	—	—	—				—	—	—	—
G. amplexans	+	+	—	—	—	—	—			—		—	—	—
G. geniculata	+	+	—	—	—	—	—	—	—	—	+	—	—	—
G. ovata	+	+	+			—		—	—	—	—	—	—	—
G. pinnatifida	—			—		—	+	—	—	—	—	—	—	—
G. primulacea	+	—	—	—	—	—	—	—	—	—	—	—	—	—
G. robusta	—	—	—	—	—	—	+	+	+	—	+	—	—	—
G. subintegra	—	—	—	—	—	—	—	—	—	—	—	—	—	+
G. varia	—	+	—	—	—	—	+	+	—	—	+	—	—	—
Scaevola aemula	—	+			—		+	—	—	—	—	—	—	—
S. albida	+	—	—	—	—	—	—	—	—	—	—	—	—	—
S. crassifolia	—	+	—	—	—	—	—	—	—	—	—	—	—	—
S. linearis	—	+	—	—	—	—	—	—	—	—	—	—	—	—
Selliera radicans	—	+					—	—	—	—	—	—	—	—
Velleia paradoxa	+	—		—	—	—	—	—	—	—	—	—	—	—

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
F. Brunoniaceae														
Brunonia australis	+	—	—	—	—	—	—		—	—		—	—	—
F. Stylidiaceae														
Levenhookia dubia	+		+	—	—	—	—	—	—	—	—	—	—	—
L. pusilla	+	—			—	—					—	—		
Stylidium calcaratum	+	—	—	—	—	—	—	—	—	—	—	—	—	
S. despectum	+	+	—	—	—	—	—	—	—	—		—	—	
S. majus	+	+	—	—	—	—	—	—	—		+	—		—
F. Compositae														
Angianthus burkittii	—	—	—	—			—	—	—	—	—	—	—	+
A. phyllocalymmeus	—			—		+	—			—	—	—	—	—
A. preissianus		+	—	—	—	—	—	—	—	—	—	—		—
A. tomentosus			—		—	—	—	+	—	—	—		—	—
**Anthemis nobilis*	+	—	—	—	—	—	—		—					—
**Aster subulatus*	+	—	—	—	—	—			—	—	—	—	—	—
Athrixia athrixioides	—	—	—	—	+	+	—	+		—	—	—	—	—
Brachyscome ciliaris	—	—	+		—	—	+	+	—	—	—	—	+	—
B. debilis	—	—	—	—	—	—	—				—	—	—	—
B. diversifolia	+	—	—	—	—	—	—	—	—			—	—	—
B. lineariloba		—	+	—	—	—	—	—	+	—	—	—	+	—
B. perpusilla	+	—	+	—	—	—	—	—	—	—	—			—
Calocephalus brownii	—	+	—	+	+	—	—	—	—		—	—		—
C. citreus	+	—	—	—	—		—	—	—	—	—	—	—	—
C. drummondii	—	—	+			—	—	—	—	—	—	—	—	—
Calotis cymbacantha		—	—	—		—	—	+	—	—	—	—		+
C. erinacea	—	—	—	—	—	—	—	—	—			+		
C. hispidula	—	—	+	—	—						—	+	—	+
**Carthamus lanatus*	—	—	—	—	—	—	—	—	+			—	—	+
Cassinia laevis	—	—	—	—			—	—	—	—	+	—	—	—
C. complanata			+	—		—	—	—	—	—	—	—	—	
C. punctulata		—	—	—	—	—	—	—	+	—	—	—		
C. spectabilis				+	+	—	—	—	—		+	—	—	—
**Carduus tenuiflorus*	+	—	—	—	—	—	—		+					—
**Centaurea calcitrapa*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**C. melitensis*	+	—	+	—	—	—	—	—	+	—	—	—	—	—
**C. solstitialis*	—	—	—	—	—	—	—		—	—	—	—	—	+
Centipeda cunninghamii	+	—	—	—				—				—	—	—
**Chrysanthemoides monilifera*	+	—		—	—	—	—	—	—	—	—	—		—
Chthonocephalus pseudevax	—	—	+	—	—	—	—	—	—	—	—	—	—	—
**Cichorium intybus*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Cirsium vulgare*	+	—			—	—			—	+		—	—	
Cotula australis	+		—	—	—		—		—	—	—			—
C. coronopifolia	+	+	+	+	—	—	—	—	—	—	—	—	—	—
C. vulgaris		+	—	—	—	—	—	—	—	—	—	—		—
Craspedia uniflora	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Crepis capillaris*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Cryptostemma calendula*	+			—		—	—	—	+	—	—	—	—	—
Cymbonotus lawsonianus	+			—	—	—	—	—	—	—	—	—	—	—
**Cynara cardunculus*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
**Erigeron bonariensis*	—	—				—	—	—	—	—	—	—	—	—
Erodiophyllum elderi				—		—	—	—	—	—	—	—	—	+
Gnaphalium japonicum	—	—	+	—	—	—	+	—	—	—	+	+	—	—
G. luteo-album	+	+	—	—	—	—	—	—	—	—	—	—	—	—
Gnaphalodes uliginosum			+	—	—	—	—	—	+	—	—	+	—	+
**Hedypnois cretica*	+	—	—	—	—	+	—	—	—	—	—	—	—	—
Helichrysum adenophorum	—	+				—	—	—	—	—	—	—	+	—
H. ambiguum			+			—	—	—	—	—	—	—		—
H. apiculatum	+	—	—	—	—	—	+	+	+	—	—	—	—	—
H. apiculatum var. *minor*	—	+	—	—	—	—	—	—	—	—	—	—	—	—
H. baxteri	+	—					+		—	—	+	—	—	—
H. bilobum	+		—		—		—		+				—	—
H. blandowskianum	—	—	—	—	—	—	—	—	—	—	+	—	—	—
H. bracteatum	—	—	—	—	—	—	+	+	—	—	—	—	—	—

TABLE 1 LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
H. catadromum	—	—	—	—	—	—	+	+	+	—	—	+	+	—
H. leucopsidium	—	+	—	—	—	+	—	+	+	—	+	+		
H. obtusifolium	—	—	—	—	—	—	+	—	+	—	+			
H. scorpioides	+	—	—		—	—	—			—	+	—	—	—
H. semipapposum	+	—	—	—	—	—	—	+	—	—	—	—	—	—
H. tepperi	—	—	—	—	—	—	—	—	+	—	—	—	—	—
Helipterum australe	+		—	—	—	—		—			—	—	—	—
H. demissum	+	—	+	—	—	—	—	—	+	—	—			—
H. floribundum	—	—	—	—	—	—	—	—	—	—	—	—	—	+
H. laeve	—	—	+	—	—	—	—	—	—	—	—	—	—	—
H. moschatum	—	—	—	—	—	—	—	—	—	—	—	—	—	+
H. strictum	—	—	+	—	—	—	—	—	—	—	—	—		—
H. variabile	—	—	+			—	—	—	—	—	—	—		+
**Hypochoeris glabra*	+	+	+			—	—	—	+	—	—	—	—	—
**H. radicata*	+	—	—	—		—	—	—	+	—	+	—	+	—
**Inula graveolens*	+	—	—	—	—	—	—	—	+	+	—	—	—	—
Isoctopsis graminifolia	—	—	+	—	—	—	—	—	—	—				+
Ixiolaena supina		+		+	—	—	—	—		—	—	—	—	—
Ixodia achilleoides	+	+	—		+	—	+	—		—		—	—	—
Lagenophora huegelii	+	—	—	—	—	—	—	—	—	—	—	—	—	—
L. stipitata	+	+	—	—	—	—	—	—	—	—	—	—	—	
**Leontodon leysseri*	+					—	—	—	—	—	—	—	—	—
Leptorhynchos medius	—	—	—	—			+		—	—	—	—	—	—
L. squamatus	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Microseris scapigera	+	+	+	—	—	—	—	—	+		+	—	—	—
Millotia tenuifolia	+		+				—	+	—		+	+	+	—
Myriocephalus stuartii		—	—	—	—	—			—	—	—	+	+	—
Olearia axillaris	—	+	—	—	+	—	—	—	—	+	—	—	—	—
O. ciliata	—	—	—	—	—	—	+	+	+	—	+		+	—
O. grandiflora	+									—	—	—	—	—
O. lepidophylla	—	—	—	—	—	—	+	+	+	—	+	—	+	—
O. muelleri	—	—	—	—	—	—	—	+	—	—	—	—	—	—
O. passerinoides	+	—	—	—	—	—	—	—	—	—	—	—	—	—
O. pimeleoides	—	—	—	—	—	—	—	—	—	—	—	—	—	+
O. pieridifolia				—			—					—	—	—
O. ramulosa	+	—	—	+	—	—		—	—			—	?	—

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
O. rudis var. *glabriuscula*	—	+	—	—	—	—	—	—	—		—	—	—	—
O. teretifolia	—	+	—	—	—	—	—	—	—	—	—	—	—	—
O. tubuliflora	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**Onopordum acaulon*	—	—	—	—	—	—	—	—	—	—	—	—	+	—
**Picris echioides*	+			—	—	—	—	—	—	—			—	—
**P. heiracioides* var. *squarrosa*	—	+	—		—		—		—	—	—	—	—	—
Podolepis capillaris		—	+	—	—	—	—	—	—	—	—	—	—	—
P. jaceoides	—	+	—	—	—	—	—	—	—	—	—	—	—	—
P. rugata	—	+	—	—			+			—	—	—	+	—
Podosperma angustifolium	—		—	—	+	—	+	+	+	—	+	+	+	—
Quinetia urvillei	+			—	—	—	—	—	—	—	—	—	—	—
Rutidosis multiflora	+	—	—	—	—	—	—	—	—	—	—	—	—	+
Senecio cunninghamii	—	+	—	+	—	—	—	—	—	—	—	—	—	—
S. gregorii	—	—	+	—	—	—	—	—	—	—	—			+
S. hypoleucus	+	—		—	—	—	—	—	—	—				
S. lautus	+	+	—	+	—	—	+	?	+	—	+	—	+	—
S. magnificus	—	+	—	—	—	—	—	—	—	—	—	—	—	+
S. minimus	—	+	+	—	—		—		—	—	—	—		—
S. multicaulis	+	—	—	—	—	—	—	—	—	—	—	—	—	—
S. multicaulis var. *dissecta*	—	—			—	—	—	—	+	—	—	—	—	—
S. odoratus	—	+	—	—	—	—	—	—	—	—	—	—	—	—
**S. pterophorus*	+	—	—	—	—		—	—	—					
S. quadridentatus	+	—	—	—	—	—	+	—	+	—	+	—	?	+
S. runcinifolius	+	—	—	—	—	—	—	—	—	—	—	—	—	—
**S. vulgaris*	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Siegesbeckia orientalis	+	+	—	—	—	—	—		—	—	—	—	—	
**Silybum marianum*	+	—		—	—	—	—	—	—	—	—	—	—	—
Solenogyne bellioides var. *gunnii*	+	—	—		—	—	—	—	—	—	—	—	—	—
**Soliva sessilis*	+	—	—	—	—	—	—		—	—	—	—		—
**Sonchus asper*	+	+	—	—	—	—	—	—	—	+	+	—	—	—
S. megalocarpus	—	+		+	—	—	—	—	—	—	—	—	—	—
**S. oleraceus*	+	—	+	—	—	—	—	—	+	—	—	—	—	+
Stuartina muelleri	+	—	+	—	—	—	—	—	—	—	—	—	—	—

TABLE 1—LIST OF SPECIES RECORDED IN FLORA AND FAUNA RESERVES IN SOUTH AUSTRALIA—*continued*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
**Taraxacum officinale*	+		–	–			–	–	–	–	–	–	–	–
**Tolpis umbellata*	+	–			–	–	–	–	–			–	–	–
Toxanthes muelleri	+	–	–	–	–	–	–		+	–	+	–	–	+
T. perpusillus	–	–	+		–	–	–	–	–	–	–	–	–	–
**Tragopogon porrifolius*	+	–		–	–	–	–	–	–	–	–	–	–	–
**Urospermum picroides*	+	–	+	–		–	–	–	–	–				
Vittadinia tenuissima	+	–	–	–		–	–	–	–	–	–	–		–
V. triloba	+	+	–	–	–	–	+	+	+	–	+	+	+	+
V. triloba var. *lanuginosa*	+	–	–	–	–	–		–	–	–	–	–	–	–
**Xanthium spinosum*	+	–	–	–	–	–	–	–	–	–	–	–	–	+

DISCUSSION

The data presented in both Tables 1 and 2 indicate that, of the total of 2,255 native species listed for South Australia, only 942, i.e. 42 p.c., have been recorded in Reserves. The remaining 1,313 species not conserved are scattered widely throughout South Australia. The data presented at the end of Table 2 indicate the number of these latter species that have been recorded for any particular region within the State. As many of the species concerned are widespread, they may be included in several of the regions; conversely, a number may be quite localised.

The Region embracing the North-East and Far North contains by far the greatest number (610) of species, in fact, 46 p.c. of the flora not conserved. It may be argued that the flora of this area is in no danger of extinction. The Simpson Desert is included within this area; its small flora (76 species according to Eardley, 1946) is certainly in no danger of extinction. The rest of the region, however, is largely under pastoral lease for cattle and sheep grazing. As may be expected in arid regions, rates of stocking are low, but unfortunately, even a small error in stocking rate may lead to overgrazing in times of drought. In the past severe overgrazing has occurred in this area and has led to the large-scale destruction of vegetation with subsequent erosion. All areas are grazed by rabbits which often reach plague numbers. No area can be said to be ungrazed by introduced animals. Seedlings of shrubs and trees have been destroyed (Wood, 1936) until, now, regeneration of much of the vegetation may be impossible unless properly protected from grazing animals.

Many of the species recorded for the previous region extend westward into the Flinders Ranges, North-West, Nullarbor Plain, the Gawler Ranges of Northern Eyre Peninsula, and also southward into the northern part of the heterogeneous Murray Lands. In fact, many of the species extend into the drier habitats of the southern, higher rainfall districts. In all, about 900 species (69 p.c.) of the 1,313 species at present not recorded in Flora and Fauna Reserves may be found in some part of this arid region.

TABLE 2*.

COMPARISON OF THE NUMBER OF NATIVE AND INTRODUCED SPECIES RECORDED IN RESERVES IN SOUTH AUSTRALIA WITH TOTAL LISTED FOR THE STATE TOGETHER WITH DISTRIBUTION OF NATIVE SPECIES NOT YET RECORDED IN RESERVES IN SOUTH AUSTRALIA.

The ten regions delineated essentially follow Black (1943 57), viz:

(i) North West	West of Oodnadatta and Flinders Ranges and north of East-West Railway.
(ii) Nullarbor Plain	From East-West Railway west of Tarcoola extending south to the Great Australian Bight.
(iii) Eyre Peninsula	Peninsula south of latitude of Ceduna and Port Augusta. This includes the Gawler Ranges.
(iv) Yorke Peninsula (v) Kangaroo Island	Black often includes these two regions in his "Southern Districts". Data recorded below are probably too low as they include only records specifically noted by Black for these regions.
(vi) Mt. Lofty Ranges and Mid-North	Fleurieu Peninsula northward to latitude of Gladstone and Terowie.
(vii) Flinders Ranges	Ranges from Gladstone-Terowie to Marree.
(viii) Far North and North East	North of Peterborough-Broken Hill railway and east of the Flinders Ranges; extending westward north of Marree to include all country east of Alice Springs railway.
(ix) Murray Lands	Extends from Mt. Lofty Ranges eastward to the Border; northward from Bordertown to the Peterborough-Broken Hill railway.
(x) South East	Region south of Bordertown.

* Some additional records for Koonamore Vegetation Reserve (column 14 in Table 1) were made *after* Table 2 was compiled; some 44 species were added and of these 14 were new to Table 1. The appropriate adjustments were not made in Table 2, because they were of the order of 2% only in a few of the final totals in Table 2.—C.M.E.

TABLE 2 — *continued.*

FAMILY	Native species: Recorded in S. Aust.	Native species: Recorded in reserves	Introduced species: Recorded in S. Aust.	Introduced species: Recorded in reserves	Distribution of native species not recorded in reserves: N.W.	Nullarbor Plain	Eyre Peninsula	Yorke Peninsula	Kangaroo Island	Mt. Lofty Ranges-Mid Nth.	Flinders Ranges	Far North & N.E.	Murray Lands	S.E.
PTERIDOPHYTA														
Cyatheaceae	1	—	—	—	—	—	—	—	—	1	—	—	—	1
Polypodiaceae	23	10	—	—	1	—	4	—	—	3	1	—	2	9
Gleicheniaceae	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Schizaeaceae	2	1	—	—	—	—	—	—	—	1	—	—	—	—
Osmundaceae	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Ophioglossaceae	2	1	—	—	—	—	—	—	—	1	—	—	—	—
Marsileaceae	3	1	—	—	1	—	—	—	—	1	2	2	2	—
Salviniaceae	2	—	—	—	—	—	—	—	—	—	—	—	2	—
Lycopodiaceae	4	3	—	—	—	—	—	—	—	1	—	—	—	—
Selaginellaceae	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Isoetaceae	1	1	—	—	—	—	—	—	—	—	—	—	—	—
GYMNOSPERMAE														
Pinaceae	5	3	—	—	1	—	2	1	1	1	2	1	2	—
ANGIOSPERMAE (MONO-COTYLEDONS)														
Typhaceae	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Potamogetonaceae	15	1	—	—	—	—	6	5	6	11	—	1	4	9
Naiadaceae	2	—	—	—	1	—	—	—	—	—	—	—	1	—
Aponogetonaceae	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Scheuchzeriaceae	10	5	—	—	—	—	2	—	1	1	—	—	2	2
Alismataceae	2	—	—	—	—	—	—	—	—	1	—	—	1	—
Hydrocharitaceae	5	—	—	—	1	—	1	1	1	3	—	—	3	2
Gramineae	199	61	87	45	30	9	10	3	3	31	40	88	34	13
Cyperaceae	107	57	2	1	3	—	5	3	8	25	12	23	14	15
Araceae	—	—	1	1	—	—	—	—	—	—	—	—	—	—
Lemnaceae	4	—	—	—	—	—	—	—	—	2	—	—	3	1
Restionaceae	10	6	—	—	—	—	1	—	1	2	—	—	—	3
Centrolepidaceae	10	7	—	—	—	—	—	—	3	1	—	1	2	3
Xyridaceae	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Eriocaulaceae	1	—	—	—	—	—	—	—	—	—	—	1	—	—
Commelinaceae	1	—	—	—	—	—	—	—	—	—	—	1	—	—
Pontederiaceae	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Juncaceae	14	10	3	2	—	—	—	—	—	1	1	1	—	2
Liliaceae	41	26	14	5	2	—	5	2	2	5	2	1	3	5
Amaryllidaceae	5	3	—	—	—	—	—	—	—	—	2	2	1	—
Iridaceae	3	2	20	7	—	—	—	—	1	1	—	—	—	1
Orchidaceae	106	69	—	—	—	—	6	4	7	28	2	—	4	9
ANGIOSPERMAE (DICOTYLEDONS)														
Casuarinaceae	10	5	—	—	1	—	2	—	—	—	—	—	1	2
Moraceae	1	—	—	—	1	—	—	—	—	—	—	—	—	—
Urticaceae	2	2	1	1	—	—	—	—	—	—	—	—	—	—
Proteaceae	38	24	—	—	5	5	3	—	—	—	3	5	1	2
Santalaceae	12 + 1	10	—	—	2	—	1	—	—	1	—	1	1	1

TABLE 2 — *continued.*

FAMILY	Native species: Recorded in S. Aust.	Native species: Recorded in reserves	Introduced species: Recorded in S. Aust.	Introduced species: Recorded in reserves	Distribution of native species not recorded in reserves: N.W.	Nullarbor Plain	Eyre Peninsula	Yorke Peninsula	Kangaroo Island	Mt. Lofty Ranges-Mid Nth.	Flinders Ranges	Far North & N.E.	Murray Lands	S.E.
Olacaceae	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Loranthaceae	11+1	5	—	—	2	3	2	—	—	1	2	6	3	2
Polygonaceae	15	3	9	6	—	—	1	—	1	6	2	6	7	4
Chenopodiaceae	124+10	38	9	2	27	4	15	7	1	11	30	76	31	2
Amaranthaceae	31	3	6	3	10	2	6	3	2	4	9	19	6	2
Nyctaginaceae	2	1		—	—	—	—	—	—	—	1	1	—	—
Phytolaccaceae	5	2	1		2	2	—	—	—	—	2	3	1	—
Aizoaceae	19+2	7	8	—	2	1	5	1	—	2	6	11	2	—
Cactaceae	—	—	2	—	—	—		—	—		—	—	—	—
Portulacaceae	20	6	2	1	3	2	3	—	—	4	2	7	1	1
Caryophyllaceae	14	8	19	8	1	—	1	1	1	3	1	3	2	4
Ceratophyllaceae	1	—	—		—	—	—	—	—	—	—	—	1	—
Ranunculaceae	5+3	6	5	1	—	—	—	—		1	1	2	2	—
Lauraceae	3	3	—	—	—	—	—	—	—	—		—	—	—
Papaveraceae	1	—	14	7	—	—	1	—	1	1	—	—	1	1
Capparidaceae	5	—	—	—	—	—		—	—	—	1	5		—
Cruciferae	44−1	8	28	12	7	7	7	7	—	6	15	24	18	5
Resedaceae		—	4	1	—	—	—	—	—	—	—	—	—	—
Droseraceae	8	7	—	—	—	—	—	—	—	—	—	1	—	—
Crassulaceae	6	6	—	—	—	—	—	—	—	—	—	—	—	—
Saxifragaceae	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Pittosporaceae	7	7	—	—	—	—	—	—	—	—	—	—	—	—
Rosaceae	4	2	8	3	—	—	—	—	1	2	—	—		2
Leguminosae														
Mimosoideae	92+1	31	—	—	15	12	11	1	2	7	14	20	11	3
Caesalpinioideae	10	4	—	—	3	—	—	—	—	—	3	4	—	—
Papilionatae	125−1	42	61	32	12	10	17	3	5	14	18	43	20	11
Geraniaceae	7	5	6	5	1	—	—	—		1	—	1	—	1
Oxalidaceae	1	1	3+7	1	—	—	—	—	—	—	—	—	—	—
Linaceae	1	1	2	1	—	—	—	—	—	—	—	—	—	—
Zygophyllaceae	21−1	11	1	—	4	2	—	—	—	—	4	7	—	—
Rutaceae	33	20	—	—	1	—	2	2	2	4	1	1	3	1
Meliaceae	1	—	—	—	—	—	—	—	—	—	—	1	—	—
Tremandraceae	4	3	—	—	—	—	—	—	—	—	—	—	—	1
Polygalaceae	5+1	3	2	1	—	—	1	—	—	1	—	1	1	1
Euphorbiaceae	29	10	11	1	5	3	3	2	2	2	6	11	7	1
Callitrichaceae	1	1		—	—	—	—	—	—	—	—	—	—	—
Stackhousiaceae	5	2	—	—	—	1	—	—	—	—	—	2	—	—
Sapindaceae	14	9	—	—	1	—	—	—	—	—	1	4	2	—
Melianthaceae	—	—	2	—	—	—	—	—	—	—	—	—		—
Anacardiaceae	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Rhamnaceae	25+1	18	1	1	—	1	3	—	2	3	—	1	—	—
Malvaceae	38	5	7	2	10	5	8	4	—	2	12	22	6	1
Sterculiaceae	12+1	7	—	—	2	—	1	1	—	—	1	1	—	—
Dilleniaceae	9	6	—	—	1	1	1	—	—	—	—	—	—	—
Guttiferae	2	2	1	1	—	—	—	—	—	—	—	—	—	—
Elatinaceae	3	1	—	—	—	—	—	—	—	—	—	2	—	—
Frankeniaceae	21+1	1	1	—	3	5	3	1	—		7	14	2	—
Cistaceae	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Violaceae	8	5	1		1	—	—	—	—	2	1	1	—	1

TABLE 2 — *continued.*

FAMILY	Native species		Introduced species		Distribution of native species not recorded in reserves									
	Recorded in S. Aust.	Recorded in reserves	Recorded in S. Aust.	Recorded in reserves	N.W.	Nullarbor Plain	Eyre Peninsula	Yorke Peninsula	Kangaroo Island	Mt. Lofty Ranges-Mid Nth.	Flinders Ranges	Far North & N.E.	Murray Lands	S.E.
Thymelaeaceae	22	12	1	—	1	2	4	—	2	2	8	4	4	1
Lythraceae	3	1	1	—	—	—	—	—	—	1	—	1	1	—
Myrtaceae	98 − 1	58	—	—	16	6	5	—	5	6	7	6	5	3
Oenotheraceae	4	3	4	1	—	—	—	—	—	—	—	—	1	—
Haloragaceae	22	13	—	—	3	—	2	1	2	2	1	3	5	1
Umbelliferae	35	19	11	5	1	2	2	4	4	8	1	4	4	6
Ericaceae	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Epacridaceae	28 + 2	25	—	—	—	—	—	—	2	1	—	—	—	4
Primulaceae	3	1	3	2	1	—	—	—	—	1	—	—	—	1
Plumbaginaceae	—	—	4	—	—	—	—	—	—	—	—	—	—	—
Oleaceae	1	—	2	1	1	—	—	—	—	—	1	1	1	—
Loganiaceae	10	8	—	—	—	1	1	—	—	—	—	—	—	1
Gentianaceae	9	3	5	2	—	—	—	1	1	—	—	1	1	4
Apocynaceae	2	1	1	1	1	—	—	—	—	—	—	—	—	—
Asclepiadaceae	4		3	2	2	2	1	1	—	1	3	4	1	—
Convolvulaceae	16	2	2	—	2	—	2	2	3	4	4	8	5	4
Polemoniaceae	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Boraginaceae	18	6	10 + 1	5	2	1	3	1	—	3	3	8	2	2
Verbenaceae	14	1	3	2	7	1	2	1	—	2	—	3	1	—
Labiatae	28	13	10	8	4	3	6	2	3	8	3	3	3	4
Solanaceae	35	6	15	5	13	9	7	1	1	4	12	15	7	1
Scrophulariaceae	23	4	19	7	1	—	6	4	5	6	5	9	6	7
Bignoniaceae	1	—	—	—	1	—	—	—	—	—	—	—	—	—
Pedaliaceae	1	—	—	—	—	—	—	—	—	—	—	1	—	—
Martyniaceae	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Orobanchaceae	1	—	—	—	—	—	1	1	—	1	1	—	—	—
Lentibulariaceae	3 + 1	4			—	—	—	—	—	—	—	—	—	—
Acanthaceae	1	—	—	—	—	—	—	—	—	—	1	1	—	—
Myoporaceae	44	12	—	—	18	14	4	—	—	3	11	11	9	—
Plantaginaceae	1	1	5	3	—	—	—	—	—	—	—	—	—	—
Rubiaceae	15	8	6	5	1	—	—	—	1	4	2	3	1	1
Caprifoliaceae	1		1											1
Valerianaceae	—	—	5	5	—	—	—	—	—	—	—	—	—	—
Dipsacaceae	—	—	2	1	—	—	—	—	—	—	—	—	—	—
Cucurbitaceae	4		4	2	1	—	—			—	1	4	1	—
Campanulaceae	17	8	—	—	—	1	1	1	2	3	1	2	2	5
Goodeniaceae	53 + 2	17	—		13	9	6	1	1	5	10	16	9	4
Brunoniaceae	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Stylidiaceae	8	5	—	—	—	—	1	—	2	1	—	—	—	1
Compositae	250 + 2	95	74	32	45	43	50	29	8	37	54	74	64	23
TOTAL	2,255	942	557	240	296	169	243	102	96	302	331	610	343	198
% Species recorded in Reserves		42%		43%										
% of 1,313 Species not recorded in Reserves					23%	13%	19%	8%	7%	23%	25%	46%	26%	15%

This large suite of species contains many families characteristic of arid regions, few of which are conserved, e.g., Koonamore Vegetation Reserve is the only Arid Zone Reserve in South Australia and this is a mere 960 acres in area (Specht and Cleland, 1961). Many of the species, although widespread in the arid zone are confined to particular microhabitats. Some areas such as the Nullarbor Plain, Great Victoria Desert, Sturt's Stony Desert and the Simpson Desert are comparatively uniform. In the ranges, however, and on the surrounding plains a great diversity of microhabitats is found; there the greatest range of species occurs. The Musgrave, Everard, Mann and Birksgate Ranges of the Far North-West, the Gawler Ranges of northern Eyre Peninsula, the northern end of the Flinders Ranges, are all situations where a wide range of species characteristic of the arid zone may be found. Reserves in any of these areas would not only conserve a large percentage of the State's flora, but would be scenically attractive to tourists.

However, such areas with their wealth of microhabitats usually do not allow the satisfactory development of extensive plant formations. The low layered woodland, shrub steppe and semi-arid tussock grassland formations (see Specht and Cleland, 1961) and their characteristic plant associations often intergrade to such an extent in such areas as to be defined with difficulty. The preservation of such formations is best made in more uniform habitats. Appropriate steps should also be taken to have selected areas on uniform sites (say, 10 square miles in area) of each formation (and association, if possible) proclaimed as Reserves, and adequately protected from rabbits and other introduced animals. These areas will not be attractive to the tourist but will be of inestimable interest to future scientists. If possible these could be chosen adjacent to the more scenic range country.

Of the 400 other species not conserved in South Australia, about 100* may be found confined to the corridor of the River Murray. Suitable sites bordering on the Murray should be sought to conserve some of these species; these sites should also be suitable as sanctuaries for birds which abound along the Murray.

The other 300 species are scattered irregularly throughout the southern part of the State. A number have been found in very limited areas, and, in some cases, are already extinct, others may be only westerly extensions of species from the Eastern States into the South-East of South Australia.

It is difficult to pinpoint possible areas for future reserves to conserve the other species. The figures given in Table 2 underestimate the possible number of species (not conserved) to be found on Yorke Peninsula and Kangaroo Island, because Black (1943-57) usually lumps records from these regions with the Mt. Lofty Ranges-Mid North region in his "Southern Districts".

Areas such as the southern Flinders Ranges, the hills near Burra, the foot of Yorke Peninsula, the southern part of the Fleurieu Peninsula and the dune-range and swamp country north of Mt. Gambier should prove worthy of investigation for future reserves. These should be examined not only in the light of the plant species they may conserve but also in the light of the plant formations and associations found in the area (Specht and Cleland, 1961).

It is pointless to insist that any of the 557 introduced plant species should be conserved, although in a few cases potential economic plants may be involved. It is interesting, but probably coincidence, that 43 p.c. of these introduced species are now found on the present Flora and Fauna Reserves — also the same percentage as that of these native species (Table 2). This invasion of reserves

* This figure is included in the figure of 343 for Murray Lands in Table 2.

by introduced species emphasises the problems of maintaining flora and fauna reserves discussed in the first paper in this series (Specht and Cleland, 1961). Steps should be taken to avoid this contamination. It may be impossible in such plant formations as the savannah woodland and mallee, but not so difficult in the other formations if contamination by rubbish and fertilizer dust is avoided.

ACKNOWLEDGMENTS

This study provides further background information for several bodies interested in flora conservation in this State. Much of the field data was gathered by the authors while members of the Flora and Fauna Investigation Committee, 1960-61. The co-operation of other members, Mr. O. Bowden (Chairman) of the South Australian Lands Department, and Mr. A. C. Bogg of the South Australian Department of Fisheries and Game, was greatly appreciated.

Further data were provided by Mr. D. E. Symon of the Waite Agricultural Research Institute (Wilpena Pound) and Miss C. M. Eardley, of the Botany Department, University of Adelaide (Koonamore Vegetation Reserve).

Dr. Hj. Eichler and Mr. P. G. Wilson of the State Herbarium of South Australia, Mr. C. D. Boomsma of the South Australian Woods and Forests Department (*Eucalyptus*), Dr. R. C. Carolin of the Botany Department, University of Sydney (Geraniaceae), and Dr. S. T. Blake, Herbarium, Brisbane (Aizoaceae) checked the identification of the plants collected. Their assistance is gratefully acknowledged.

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ERRATA

In *Flora Conservation in South Australia. Part I*, by Specht and Cleland. Trans. Roy. Soc. South Australia, **85**, pp. 177-196 (1961).

P. 189. Under "Tussock Grassland Association (ii)", read "*Lomandra dura-Lomandra effusa* (irongrass) association" instead of "*L. dura-L. multiflora* . . . association". The genus *Lomandra* is difficult taxonomically.

P. 192. Next-to-last paragraph. *Myoporum platycarpum* is not *restricted* to the east of the Flinders Range as stated, but is also quite common west of this Range from Port Germein northwards.

THE PLANT ECOLOGY OF LOWER EYRE PENILNSULA, SOUTH AUSTRALIA

BY D. F. SMITH

Summary

A detailed study has been made of the plant ecology of Lower Eyre Peninsula. Archaean rocks, lateritic peneplain remnants and calcareous loess have, in various combinations, formed a wide variety of soils; and with a mean rainfall range from 12-23 inches per annum, a wide variety of plant habitats is provided. The autecology of 21 Eucalypts and three other species is discussed, some in detail. Special interest centres on *Eucalyptus cladocalyx* which here has its largest area of natural occurrence. The plant communities are grouped as malice, woodland or sclerophyll scrub and the floristic composition of each is given. A vegetation map has been compiled. As virtually all the of the species present are distant from their main location, their presence and extent of occurrence have considerable ecological significance. This is discussed in relation to recent climatic history and evidence is presented for retreat and survival as relic patches, rather than long distance dispersal and colonisation.

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(*Communicated by D. E. Symon*)

[Read 13 September 1962]

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INTRODUCTION

The large variety of soils and the wide range from 13-24 in. of average annual rainfall in Southern Eyre Peninsula makes it an interesting area for ecological study. The woodland areas were occupied as early as 1840, but the mallee and sugar gum scrub have mostly been settled and cleared since 1900. This settlement has modified some plant communities and almost obliterated others.

PHYSICAL ENVIRONMENT

1. GEOLOGY

The geology of the area has been described by Johns (1961). Ecologically the lateritic areas and the Recent and Pleistocene sands and limestone are important. Their distribution and relationship to other areas has been discussed by Smith (1960).

2. PHYSIOGRAPHY

Most of Lower Eyre Peninsula is gently undulating with some resistant cores of quartzite forming small ranges up to 1,400 ft. high on the western side. On the eastern side, the Koppio Hills extend from near Port Lincoln northward. They are capped in many places by remnants of a lateritic plateau, sloping gently from 8-900 feet in the north to 600 feet in the south and bounded by a definite fault line on the eastern side. The relationship of topography to soil type, vegetation and land use is summarised in Fig. 2.

* Now of the School of Agriculture, University of Melbourne.

3. Drainage

The Tod River is the largest watercourse in the area, and it is rarely perennial. In the moister parts of the Koppio Hills, spring-fed streams do flow in the summer, but are soon lost in stream bed gravels, forming moister habitats. Flooding by westward flowing streams has apparently influenced soils and vegetation, especially near Cummins. These drainage lines have been dammed back by the development of aeolianite dunes (or the accumulation of siliceous sands) forming salt lakes and swamps with much water passing into the aeolianite or sands, providing habitats for patches of *Eucalyptus camaldulensis* (red gum) vegetation. The aeolianite may act as an important aquifer, especially when resting on impermeable Archaean rocks (Johns, 1961).

CLIMATE

A detailed study of climate is not possible due to the absence of recorded data other than for rainfall which is reasonably covered. Crocker (1946a) has summarised the available data for the whole peninsula. The climate is typically Mediterranean with 70 p.c. of the rainfall in the May-October period and a long, hot, dry summer.

The significance of the rainfall data for native species, many of which are perennial and summer-growing, is quite different to that for agricultural crops dependent on winter-spring conditions. Soil moisture storage from winter rains will be very important and soil type will modify rainfall effects on native vegetation more than for winter annual growth.

Since recording began there appear to have been no periods likely to seriously affect the native plants, i.e. no run of wet seasons or very dry ones. At Cummins the year 1957 was very dry (8 in.) but it followed the wettest year on record (almost 25 ins.). Thus while 1957 was disastrous agriculturally it had little effect on native vegetation because of soil storage from the previous year.

A rainfall map (Fig. 1) has been compiled using data for the 1916-57 period, mostly supplied by the Commonwealth Bureau of Meteorology with some interpolation from farmers' records. The average rainfall for the period 1941-57 has seldom equalled the 1911-40 ("normal" period) average. Most of the Koppio Hills and Cummins area has received below "normal" by as much as 2·2 inches at Green Patch – while north of this has been above "normal" – 1·1 inches at Yeelanna. Thus use of the 30-year normal has been misleading in earlier maps, especially in drawing the 16-inch isohyet near Yeelanna.

The annual average rainfall at Cummins from 1916-57 was 17·32 inches with a mean variation of 17 p.c. or 3·0 inches.

In 56 p.c. of the years recorded rainfall was within 3·0 inches of the mean and in only 7 p.c. has the variation been greater than 6 inches.

SOILS

The only detailed soil survey carried out in the area is that of Stephens (1943) who surveyed a small area of lateritic soils near Wanilla prior to its use for Soldier Settlement. However, knowledge of the area has been increased by the work of Crocker (1946a, b), French (1958) and Smith (1960). A survey of a portion of Kangaroo Island by Northcote and Tucker (1948) is of interest in the close similarities of some soil types.

The ecologically important soil groups are—

1. *The Lateritic Derivatives*

These are the most widespread group. Normal lateritic soils with a sandy A horizon are widespread in the Koppio Hills on wider divides, on the gently undulating Wanilla area (Stephens, 1943) and on the western side of the peninsula near Coulta and Kapinnie. Shallower lateritic gravelly sandy loams and gravelly clay loams occur where truncation has occurred.

These soils are generally acid (except in the north where much lime is present), have poor water-holding capacity, low nitrogen and phosphate status and low total exchangeable cations.

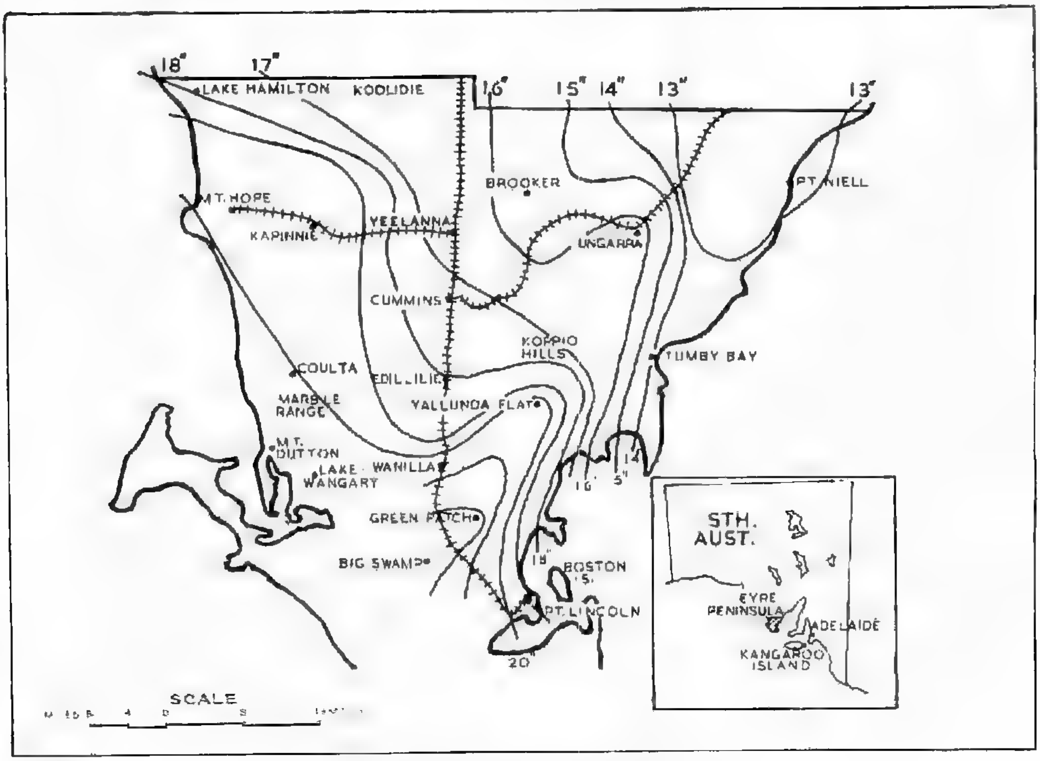


Fig. 1. Locality and rainfall map.

2. *Red-brown Earths*

A number of areas of typical red-brown earths have developed, especially along the eastern side of the Koppio Hills. On the western side near Cummins and to the north near Ungarra, a wide range of red-brown and brown-grey soils of varying texture (but usually clay) have been formed on the outwash material from the hills. Varying additions of calcareous loess, siliceous sand and cyclic salt have contributed to the present complex mosaic of red-brown earths, heavy grey clay loams, solonised brown soils and solodic soils. Physical and chemical characteristics of these soils vary tremendously. They are usually just alkaline, and of moderate fertility with calcium dominant in the exchange complex, except for the solodic types. Solonised types have the poorest water status and the red-brown earths the best.

3. *Rendzinas and Terra Rossas*

The expanse of limestone along the western coast is generally covered by a thin mantle of grey-black or red-brown loams and sandy loams, although on slopes the limestone may be bare. Some other limited areas of terra rossas occur where sufficient limestone has accumulated to dominate soil formation. Many such patches, an acre or two in extent, occur throughout the Kapinnie, Cummins and Yeelanna districts and have typical vegetation. Accumulations of calcareous sands and sandy loams also occur in association with the large expanse of limestone.

The rendzinas and terra rossas are typically alkaline, quite high in fertility and have low water storage capacity.

4. *The Deep Sands*

Areas of calcareous sand occur along the coast and as deep pockets associated with the limestone (up to 83 p.c. calcium carbonate with a pH of 8·9) even as far inland as the main railway line near Karkoo.

Deep siliceous sands occur in restricted areas, mainly at Wangary, then south and west of Cummins and in a complex area north of Yeelanna-Ungarra. Most of these have a pH 5·8-6·0, and are of very low fertility with low water storage capacity.

5. *Soils Associated with Archaean Rocks*

Depending on topography these may be skeletal or quite deep soils on the mid and lower slopes, varying greatly in texture and fertility according to rock type. Some yellow solodic soils occur.

In terms of soil fertility and water storage capacity this group supply the most favoured habitats for plant growth and carried savannah woodland vegetation.

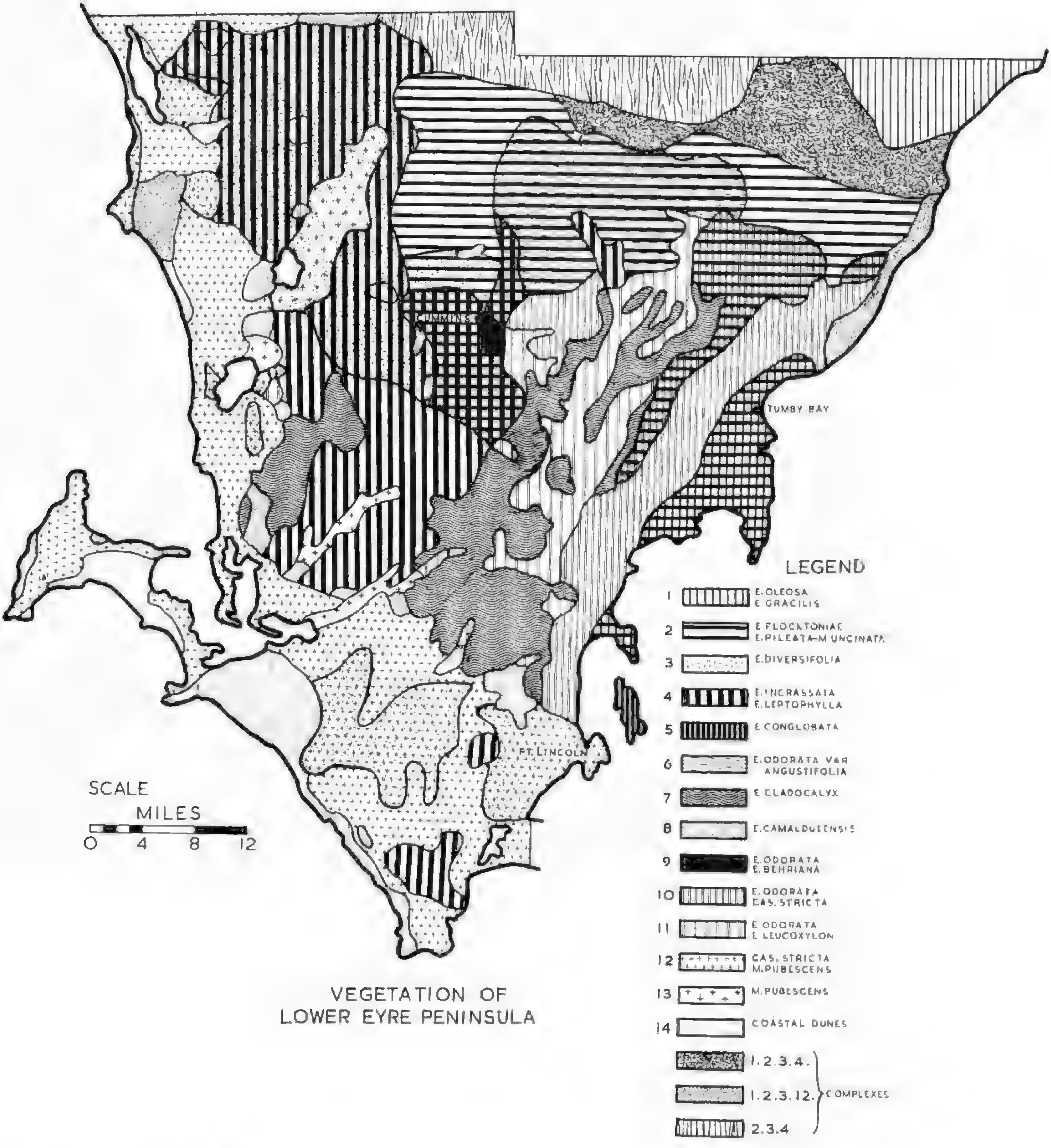
6. *Solonised Brown Soils*

South, west and north of Yeelanna considerable areas of these soils occur, carrying the typical mallee scrub with *Eucalyptus flocktoniae* and *Eucalyptus pileata* as dominants. As usual these soils are strongly alkaline (pH 8·5), have relatively high nitrogen and phosphorus status and total soluble salts of 0·1 p.c. Calcium and magnesium contribute almost equally to the relatively high cation exchange capacity.

CLIMATIC HISTORY

Crocker (1946b) and Crocker and Wood (1947) have discussed post-Miocene climate in Australia, and Smith (1960) has discussed the Eyre Peninsula evidence in detail. The Recent aridity would appear to have had a profound influence on Eyre Peninsula vegetation (see later).

Downes (1954) has suggested that present day drought conditions represent average conditions during the arid periods, i.e. average annual rainfall was down almost to half of the present day amounts. Botanical evidence suggests that on Eyre Peninsula the reduction was less severe than this — from 20 inches down at most to 13 inches. Further, the zone of maximum solonisation on Eyre Peninsula (the red and yellow solodic soils) is now somewhat drier than suggested by him. His principle that high calcium status markedly reduces morphological change during desalinization of the surface is strongly confirmed.



VEGETATION OF LOWER EYRE PENINSULA

When calcium is low, as in the siliceous sands and leached lateritic soils even moderate present rainfall (13-18 inches) has caused the development of solodized solonetz and solodic soils and vegetation changes accordingly.

VEGETATION

Introduction

The only previous study of the ecology of Eyre Peninsula was made by Crocker (1946a). Only a small percentage of the southern area is still uncleared, and of this most must have been affected by fire, livestock, rabbits, competition from introduced species, and other influences due to settlement. Distribution of the original vegetation has been assessed by a consideration of relic patches, old records, opinions of early settlers and remaining vegetation along roads, with allowance where possible for the known influence of settlement on the frequency or distribution of a species.

Coaldrake (1951) lists depth of sand, water status, presence of massive limestone and burning as major factors influencing distribution of plants in the Ninety Mile Plain, and these factors seem to operate in a very similar way in this region. Fire has not influenced such large areas at the one time, at least in recent years.

Eucalypt identifications have been based mainly on the key of Burbidge (1947) and checked by C. D. Boomsma of the South Australian Woods and Forests Department. Other species have been identified and/or checked by the National Herbarium, Melbourne, using Black's Flora of South Australia in almost all cases. A set of specimens has been deposited at that Herbarium. Floristic lists have been compiled including comparisons with related vegetation units elsewhere. Copies are available from the author.

Notes on Individual Species

1. *Eucalyptus camaldulensis* (river red gum)

River red gum specimens on Lower Eyre Peninsula are generally very similar in tree size, bud and fruit characteristics and location, to those occurring elsewhere in Australia. However, there is apparently some hybridization with *Eucalyptus cladocalyx* and *Eucalyptus leucoxylon* such as at Chapman's Swamp, five miles west of Wanilla, the hybrids having larger fruits than normal, yet otherwise reasonably typical appearance. This species is restricted to areas where soil is moist to a considerable depth, i.e. former stream beds now covered with recent sediments, or where streams run into aeolianite limestone, giving shallow watertables. It does not occur naturally in the Koppio Hills where *E. leucoxylon* occupies sites on which one would expect to find it. The one valley occurrence is just east of Wanilla. The largest individual area is at Dutton, on meadow podzolic type soils at the foot of the Marble Range. Several patches, totalling several thousand acres, occur at Koolidie Station, on the northern boundary of the Hundred of Mitchell (Pl. 2, Fig. 2). Here *E. camaldulensis* and *Callitris propinqua* form an ecotone on shallow sandy loams over travertine where a creek loses itself under the travertine, giving a watertable at 10-25 feet. On ridges where the watertable is deeper there is no red gum.

2. *Eucalyptus cladocalyx*

This species is remarkable for its discontinuous distribution in South Australia, to which its natural occurrence is restricted. It occurs on Kangaroo Island Lower Eyre Peninsula, the Cleve Hills, and the Southern Flinders Ranges, each occurrence being on a different type of soil* and floristically unrelated. On Lower Eyre Peninsula it is often depauperate, and always a twisted tree (Pl. 1, Fig. 1) growing over sclerophyllous shrubs on lateritic soils.

C. D. Boomsma (personal communication) has drawn attention to the fact that specimens from the Flinders Ranges, when planted on Eyre Peninsula alongside local specimens, grow straight and more vigorously, indicating some genetic divergence.

The floristic lists compare the *E. cladocalyx* association with its occurrence elsewhere (Baldwin and Crocker, 1941; Boomsma, 1946). Only six of the 66 species from the *E. cladocalyx* association on Eyre Peninsula have been recorded in the *E. cladocalyx* association on Kangaroo Island although some 45 of the 66 have been reported from the Island. Likewise only 11 species are common to *E. cladocalyx* stands in both Eyre Peninsula and Flinders Ranges, but 30 of the 66 are recorded for the Flinders Ranges. Thus, if the *E. cladocalyx* distribution is due to retreat to give a discontinuous distribution, survival and some spread, it shows the puzzling feature of failure to have many constant companions. If all species making up an association have not an identical range but an overlapping range, it is possible that in a severe battle for survival almost all companions could be lost. It is possible that the prominence of *E. cladocalyx* on Eyre Peninsula is due to the absence of *Eucalyptus baxteri* despite the occurrence of situations where soil and rainfall conditions appear to be suitable for it by comparison with Kangaroo Island where the lower rainfall limit is approximately 21 inches. If *E. baxteri* was present *E. cladocalyx* might be limited to the drier lateritic soils and skeletal ridges, whereas it now occupies all the peneplain surfaces of the Koppio Hills where rainfall is greater than 16 inches, some slopes and even valley floors. Soils are generally moderately wet, with reasonable drainage due to slope or the presence of rock fragments or pisolitic ironstone gravel. It attains its greatest size on well-drained loams near Yallunda Flat, reaching a diameter of three feet and a height of 60 feet, but is never the large, handsome tree of the Flinders Ranges. Many of the larger trees have been removed and milled for rough farm work.

Near Wanilla and towards Edillilie patches occur well out onto the plain, frequently depauperate. The reason for its failure to spread across the plain appears to be related to the degree of water logging. Near the Marble Range and westward to within a mile of the coast at Mt. Dutton the tree attains a reasonable frequency, often mixed with *E. camaldulensis*, *E. leucoxylon* and *E. odorata*, but in a few cases as pure stands on lateritic remnants.

The boundaries of its occurrence are often very sharp. On the south and west this is apparently due to marked soil changes where the travertine-capped aeolianite mantle overlies the laterite. On the east, where the plateau laterite gives way to skeletal chocolate soils on steep slopes and a rain shadow operates, combined soil and climatic factors determine its margin. At the north-western limit the change is still relatively sudden, with depauperate *E. cladocalyx* (Pl. 1, Fig. 1) giving way to *Eucalyptus incrassata* on the peneplain remnants but at

* Cleve Hills—a few hundred acres of small trees on alluvium. Kangaroo Island—a tall tree on alluvium forming "atypical savannah merging to sclerophyll forest" (Northcote and Tucker, 1948). Flinders Ranges—large handsome tree on quartzitic ridges above 1,000 feet contour. Savannah woodland (Boomsma, 1946).

its northern margin it is a tree of up to 20 feet in height. Fig. 5 indicates some of the relationships of *E. cladocalyx* and other eucalypts north of Yallunda Flat.

Thus on Eyre Peninsula dense stands only occur on lateritic or related soils and never naturally on limestone soils, which is interesting in view of the widespread and successful planting of it on such soils elsewhere. Its ecological limit may be related to subsoil or surface drainage and/or calcium carbonate enrichment in some way, perhaps operating only on seedling establishment and survival, as plantations elsewhere are usually planted as seedlings and watered the first year. To the north where its margin cannot be explained in edapho-climatic terms, it may be that in spreading from a centre of survival it has only reached this point. Further spread would be prevented by grazing as although young trees grow densely after firing they are easily grazed out.

3. *Eucalyptus leucoxylon*, var. *macrocarpa*

E. leucoxylon occurs extensively with *E. odorata*, but no hybrids have been noted on Eyre Peninsula which is of interest in the light of the observations of Pryor (1955), who records hybridising near Adelaide.

E. leucoxylon is found on alluvial soils of relatively high fertility on valley floors and lower slopes where moisture penetration is good, yet severe and prolonged waterlogging does not occur. Below 18 in. rainfall it is present only along creeks, e.g. it follows the Ungarra Creek out onto the plain into a 14 in. rainfall. It appears around the Marble Range where coarser sediments have been deposited. Its occurrence east of Yeelanna at Brooker where wind-blown siliceous sands have piled up in a drainage line is in a habitat usually occupied by *E. camaldulensis*.

4. *Eucalyptus odorata*

Both *E. odorata* and *E. odorata* var. *angustifolia* are widespread almost throughout the area under discussion.

(a) *E. odorata*

This tree form appears to be very similar to other occurrences in South Australia. It is the sole dominant on the most fertile soils – red-brown earths, chocolate skeletal soils of the upper slopes and a wide belt of fertile transitional red-brown earths from Lipson through Stokes to the railway line at Cockaleechie. Outliers occur at Mt. Isabella, north-east of Yeelanna, surrounding an outcrop of Archaean rocks, near Mt. Hope and near the Marble Range. Rainfall is always 16-19 inches and soils are always relatively fertile and well drained. There is a transition through an ecotone to *E. leucoxylon* where drainage is inferior as in the valleys in the southern half of the Koppio Hills.

(b) *E. odorata* var. *angustifolia*

The form of this variety is quite constant, being 6-12 feet high usually in clumps. It occurs on heavier textured, more waterlogged patches than the tree form within the same overall climatic limits. It is difficult to kill by burning and ploughing so is now conspicuous where it may not originally have been a prominent member of an association.

5. *Eucalyptus behriana*

E. behriana as a mallee form is scattered widely but generally infrequently through the mallee formations on the lower western slopes of the Koppio Hills from Wanilla to Yeelanna, and odd individuals are found along drainage lines further west. Specimens fit into the general type description of Blakely (1955), being conspicuous for their very broad leaves (up to 2 in.) and terminal paniculate inflorescence.

Rodger (1953) suggests that the typical habitat for this species is on dry soils, frequently calcareous sandy loams and sands. However, on Eyre Peninsula *E. behriana* is more usually found on heavy grey silty loams with 17-19 inches of rainfall, fitting more the habitat range described by Litchfield (1956) for the Coonalpyn Downs.

Due east of Cummins (Pl. 2, Fig. 1) *E. behriana* occurs as a co-dominant with *E. odorata* var. *angustifolia* on an area of grey silty alluvium with poor subsoil drainage. This is the only recorded occurrence of it as an association dominant in the area and provides a link with Victorian observations where Rodger (1953) lists *E. behriana* as commonly occurring with *Eucalyptus fruticetorum* (considered by Burbidge as being synonymous with *E. odorata* var. *angustifolia*) and *E. viridis*, a closely allied member of the *Odorata* complex.

6. *Eucalyptus calcicultrix*

Compared with other locations, *E. calcicultrix* is easily identified on Eyre Peninsula. It is restricted to the western side of Lower Eyre Peninsula, usually on deep calcareous sands and sandy loams over limestone in undoubtedly very dry habitats.

7. *Eucalyptus huberiana*

On Eyre Peninsula this species is not the handsome forest tree of other parts of Australia, but has curved trunks, giving a spreading, even straggling appearance. It occurs in two small patches some 15 miles apart and may not be indigenous. The main one consists of a dense clump of trees near the old Mikkara homestead, south of Port Lincoln, with odd trees within two miles; the second occurs west of the town near Big Swamp, and adjacent to the old coach road, consisting of some 20 trees. Bearing in mind their rapid regeneration after firing, both occurrences could have been derived from one or two trees planted near an old homestead and a coach watering point. On the other hand, location near an old homestead is not necessarily evidence of the trees having been introduced. In an area of mallee a group of larger trees would be a likely site for a homestead, especially as underground water could be found under the travertine layer.

Climatic considerations could support a natural occurrence, as the climate would be similar to its habitat elsewhere, with moderate temperature and reliable rainfall. Although there is a veneer of travertine at the southerly occurrence, roots would be in moist soil at reasonable depth in both cases. The two groups of trees are on opposite sides of a tongue of travertine which covers much of the area suitable climatically for its growth. Thus it is not surprising that its distribution is limited. However, there is some doubt as to how it survived the recent aridity, and subsequently came to occupy its present situation. It could be expected to have survived in the Koppio Hills also and to have expanded considerably more than it has with a recent increase in rainfall. All things considered, planting by early settlers seems likely.

8. *Eucalyptus diversifolia*

As elsewhere in South Australia, the occurrence of *E. diversifolia* is closely related to travertine limestone formations. It is the sole tree dominant over a scrub on limestone ridges near Kapinnie and Lake Hamilton.

9. *Eucalyptus incrassata*

Specimens vary in size of fruit, ribbing of fruit, and coarseness of foliage, but there appears to be less local variation than recorded by Coaldrake (1951) in the Upper South-East of South Australia, and within this region it grades into *E. pileata* rather than *E. anceps*. French (personal communication) has also verified the forms found here as *E. incrassata* var. *costata* (Burbidge) with some tendency to the even coarser var. *angulosa* (Benth). Certainly Burbidge's comment that these two are points in a series is borne out. No attempt has been made to separate them in this study, the specific name only being used.

E. incrassata is the most common mallee on solodized solonetz soils and the shallow secondary laterites on the Wanilla plain. In a few cases it has been found as a dominant on deep coastal siliceous sand dunes.

On the Cummins plain where "ripples" of siliceous sand form a mosaic on the otherwise heavy clay flood plain, *E. incrassata* follows closely the sand under which solonization has been most marked. Its tolerance to winter water-logging and summer dessication apparently enable it to maintain this distribution. Its tolerance to salinity (or physiological drought) allows it to persist further into some saline situations than other mallees.

Several trees occur on Boston Island near Port Lincoln. These are particularly coarse forms, having large, prominently-ribbed fruits and thick leaves.

10. *Eucalyptus pileata*

This and other members of the *dumosa* group present show considerable variation. *E. dumosa* as described by Burbidge (1947) is absent, but *E. pileata*, which is extremely widespread and often dominant, is similar in many ways. *E. anceps* (or an allied form) is common also, and *E. rugosa* and *E. conglobata* have a more restricted distribution.

E. pileata in its most common form matches the description of Burbidge. However, there is much variation in the fruits — small with faint ribs, smooth fruits, and larger fruits with more prominent ribs all occur. These last tend towards *E. incrassata*. Pedicel length also varies, grading towards *E. anceps*. *E. pileata* is widespread with *E. flocktoniae* in typical mallee formations on soils with broken nodular limestone in the profile and often on the surface.

Its rainfall limits appear to be 14-18 inches, being replaced by *E. gracilis* on the drier side of its range.

11. *Eucalyptus anceps*

Burbidge (1947) discusses the difficulty in differentiating this species from *E. pileata*, *E. rugosa* and *E. conglobata*, and in this study quite a range of material has been grouped as *E. anceps*. Certainly the presence or absence of a pedicel is not a good diagnostic character, and several pedicellate forms, too small and plain of fruit for *E. pileata*, have been included. The species is quite widespread at low frequency but never dominant on Lower Eyre Peninsula.

12. *Eucalyptus rugosa*

E. rugosa is a reasonable constant member of the *dumosa* group. It reaches its greatest frequency near Port Lincoln on or near the edge of the aeolianite limestone.

13. *Eucalyptus conglobata*

According to Blakely (1955), *E. conglobata* only occurs in Western Australia and South Australia and in the latter only on Eyre Peninsula and Kangaroo Island. On the Eyre Peninsula mainland it is scattered through other mallee associations near Port Lincoln, essentially as a stunted malle, often on lateritic soils. However, the absence of competitors and firing appear to have permitted it to develop into a dominant tree up to 40 feet high on Boston Island, where it forms an attractive woodland (Pl. 2, Fig. 3). Unfortunately, recent burning has destroyed many individuals — its peeling lower bark and bulbous, hollow butt make it fire-susceptible. It is also recorded on Taylors Island further south.

14. *Eucalyptus brachycalyx*

This also seems a reasonably fixed type except for the variety *chindoo*. It is not ecologically important, occurring at low frequency in the drier mallee scrub.

15. *Eucalyptus flocktoniae*

Field experience suggests that in certain localities this and *E. oleosa* form a complex, with intergrading of material from even small areas. French (personal communication) has confirmed this view. However, in many other areas on Lower Eyre Peninsula quite distinct *E. flocktoniae* can be identified, and in others quite distinct *E. oleosa* and various varieties, especially var. *glauca*.

Burbidge (1947) considers that *E. flocktoniae* is a link between *E. oleosa* and the Western Australian species *E. torquata*, and this Eyre Peninsula observation confirms this, although such difficulties have not been reported elsewhere. C. D. Boomsma, on examining material collected by the author, has suggested that *E. flocktoniae* and *E. oleosa* are more directly related than was earlier thought (Boomsma, 1949).

Both species, and all intergrades, are always true "mallees" in habit occurring on grey and brown calcareous loams and sandy loams, frequently solonised — typical "mallee" soils. *E. oleosa* in its strict sense generally occurs with *E. gracilis* in drier areas with rainfall below 14 inches per annum; *E. flocktoniae* with *E. pileata* is found on similar soils in wetter areas, as near Cummins where *E. flocktoniae* is quite a distinct species, matching the description of Burbidge (1947).

16. *Eucalyptus oleosa*

On Lower Eyre Peninsula specimens of *E. oleosa* var. *glauca* are particularly common with much true *E. oleosa* and a full range exists in some localities from *E. oleosa* through var. *glauca* to *E. flocktoniae*. One such series was collected over a square chain area near Mt. Hope. Yet, curiously, over much of the region the species and its variety are quite distinct from each other and from *E. flocktoniae*.

This is, of course, the widespread characteristic mallee of the arid zone of South Australia, and is only important in the drier north-east corner of the area under study.

17. *Eucalyptus leptophylla*

Over most of its occurrence this species matches the description of Burbidge (1947), but forms with thicker fruit walls and wider leaves cause some confusion. It is suggested that some hybridisation with *E. gracilis* may have occurred. The greatest variation in this species occurs in the Hd. of Mitchell.

E. leptophylla is widespread, especially with *E. incrassata*, occurring on slightly moister soils than pure stands of the latter.

18. *Eucalyptus uncinata*

Although specimens have been identified as *E. uncinata*, they could quite easily have been named shortly pedicellate *E. leptophylla*.

19. *Eucalyptus gracilis*

This species is rarely confused. Some forms appear to grade towards *E. leptophylla*, but if buds or flowers are present, it can be distinguished on stamen characteristics. A form found only on Boston Island has a very small cap, much narrower than the fruit, and foliage resembling *E. largiflorens*. *E. gracilis* occurs widely on solonised brown soils with moderate to heavy limestone, varying in texture from clay loams to sandy loams and usually receiving less than 14 inches average annual rainfall.

20. *Eucalyptus calycogona*

E. calycogona appears to grade completely into the coarse form, var. *staffordii*. It is quite widespread, especially with *E. flocktoniae-E. pileata* around Cummins. On some shallow red clay loams near Ungarra it is occasionally the sole dominant over small areas.

21. *Eucalyptus landsdowneana*

This member of the *odorata* complex was not widely collected, being restricted to the Port Lincoln-Wangary area at low frequency.

22. *Callitris propinqua* (Native Pine)

"Pine" does not occur extensively except in the north of the region on calcareous sands and sandy loams near Koolidie. It is much sought after as fence posts and has been heavily cut over. Further south soils are not particularly suitable for its growth.

23. *Acacia pycnantha*

Of the many species which have been introduced and now have a wide distribution the only tree species is *A. pycnantha*. Claimed to have been introduced in the 1880's, it is now widespread above 17 inches of rainfall on soils ranging from the sandy lateritic types of the hills to the heavy clays near Cummins. On the former it may become a secondary dominant after scrub burning.

24. *Xanthorrhoea tateana* (Yacca)

Yaccas occur throughout the *E. cladocalyx* woodland of the Koppio Hills (including some soils — for instance, skeletal slopes, on which *E. cladocalyx* does not grow) and throughout the Wanilla area. In the latter it extends beyond the *E. cladocalyx* association into the *E. incrassata* heath at least as far north as Kapinnie and inland to about six miles west of Cummins. It is always on sandy soils with rainfall usually above 17 inches, but perhaps slightly less in the Koppio Hills.

THE PLANT COMMUNITIES

The general relationships of the plant communities identified are shown in Figs. 2, 3, 4, 5, in Table 1, and in the floristic lists.

TABLE I

The Plant Communities

Formation	Association	Structural formula	Types and Societies	Soils and topography	Climatic Range
Mallee scrub	*E. oleosa-* *E. gracilis*	T/S_1 (v.d.) $-T/S_1S_2$ (d)		Undulating sandy and solonised brown soils, lime at surface or in profile	Mean annual rainfall less than 14″
			E. pileata (T)	Heavier soils showing influence of laterite	Apparently only near wetter margin, i.e., 13-14″
			E. calycogona (T)	Red soils tending to skeletal on ferruginous parent material	
	E. foctoniae- *E. pileata* *Melaleuca uncinata*	T/S_1S_2 (m.d.)		Red brown, brown and grey loams with heavy but broken limestone in the profile	13-18″
			Edaphic complex: *E. incrassata* -*E. leptophylla* (T)	Siliceous sands (usually 6-12″) accumulated on the above soils with increased solonisation	
				Occasionally on small areas of deep lateritic remnants or accumulations	
			Edaphic complex: *E. calycogona* (T)	Some drier sandy loams with fair drainage	14-18″
			Edaphic complex: *E. diversifolia* (T)	Travertine islands, or tongues of limestone, usually of no great thickness	13-18″
	E. diversifolia	T/S_1S_3 (d)		Very shallow loams on thin travertine	More than 13″
			E. conglobata	Deep calcareous sands. Mixed travertine and heavy ferruginous gravels	
			E. calcicultrix (T)	Slight accumulations of calcareous sands on travertine	
	E. incrassata- *E. leptophylla*			Infertile soils subject to water-logging and severe drying out- either solodized solonetz, solodic or lateritic soils	Less than 18″

TABLE 1.—The Plant Communities—*continued*

Formation	Association	Structural formula	Types and Societies	Soils and topography	Climatic Range
Mallee broombush	*E. incrassata* *E. leptophylla* *M. uncinata*	T/S_1S_2 (m.d.)	*E. incrassata-M. uncinata* (T)	Solonised brown and grey sandy loams, areas of shallow siliceous sand over clay	Less than 20″
			E. leptophylla (T)	Areas suffering less moisture stress than above	16-17″
			E. cladocalyx (T) (ecotone)	Drier parts of lateritic residuals on divides normally carrying *E. cladocalyx* association. Normal lateritic soils	18-20″
Mallee heath	*E. incrassata*	$T/S_1/S_2$ (d)	*Xanthorrhoea tateana-Banksia marginata*	Normal lateritic soils. Shallow laterite of Wanilla plain	18-20″
Savannah woodland	*E. odorata*	T.G.		Well drained red clay loams and some chocolate loams	16-19″
	E. odorata var *-E. behriana*	T.S. ? (d)		Deepish grey alluvium of medium but uniform grain size	17-19″
	E. odorata-C. stricta	T (m.d.)		Stony chocolate loams of upper slopes and certain skeletal soils on Archaean rocks	15-19″
	E. odorata-E. leucoxylon	$T S_1G$ (m.d.)		Drier alluvial soils of valley floors and lower slopes	More than 17″
	C. stricta-Melaleuca pubescens	T (o)		Shallow terra rossas and rendzinas	More than 16″
	E. camaldulensis	T (o)		Various localities in the "mallee" where deep penetration of the solum occurs and other areas with shallow water-tables	More than 17″
Sclerophyll	*E. cladocalyx*	$T S_1$ (d)		Well drained lateritic podzols, especially deeper profiles. Down slopes and in well drained valleys	More than 17″ 16-17″
			Xanthorrhoea tateana (S)	Shallow podzols	More than 17″
			C. stricta (T)	Mixed laterite and stony chocolate loams	
	E. diversifolia	T/S_1S_2 (d)		Shallow sandy loams over travertine	More than 20″

EXPLANATORY NOTES FOR FIG. 2

	General description of country	Soils	Vegetation dominants
a. N.-S. section through Cummins	1. Undulating aeolian travertine limestone	Shallow rendzinas and terra rossas	*C. stricta*, *M. pubescens*, savannah woodland
	2. Mixed gentle slopes and swampy areas	Some calcareous sands, rendzinas and peaty soils	*C. stricta*, *M. pubescens*, *E. diversifolia*, *E. calcicultrix*
	3. Low lying swampy area subject to flooding	Rendzinas and shallow peaty soils	Cutting grass and rushes
	4. Slightly dissected lateritic plain	Lateritic podzols	*E. incrassata*, heath
	5. Outwash fan and plain from dissection of area to the east. Poor drainage	Red brown earths, grey soils of heavy texture, solodic soils, and mallee soils	*E. pileata*, *E. flocktoniae*, *E. incrassata*, mallee scrub and broombush
	6. Undulating area, rises of travertine limestone	Solonised brown soils, some terra rossas	*E. pileata*, *E. flocktoniae*, *E. diversifolia*, scrub
	7. Rising land towards Yeelanna	Red brown earth of heavy texture	*E. pileata*, *E. flocktoniae*
b. E.-W. section through Mt. Greenly and Tumby Bay	1. Steep slopes of Mt. Greenly	Skeletal	*C. stricta*
	2. Bed of Lake Greenly	—	—
	3. Northern slope of Marble Range	Stony and lateritic podzols	*E. cladocalyx*, *E. incrassata*
	4. Wide drainage lines	Alluvium and solonchaks	*M. pubescens*, *Ghania trifida*, *Cladium filum*
	5. Flat outwash plain often crab-holey and water-logged	Grey soils of heavy texture, some red brown earths	*E. pileata*, *E. flocktoniae*, *E. incrassata*
	6. Dissected slopes	Variable stony podzols	*E. odorata*, *C. stricta*
	7. Peneplain surface	Lateritic soils	*E. cladocalyx*
	8. Valley slopes	Variable stony loams and alluvial soils	*E. odorata*, *E. leucoxylon*
	9. Peneplain surface	Lateritic	*E. cladocalyx*
	10. Deeply and sharply dissected	Skeletal	*C. stricta*
	11. Gently sloping outwash plain	Red brown earths	*E. odorata*
c. N.E.-S.W. section through Koppio, Stokes and Ungarra	1. Undulating aeolian travertine limestone	Shallow rendzinas, terra rossas, and some calcareous sands	*C. stricta*, *M. pubescens*, *E. diversifolia*
	2. Big swamp basin	Peaty soils on fringe	*E. camaldulensis*
	3. Slightly tilted shallowly dissected lateritic peneplain	Lateritic podzols	*E. cladocalyx*
	4. Dissected, often steep slopes of Tod River Valley	Variable loams, usually stony and podzolised. Some skeletal	*E. cladocalyx*, *E. odorata*, *E. leocoxylon*
	5. Slightly tilted, more sharply dissected lateritic peneplain	Lateritic podzols	*E. cladocalyx*, *E. incrassata*
	6. Outwash plain	Alluvium and red brown earths	*E. leucoxylon*, *E. odorata*, *E. pileata*
	7. Undulating	Red lateritic loams, and red brown earths	*E. flocktoniae*

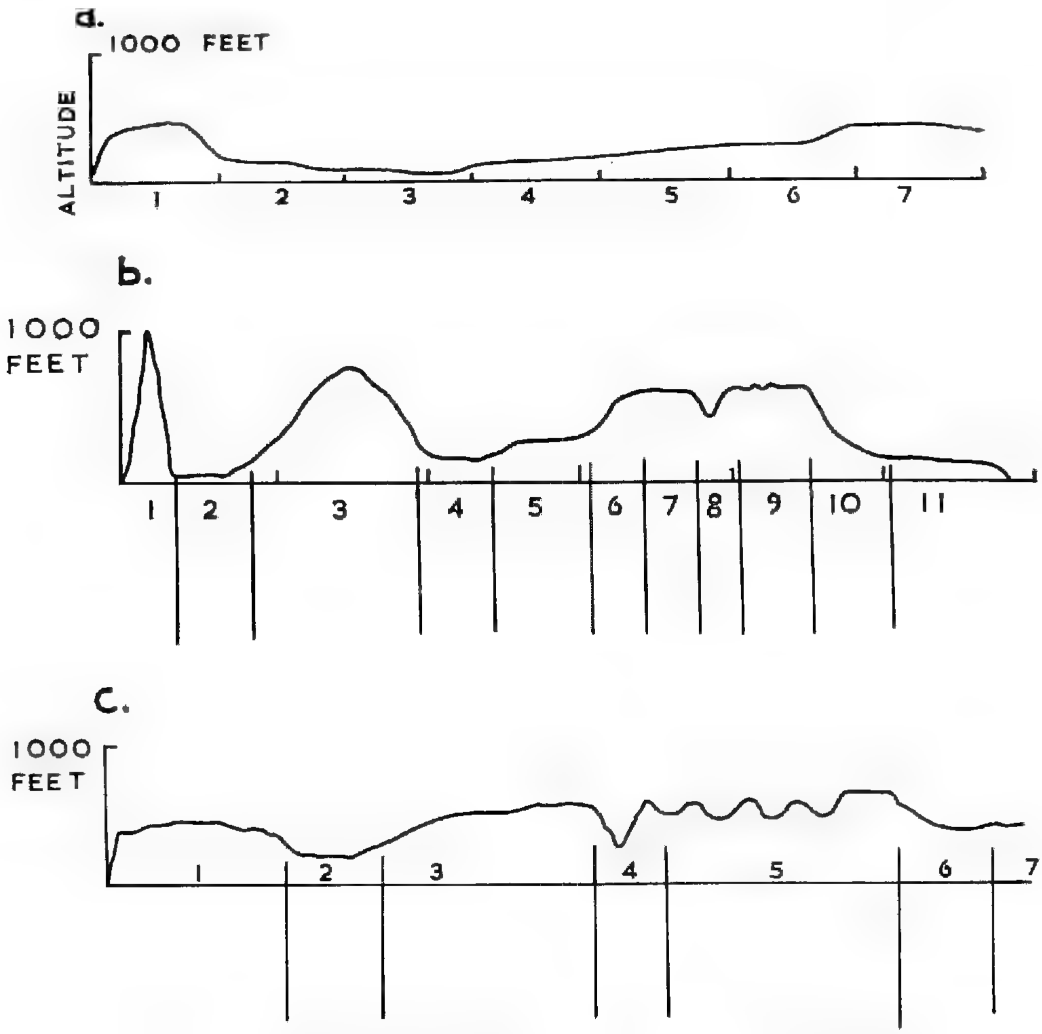


Fig. 2. Diagrammatic cross-sections through lower Eyre Peninsula.

a. North-south through Cummins.
b. East-west through Mt. Greenly and Tumby Bay.
c. North-east-south-east through Koppio, Stokes and Ungarra.

A. The Mallee

(1) *General*

It is possible to recognise certain basic associations in the mallee, especially in the less complex areas to the north, and these also appear in Lower Eyre Peninsula where soils are similar. A number of associations and types occur as an edaphic complex, more or less as suggested by Crocker (1946a). Some revision of the eucalypt classification has occurred since his work (Burbidge, 1947; Boomsma, 1949) and it is clear that his *E. dumosa* is now generally classified as *E. pileata*, and his *E. angulosa* as *E. incrassata*. Eight reasonably distinct and consistent major units of mallee vegetation have been recognised. They are:

a. *E. oleosa-E. gracilis* association.

b. *E. incrassata-E. leptophylla* association.
   i. *E. incrassata-Melaleuca uncinata* type.
   ii. *E. leptophylla* type.
   iii. *E. incrassata* type.

c. *E. flocktoniae-E. pileata-Melaleuca uncinata* association.

d. *E. diversifolia* association.
   i. *E. diversifolia-E. calcicultrix* type.

Their relationships are shown in Fig. 3.

The vegetation pattern is extremely complex on such areas as the Cummins plain where variations in calcium carbonate content from quite massive travertine to faint marl, in drainage from free to waterlogging, and in siliceous sand cover (and hence degree of solonisation) from 9 inches to none may all occur in various combinations within a few acres.

Another unit of vegetation which could be mentioned here is *E. conglobata* woodland. It occurs as a mallee less than 10 feet high near Port Lincoln on the margin of the travertine and laterite, and on Boston Island it forms a woodland usually as a tree with one trunk, but a bulbous base not unlike a mallee.

(2) *Individual Communities*

a. *E. oleosa-E. gracilis* Association.

This association is quite widespread on Eyre Peninsula, especially around Cleve, Kimba and Wudinna, obviously being more tolerant to arid conditions than any other mallee association in this region. In the area studied it is almost limited to the drier east coast region with less than 14 inches of annual rainfall.

Soils are usually red-brown sandy loams with lime rubble or travertine at 8-11 inches, often having free surface limestone, and best described as sandy solonised brown soils. Above 14 inches of average annual rainfall it occurs only on very light-textured soils, as near Mt. Hope where it is intermixed with the *E. diversifolia* and *E. flocktoniae-E. pileata* associations over a small area.

This association is usually a mallee scrub with a rich under-storey of shrubs (especially after burning), the most common being *Melaleuca uncinata*, *Rhagodia crassifolia*, *Lasiopetalum behrii*, *Acacia gillii*, *A. spinescens*, *Pimelea dichotoma*, *Dampiera rosmarinifolia*, *Loudonia behrii*, *Didiscus ornatus*, *Amyema miraculosa* var. *melaleucae*, *Dodonaea hexandra*, *Eutaxia microphylla*, *Halgania cyanea* and *Dodonaea baueri*.

b. *E. incrassata-E. leptophylla* Association

The balance between codominance of the two eucalypts and individual dominance is a very delicate one. The association occurs in areas of solonised soils with a mantle of siliceous sands or areas of shallow laterite profiles. *E. incrassata* is apparently very resistant to both drought and waterlogging, with *E. leptophylla* less resistant to drought.

On deeper sandy areas, up to four feet or more in depth, *E. incrassata* occurs as the sole tree dominant, or with an odd tree of *E. diversifolia*. *E.*

leptophylla is more evident when sand is less than nine inches, being co-dominant with *E. incrassata* and *M. uncinata*. On wetter flats with a few inches of sand *E. leptophylla* may be the sole dominant.

On sandy lateritic profiles west of Cummins near the lakes, *E. incrassata* and *E. leptophylla* form an open mallee heath formation, with a rich under-storey. *Melaleuca decussata, Hibbertia stricta, Grevillea ilicifolia, Cheiranthera linearis, Hakea cycloptera, Hibbertia sericea* var. *major, Baeckea behrii, Pultenaea trinervis* and *Spyridum vexilliferum* are the most common shrubs. *Xanthorrhoea tateana* is present, especially towards the south.

On the shallow lateritic soils near Wanilla a very stunted form of *E. incrassata* (3-5 feet high) occurs with *M. uncinata* and with *E. leptophylla* present on moister soils. *E. incrassata* also occurs on the dry tops of the divides in the northern Koppio Hills, replacing *E. cladocalyx*.

The under-storey on the Cummins plain is discussed jointly with that of the *E. flocktoniae-E. pileata-M. uncinata* association.

c. *E. flocktoniae-E. pileata-M. uncinata* Association.

This association is very widespread on solonised brown and grey-brown or red-brown loams with heavy limestone rubble in the profile and frequently with surface stones. Surface texture and colour varies considerably from loams to clay loams and clays. Limestone may be so heavy as to form massive ridges, carrying *E. diversifolia*, especially between Cummins and Yeelanna. In the wet hollows of the drainage lines near the hills the association is replaced by *E. odorata* var. *angustifolia*, a whipstick mallee. Where siliceous sands or lateritic profiles occur *E. incrassata* replaces it and where sandy solonised soils occur the *E. oleosa-E. gracilis* association is dominant.

Associated eucalypts are *E. leptophylla* and *E. calycogona*, which is almost a dominant on some sites. The under-storey is quite rich, with much inter-twining *Cassytha melantha*. Low acacias such as *Acacia microcarpa* and *A. acinacea*, and *Melaleuca uncinata* are frequently prominent, with also *Daviesia pectinata, Eutaxia microphylla, Lasiopetalum behrii, Baeckea crassifolia, Hakea cycloptera* and *Hibbertia stricta*. A wide variety of orchids occurs in season.

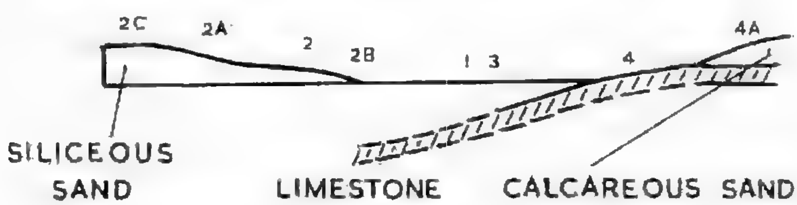


Fig. 3. Relationship of mallee communities.

1. *E. oleosa-E. gracilis* association.
2. *E. incrassata-E. leptophylla* association.
   - A. *E. incrassata-M. uncinata* type.
   - B. *E. leptophylla* type.
   - C. *E. incrassata* type.
3. *E. flocktoniae-E. pileata-M. uncinata* association.
4. *E. diversifolia* association.
   - A. *E. diversifolia-E. calcicultrix* type.

Most of these undershrubs persist even on the lighter soils where *E. incrassata* and *E. leptophylla* are the dominant trees, with perhaps more *Dampiera rosmarinifolia*, *Dillwynia hispida* and *Prostanthera microphylla*. In wet hollows *Callistemon macropunctatus* (syn. *C. rugulosus*), *Lasiopetalum behrii* and *Melaleuca acuminata* are the most prominent shrubs.

Where travertine limestone occurs in the soil at shallow depths the chief shrubs are *Acacia spinescens*, *Lasiopetalum behrii*, *Grevillea ilicifolia*, *Goodenia geniculata* and *Correa reflexa*.

d. *E. diversifolia* Association

Although this is frequently open it may occur as dense whipstick mallee with no under-storey. Its occurrence is virtually restricted to travertine areas with very shallow soil coverings. The limestone is rarely thick and usually cracked. Many of the shrubs are those found in mallee scrubs nearby, with more of the high rainfall sclerophyll species near Port Lincoln.

Towards the western coastline where calcareous sands have accumulated on the travertine *E. diversifolia* and *E. calcicultrix* occur together with or without scrub elements.

e. *E. conglobata* Association

The association is only found on Boston Island (Pl. 2, Fig. 3) and perhaps Taylors Island. Associated eucalypts are *E. gracilis* and *E. incrassata* and a few sclerophyllous shrubs – *Anthocercis anisantha*, *Pimelea stricta* and the fern *Cheilanthes tenuifolia*. Others may have been exterminated by sheep grazing.

B. Savannah Woodland and Sclerophyll Scrub

(1) *General*

It is frequently difficult to determine the original extent of sclerophyll scrub, as large areas, through grazing out of the under-storey, may now have the appearance of woodland. Of the eucalypts present, *E. odorata* and *E. camaldulensis* are possibly the only two which formed a true savannah woodland, the former as a single dominant and with *E. leucoxylon* on alluvial soils in the Koppio Hills and *E. camaldulensis* in isolated small areas especially near Wangary and Mt. Dutton. *E. cladocalyx* is usually the dominant in a dry sclerophyll scrub, and where it now appears as a savannah woodland the shrubs have apparently been eliminated by grazing.

(2) *Individual Communities*

a. *E. cladocalyx* Association

As a sclerophyll scrub this occurs on residual lateritic podzols on the plateau remnants of the hills (Pl. 1, Figs. 1 and 2) and also extensively near the Marble Range. Its margin is sharp (see notes on individual species).

At its northern limits *E. cladocalyx* forms an ecotone with *E. incrassata* over a dense mallee scrub. *Daviesia polyphylla* and *Pultenaea teretifolia* form local societies. *Xanthorrhoea tateana*, *Spyridium vexilliferum*, *Hakea rugosa*, *H. cycloptera*, *Astroloma conostephioides*, *Grevillea ilicifolia*, *Hibbertia stricta*, *Lasiopetalum behrii* and *Melaleuca uncinata* are the most common shrubs. Trees of *Casuarina stricta* and *Acacia pycnantha* are present.

Near Wanilla on the edge of the peneplain and down the slopes on normal lateritic profiles, *E. cladocalyx* forms a canopy over a dense and varied scrub. *Xanthorrhoea tateana* and *Acacia rupicola* are extremely common, while *Baeckea* *behrii, Daviesia brevifolia, Grevillea ilicifolia, Astroloma humifusum, A. conostephioides, Melaleuca uncinata. Hibbertia stricta* and *Exocarpus sparteus* are less so, with many other minor species.

On the shallow gneissic stony loams of the slopes the under-storey is relatively poor, and *Xanthorrhoea tateana* may form a society. *Casuarina stricta* is also more common on these soils.

b. *E. odorata-Casuarina stricta* Edaphic Complex

(i) *E. odorata* as a pure dominant.

As a tree form, *E. odorata* occurs almost as a pure dominant in many places on lower Eyre Peninsula. The edaphic and climatic factors controlling its distribution have been discussed in the notes on individual species. Ground cover is usually *Danthonia semiannularis* and various *Stipa* spp. with some *Dianella revoluta* and *Bulbine semibarbata.*

On the deeper red-brown earths of the Cockaleechie Valley, mallee scrub merges into an *E. odorata* woodland. The transitional stage contains woodland and mallee scrub elements -- *Dianella revoluta, Bulbine semibarbata, Enchylaena tomentosa, Acacia acinacea, Cassinia complanata. Dodonaea baueri, Muehlenbeckia adpressa, Thryptomene micrantha, Lasiopetalum baueri, Eutaxia microphylla* and *Daviesia pectinata* being most obvious.

E. odorata also occurs in a whipstick mallee form and its ecological relationship to the tree is one of the most puzzling features encountered. Its habitat has been discussed earlier (see notes on individual species). It is rarely a dominant in an association, and does not seem to grade into the tree form. A variety of shrubs may be present from surrounding scrub.

(ii) *E. odorata-Casuarina stricta* Savannah Woodland.

Where soils are shallower, steeper sloping and apparently drier, *E. odorata* is increasingly mixed with *Casuarina stricta*, which may completely replace it on very steep skeletal soils. Along the eastern scarp of the Koppio Hills *C. stricta* appears to have been the sole tree dominant but in several places -- as near the Burrawing Mine, west of Tumby Bay -- *E. odorata* occupies some surprisingly steep situations.

(iii) *E. odorata-E. leucoxylon* Association

This association occurs on all the well-drained alluvial sites in the Koppio Hills, and also near the Marble Range. Although *E. odorata* may be almost absent in a few localities, it is probably better to consider the presence of both as an association rather than an ecotone of *E. leucoxylon* and *E. odorata* association. The association reaches its maximum development near Yallunda Flat, where both members are found well up the slopes. This is one of the few cases where remnants of apparently untouched vegetation were not seen. Being on fertile, well-watered soils, much of this association was cleared soon after settlement. It was apparently a savannah woodland.

(iv) *E. odorata* var. *angustifolia-E. behriana* Association

Although *E. behriana* can be found scattered over a wide area on grey silty loams in and west of the Koppio Hills, it only reaches dominance in a few places. East of Cummins where a number of creeks give a considerable area of this type of soil, *E. odorata* var. *angustifolia* and *E. behriana* are co-dominant. This vegetation type apparently extended over some thousand or more acres. Shrubs may be present.

c. *E. camaldulensis* Savannah Woodland.

At Dutton and Wangary *E. camaldulensis* savannah woodland covers a few thousand acres on areas of alluvium and meadow podzolic soils. Patches also occur in isolated areas throughout the plain where there is deep water pentration of the soil. Otherwise *E. camaldulensis* occurs in an ecotone with *E. diversifolia* where water flows into or under the travertine. (See Fig. 4.)

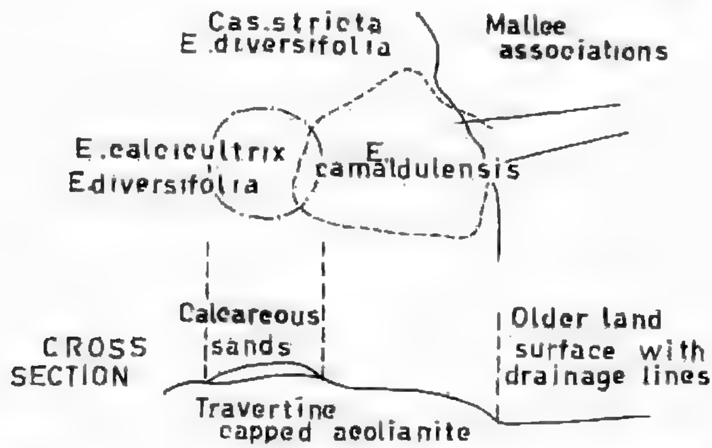


Fig. 4. Location of *Eucalyptus camaldulensis* in relation to limestone.

d. *Casuarina stricta-Melaleuca pubescens* Savannah Woodland.

Although a common association on upper Eyre Peninsula this only occurs in a strip along the west coast from near Port Lincoln to Lake Hamilton on rendzinas and terra rossas. *M. pubescens* is present especially on lower slopes, being rare on skeletal rises. Towards Port Lincoln this association is interspersed with *E. diversifolia* mallee scrub. Large areas are completely devoid of trees, only rotting trunks indicating the former dominants. *C. stricta* is a short-lived tree and rabbits and sheep have prevented regeneration.

Principal native grasses appear to have been *Danthonia semiannularis*, and *Stipa eremophila*. *Spinifex hirsutus* is very common near the coast and *Nicotiana glauca* (tobacco bush) near Lake Greenly.

This association also occurs along the coast north of Tumby Bay, where shallow loams have formed over Archaean rocks. Much of this land has been cleared, and it is difficult to tell whether the original vegetation contained much *M. pubescens*, or was pure *C. stricta* woodland. *Lomandra leucocephala* remains common on skeletal slopes to the north and *Xanthorrhoea tateana* to the south.

e. *Casuarina stricta*

On skeletal soils on the steep faces of such hills as Mt. Dutton and Mt. Hope, *Casuarina stricta* appears to have always been the sole dominant. Its relationship with *E. odorata* on the eastern fringe of the Koppio Hills has already been described.

f. *Melaleuca pubescens* is often the sole dominant on shallow soils near the edges of salt lakes.

C. Ecotones

Because of the complexity of the soil pattern, the dependence of vegetation on soil characteristics, and the gentle climatic gradients, ecotones frequently occur, some so frequently as to be given association rank, e.g. *E. odorata* with *E. leucoxylon* and *E. odorata* with *Casuarina stricta*. This is, of course, to be expected where several species have habitat ranges which differ only slightly. Because the margin of the *E. cladocalyx* scrub is often sharp ecotones between it and the mallee are not as common as might be expected.

Main ecotones are—

(a) *E. cladocalyx-E. incrassata-E. leptophylla.*

This occurs near the north-western margin of the sugar gum where *E. incrassata* is present on the drier lateritic soils of the peneplain in sparse and depauperate stands of *E. cladocalyx.*

(b) *E. cladocalyx-E. odorata* var. *angustifolia.*

Just below the breakaway edge of the lateritic capping of the peneplain there is frequently a band of this ecotone. The presence of lateritic gravel and stone, and soakage from the peneplain apparently make ecesis of both possible. Fig. 5 shows this relationship.

(c) *E. odorata-Casuarina stricta.*

This ecotone is undoubtedly an expression of the gradual transition from dry skeletal soils (carrying *Casuarina stricta*) to the deep, well-drained, red-brown loams at the foot of slopes or chocolate loams of the gentler mid-slopes both of which carry *E. odorata.*

(d) *E. diversifolia-Casuarina stricta-E. camaldulensis.*

As already described these form an ecotone at the edge of the travertine (Fig. 4), the *E. diversifolia* and *C. stricta* being adapted to surface conditions—shallow, dry rendzinas—and the *E. camaldulensis* persisting because of underground water at shallow depths.

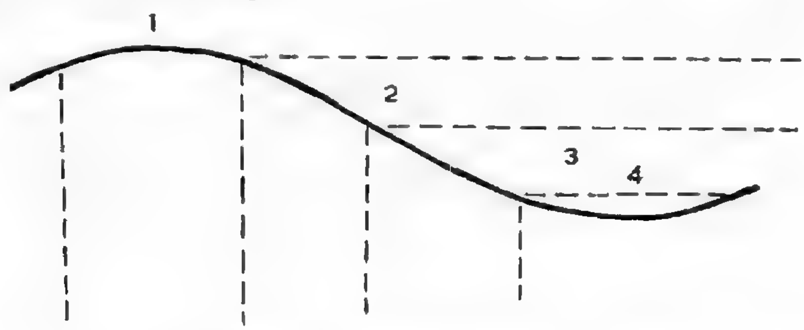


Fig. 5. Vegetation of the dissected peneplain and slopes.

1. *E. cladocalyx* scrub on peneplain.
2. *E. cladocalyx-E. odorata* var. *angustifolia* scrub below breakaway edge.
3. *E. odorata* woodland on variable stony loams on slopes.
4. *E. odorata-E. leucoxylon* on valley floor alluvium.

(e) *E. camaldulensis-Callitris propinqua.*

This ecotone at Koolidie Station is due to similar conditions to (d) above, with *Callitris propinqua* on deep sandy soils overlying limestone with a shallow watertable.

D. DISCUSSION

(a) *Relationship of the Plant Communities.*

The structure, range and relationship of the plant communities is summarised in Table 1. The structural formulae are based on the work of Wood (1960). Figs. 3-5 indicate other aspects especially the effect of local changes in soil factors on vegetation.

(b) *Ecological Significance of Species Distributions.*

Because of arid conditions prevailing across northern Eyre Peninsula, the moister southern portion carries a flora which is completely isolated from that of similar climatic zones in South Australia and Western Australia.

It seems likely from a consideration of climatic data and soil type studies that rarely, if ever, would a species from lower Eyre Peninsula have a continuous distribution through this northern part to some other occurrence. Mean annual rainfall falls below 10 inches around Whyalla and on the Nullarbor Plain. Crocker (1946a) describes the vegetation of this region — an *Acacia sowdenii-Casuarina lepidophloia* edaphic complex with saltbush and bluebush, typical of much of the north-west of South Australia.

Thus most species found in the region here described are separated from their main occurrence. Wood (1930) has compared the sclerophyll vegetation of Kangaroo Island and the adjacent peninsulas, and found only 10 recorded species to be endemic to Eyre Peninsula. Crocker and Wood (1947) have suggested that a period of aridity during the mid-Recent, apparently sudden in onset, caused a widespread destruction of vegetation, a retreat to centres of survival where steep climatic gradients enabled the relatively slow-moving vegetation units to keep pace with climatic change, and the initiation of changes in soil morphology. This last is fully discussed by Crocker (1946b). Crocker and Wood further suggest that a slightly moister present climate has permitted expansion from these centres of survival, but onto a soil mosaic unrelated in many ways to that preceding retreat. Their list of probable centres of survival includes the Koppio Hills and Cleve Hills on Eyre Peninsula, the Gawler Ranges across its northern boundary, Kangaroo Island, and the Mt. Lofty and Flinders Ranges on the mainland. They also quote examples from Eyre Peninsula vegetation to support their arguments.

Table 2 shows the occurrence elsewhere of the eucalypt species recorded on lower Eyre Peninsula. In most cases varieties have been grouped together under the specific title. The groupings of species in brackets according to the relationship suggested by Boomsma (1949) indicates the strong development of certain groups.

From the consideration of present topography and rainfall gradients it is apparent that of the survival centres suggested by Crocker and Wood, Mt. Lofty and Flinders Range would be favourable to high rainfall species and variable in habitats, Kangaroo Island would be slightly less favourable and less varied, Eyre Peninsula still less, and Yorke Peninsula very poor. High rainfall country eucalypts, even if they did occur on Eyre Peninsula, would be forced south, then extinguished. When rainfall increased again they could not recolonise unless powers of long distance dispersion were high.

If we assume that the past climatic range of the species was as it is today, we can predict which species would have survived. Table 3 lists a number of higher rainfall eucalypts, the rainfall range given for various areas, and the

TABLE 2

Occurrence of Lower Eyre Peninsula Eucalypts in other regions in South Australia

Species	Elsewhere on Eyre Peninsula	Yorke Peninsula	Kangaroo Island	Flinders Range Area	Mt. Lofty Range Area	Western Aust.	Upper South East and Murray Mallee
E. camaldulensis	+	–	–	+	+	+	+
E. diversifolia	+	+	+		–	+	+
E. incrassata	+	+	+	+	+	+	+
E. conglobata	+	–	+	–	–	+	–
E. anceps	+	+	+	+	+	+	+
E. rugosa	+	–	+	–	+	+	+
E. pileata	+	+	+	–	+	+	–
E. brachycalyx	+	–	–	+	–	–	+
E. leptophylla	+	+	+	+	+	+	+
E. uncinata	+	–	–	–	–	+	–
E. oleosa	+	+	+	+	+	+	+
E. flocktoniae	+	+	–	–	–	+	–
E. calycogona	+	+	+		+	+	+
E. gracilis	+	+	–	+	–	+	+
E. huberiana	–	–	+	–	+	–	+
E. leucoxylon	+	–	+	+	+	–	+
E. calcicultrix	+	+	–	+	+	–	+
E. odorata	+	+	+	+	+	–	+
E. odorata var. *angustifolia*	+		–	+	+ (?)	–	–
E. landsdowneana	+	–	+	–	–	–	–
E. behriana		–	+	+	+	–	+
E. cladocalyx	+		+	+	–	–	–
22	20	11	15	13	14	13	15

Sources of information for Tables 2 and 3: Baldwin and Crocker (1941), Black (1945-52), Boomsma (1946), Burbridge (1947), Coaldrake (1951), Crocker, 1944), Jessup (1948), Litchfield (1956), Northcote and Tucker (1948), Rodger (1953), Specht (1951), Specht and Perry (1948), and Wood (1930).

figures of Rodger (1953) for their general range. Thus a period of aridity when rainfall fell, say, 5 inches below the present level would eliminate all *E. obliqua*, *E. baxteri*, and perhaps *E. viminalis* from Eyre Peninsula and all but *E. camaldulensis* from Yorke Peninsula (and as there are no watercourse sites anyway all six would probably be extinguished). *E. odorata*, which is generally recognised as having a slightly drier range than *E. leucoxylon* and *E. cladocalyx*, could survive on Yorke Peninsula.

TABLE 3

Climatic ranges of some eucalypts in South Australia

Species	Mean Annual Rainfall					
	Mt. Lofty Range	Flinders Range	Kangaroo Island	Eyre Peninsula	General (Rodger)	Wet Days (Rodger)
E. obliqua	35-45	—	23		30-50	100-200
E. viminalis	30-40	-	—	23	25-55	80-150
E. baxteri	30-45	—	24	—	25-30	100-160
E. leucoxylon	25-40	16		17	15-35	75-125
E. camaldulensis	18-35	13	—	15	10-25	40-150
E. cladocalyx		18	20-30	16	15-25	70-110
					Yorke Peninsula	
Max. rainfall in area	45"	30"	26"	23"	20"	
Max. no. wet days inland	150	100	120	95	112	

An Arid Period rainfall decline of the magnitude suggested by Downes (1954) would mean an average annual figure of 12-13 inches near Green Patch, which now receives 23 inches. If this was the moistest part of lower Eyre Peninsula, survival of *E. cladocalyx*, *E. leucoxylon* and even *E. odorata* would have been difficult. This suggests that the proposed rainfall decline in the Arid Period is excessive, and combined with evidence from Yorke Peninsula (where *E. odorata* only has survived), a decline of 5-6 inches in the present 20-23 inches rainfall zone appears more likely.

Little is known of the methods or the range of dispersal of eucalypts. An alternative explanation to that of Crocker and Wood – that the Eyre Peninsula vegetation is a relic of once widespread vegetation – is that all of these eucalypts have been introduced by long distance dispersal from other centres. The presence of *E. cladocalyx* as a dominant without many of its usual under-storey elements could be used as an argument for this. Its absence from Yorke Peninsula and the Mt. Lofty Range, however, argues against this. Furthermore, the *E. cladocalyx* on Eyre Peninsula is quite a different ecotype occurring in a different habitat (see notes on individual species). In fact, the absence of eucalypts from situations is probably better evidence for the theory of Crocker and Wood than their presence. A number of cases can be cited.

(i) *The Distribution of Eucalypts on Offshore Islands.*

From all information available it seems that the only eucalypts on offshore islands are—

Boston Island: *E. conglobata*, *E. incrassata*, *E. gracilis*.
Taylors Island: *E. conglobata*.
Thistle Island: *E. camaldulensis*, *E. incrassata*, *E. diversifolia*.

If long distance dispersal was intensely operative one would expect a greater range of eucalypts on these islands, and at least some on the other islands which have none, all being relatively so close to a mainland rich in eucalypt species.

(ii) *The Distribution of* E. camaldulensis.

This tree occurs only to the west of the watershed of the Koppio Hills, despite the apparent suitability of several valley sites in the hills. It is suggested that survival somewhere near Wanilla (possibly several centres) may have provided seeds which through water movement spread downstream to many of the present sites, but not over the divide.

(iii) *The Absence of Certain Species near Sleaford.*

A strip of travertine stretches from the west coast to near Port Lincoln, effectively separating the lateritic soils of the Sleaford region from the main area. Although no reliable rainfall data is available, it is obvious that it is at least 20 inches per annum, i.e. quite a suitable habitat for *E. cladocalyx*. Slight valleys should be suitable for *E. leucoxylon* and *E. odorata*. If long distances dispersal was operative to any extent these species should be present. On the other hand, if the centre of survival was in the Koppio Hills and distribution depends on migration, this belt of shallow soils on limestone would prove a very effective barrier to migration, giving the present distribution.

GENERAL CONCLUSIONS AND DISCUSSION

The vegetation units of the area show a general similarity with units having the same dominants elsewhere. A very detailed study of the Hundred of Stokes, which includes the north-western and northern boundaries of the sugar gum community, should prove worthwhile. It also contains most of the other major units of vegetation, and has the advantage of having several large, uncleared areas of scrub, two of these being more than 5,000 acres each. Both appeared to have escaped any major disturbance, such as firing, at least in recent years.

The Hundred of Kiana which straddles the margin of the travertine-capped aeolianite of the western coast also has an interesting range of soils and uncleared vegetation, worthy of closer study. However, active clearing in the last decade with extensive firing must have left a mark on much of this. The Hundred of Flinders, which is a flora and fauna reserve, has not been dealt with in this paper. While the author has visited the western edge on several occasions, it was felt better to omit it than to map it from aerial photos only. It apparently is largely a sandy and stony area like other coastal regions, but there are several outcrops of Archaean rocks giving a range of soil types, and some lateritic remnants. As climatic conditions are undoubtedly fairly uniform throughout, a detailed study of this almost untouched area should also be of great value.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the late Professor J. G. Wood, who suggested this work and spent much time in stimulating discussion. Dr. R. L. Specht has read the manuscript and made many valuable comments.

In the field the late Mr. Worsely Johnston, Agricultural Adviser at Port Lincoln, was always a helpful critic and friend. Mr. John Roe of Tumby Bay, Messrs. E. and W. Nosworthy of Lake Hamilton, and many other Eyre Peninsula people assisted both in hospitality and discussion on land settlement, vegetation and soils.

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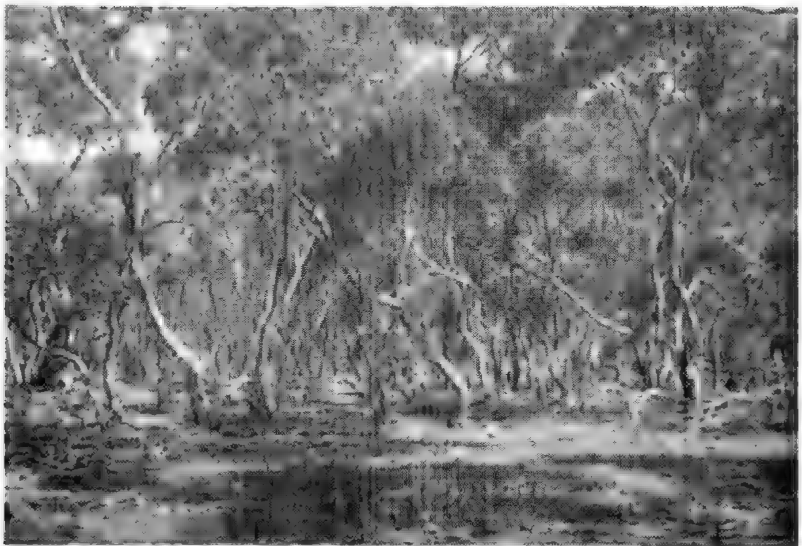

Fig. 1. Depauperate *Eucalyptus cladocalyx* near its north-western limit near Stokes.

Fig. 2. Large specimen of *E. cladocalyx* near Wanilla.

Fig. 1. *E. behriana* near Curtiwilla Creek east of Cummins.

Fig. 2. *E. camaldulensis* at Koolidie Station homestead growing in travertine limestone.

Fig. 3. *E. conglobata* woodland on deeper soils of Boston Island near Port Lincoln.

GEOPHYSICAL SURVEY OF THE OFFICER BASIN, SOUTH AUSTRALIA

BY I. A. MUMME

Summary

A combined gravity and magnetic survey was conducted from Fisher (on the Transcontinental Railway) across the Great Victoria Desert to Mount Davies, to investigate the possibility of a deep sedimentary basin occurring between the Nullarbor Plain stable shelf and the Musgrave nucleus, as suggested from the results of trial airborne magnetometer surveys conducted by the Bureau of Mineral Resources in 1954. This gravity work shows that a significant "gravity low" coincides with the assumed basin detected by the airborne magnetometer and also strongly suggests that such a basin (which has been called the Officer Basin) actually exists.

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[Read 8 November 1962]

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INTRODUCTION

A series of gravity and magnetic observations were carried out at approximately two-mile intervals across the Officer Basin at the request of Exoil Pty. Ltd., Sydney, to investigate the possibility of a sedimentary basin of considerable depth occurring between the Nullarbor Basin stable shelf and the belt of ranges situated along the N.T.-S.A. border comprising the Musgrave nucleus.

The possible existence of such a sedimentary basin was brought to light by an airborne reconnaissance magnetic survey conducted by the Bureau of Mineral Resources during May, 1954. (J. H. Quilty and P. E. Goodeve, 1958.) These magnetic results indicate that the greatest thickness of possible oil-bearing sediments in western South Australia are to be found in an area designated as the Officer Basin which extends for approximately 100 miles south from the known southern margin of the Musgrave nucleus.

PREVIOUS GEOPHYSICAL METHODS

The earliest geological and geophysical investigations in western South Australia for possible oil-bearing sediments were confined to the Nullarbor Plain area, and consequently the area occupied by the Great Victoria Desert was completely neglected, for geologically it was considered to be of little interest.

In 1954 the Commonwealth Bureau of Mineral Resources carried out a reconnaissance airborne magnetic survey over certain areas of western South Australia, and adjoining areas in Western Australia. The area surveyed extends from Oodnadatta in the east to Kalgoorlie in the west, and from the Northern Territory border in the north to the Great Australian Bight in the south.

The results of this airborne magnetic survey indicated that the greatest thickness of sediments in western South Australia is to be found in the area comprising the Great Victoria Desert. This sedimentary basin has been designated as the Officer Basin.

* Geophysicist, Department of Mines, South Australia.

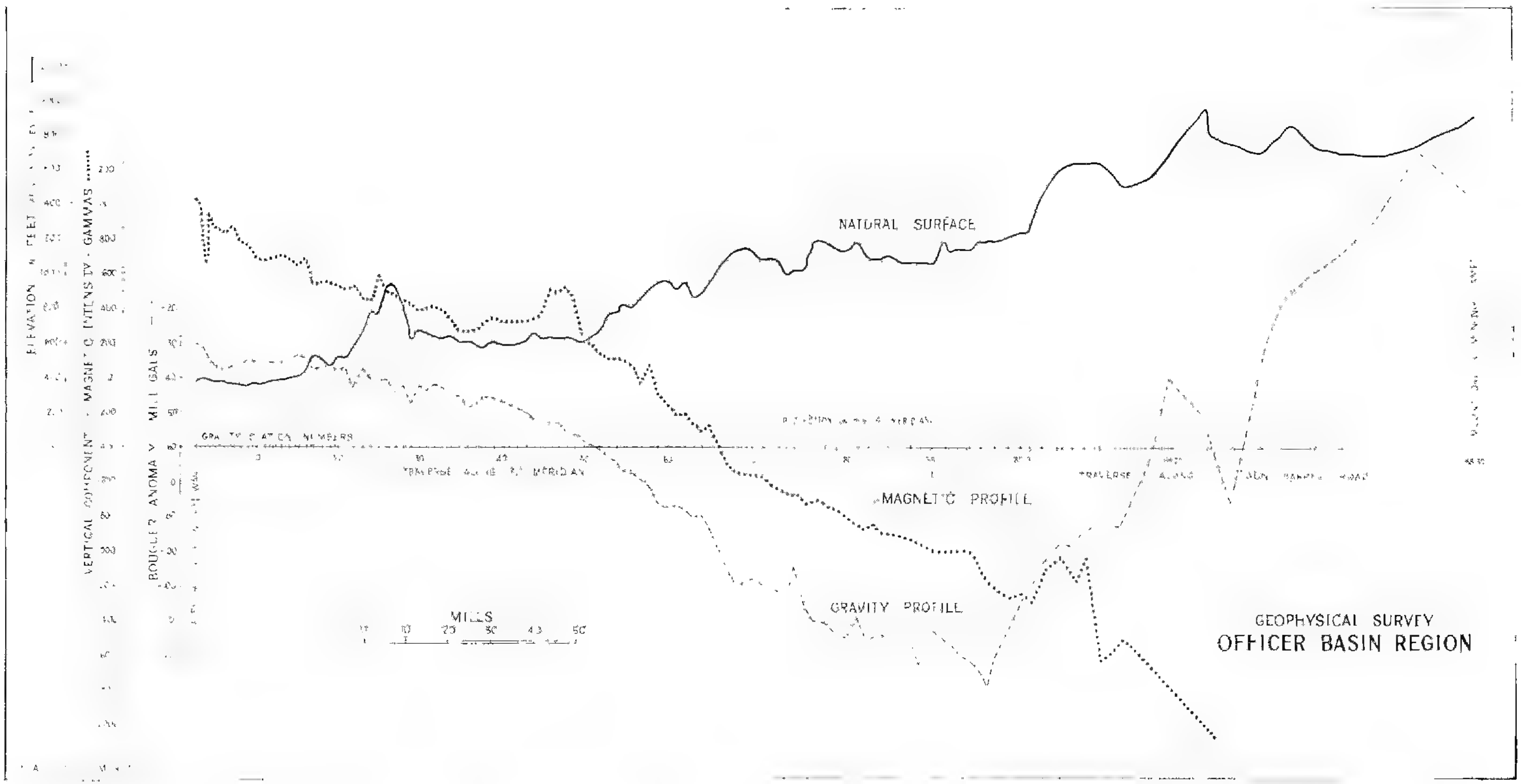

Fig. 1. Plan showing location of magnetic and gravity stations between Fisher and Mt. Davies, together with variations in elevation, gravity, and the vertical component of the earth's magnetic field for traverse between Fisher and Mt. Davies as projected on the 131° of longitude.

METHODS USED

(a) *Geophysical Station Location*

Along the helicopter traverse from Fisher to the Gun Barrel road the geophysical stations occupied were located with the aid of scaled aerial photographs.

In the Great Victoria Desert the stations were located between dunes and every fifth station was marked by a yellow flag.

Along the Gun Barrel road to Mt. Davies and along the road from Mt. Davies to Oodnadatta, the stations occupied were located from aeronautical charts and fixed by speedometer readings.

The survey was carried out in four stages. The first stage was conducted by helicopter from Fisher on the Transcontinental Railway (latitude 30°30′) for a distance of 180 miles along the 131° of longitude as far as the intersection of that meridian and the Gun Barrel road at a latitude of approximately 28°0′ (see plan L60-149).

Gravity, magnetic and altitude measurements were taken at intervals of approximately two miles over this section of traverse, and 80 stations were occupied.

The second stage of the survey was conducted from station 71 of the helicopter traverse along a road leading towards Emu, and then up the Gun Barrel road to the termination of the helicopter traverse at station 88. Gravity, magnetic and elevation determinations were made, and 19 stations occupied in this section of the survey.

The third stage of the survey was conducted from the end of the helicopter traverse (station 88), up the Gun Barrel road to Mount Davies. Thirty gravity stations were determined along this part of the traverse with an average distance apart of 6·4 miles.

Magnetometer readings were conducted simultaneously with the gravity readings as far as station 88.21.

The last stage of the survey comprised a reconnaissance gravity survey from Mount Davies through Granite Downs to Oodnadatta (see plan L61-7).

Gravity observations were made on a number of astrofixes established by L. Beadell (surveyor) from the Department of Supply.

(b) *Gravity Observations*

The gravity observations were conducted with a World Wide gravimeter, which has a sensitivity factor of 0·11290 milligals per division. Absolute gravity values were obtained by tying into gravity stations established by the Bureau of Mineral Resources.

The readings were reduced by applying the following corrections:

(1) Drift correction,
(2) Elevation correction, and
(3) Latitude correction.

The gravity results were expressed as Bouguer Anomalies (in milligal units).

The drift corrections were generally found to be very small.

Elevations for the gravity stations were obtained by microbarometer, aneroid and altimeter measurements.

An elevation correction of 0·60 milligals per vertical foot was accepted (which corresponds to a density of 2·67 grammes per c.c.).

(c) *Magnetic Observations.*

The relative vertical magnetic intensity values were measured with a Hilger Watt's vertical force magnetometer which had a sensitivity of 30·0 gammas per division.

To convert the magnetometer values into approximately absolute magnetic intensity values a factor of 50,000 gammas must be added.

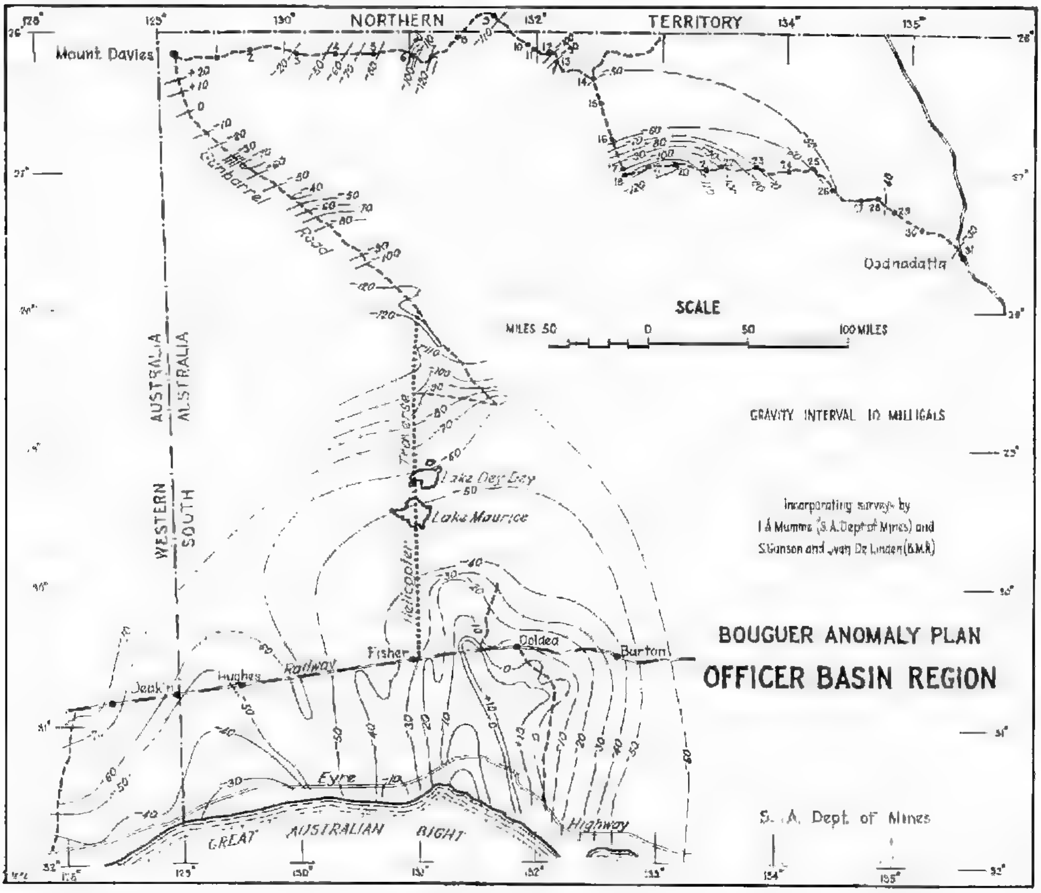

Fig. 2. Bouguer Anomaly plan of the Officer Basin and surroundings from results of surveys conducted by S. Gunson, J. Van de Linden and I. A. Mumme.

CONCLUSIONS

The gravity work shows that a significant "gravity low" coincides with the assumed basin detected by the airborne magnetometer, and also strongly suggests that such a basin (which has been called the Officer Basin) actually exists.

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THE WOOLTANA VOLCANIC BELT, SOUTH AUSTRALIA*

BY RAYMOND CRAWFORD

Summary

Mapping of the Wooltana Volcanic Belt, Northern Flinders Ranges, South Australia, has shown that 2,000 ft. of Willouran trachytic lavas with minor andesites and rhyolites outcrop along the southern margin of the Mount Painter complex and extend southward along the eastern boundary of the ranges two miles beyond Wooltana H.S. They are overlain by Torrensian arenaceous and dolomitic beds and those unconformably by Sturtian glacial beds. The area has been bisected by a steep reverse fault (Paralana Fault) system, and associated splintering and wrench faulting is combined with tight folding in the north and west. The northern part of the area is regionally metamorphosed. Copper and asbestos mineralization is widespread. Gold, uranium and beryllium occur. Comparison with other recorded Precambrian volcanics in South Australia, both in situ and diapirically emplaced, suggests that the original area of extrusion exceeded 30,000 sq. miles. A general comparison is made with volcanics similar in age and type elsewhere in Australia. A suggested possible common origin with the Gawler Range Porphyry and Moonta Porphyry in South Australia is discussed. The mineralization of the Adelaide System sediments is suggested to be exhalative-sedimentary in type.

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[Read 11 April 1963]

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Copper and asbestos mineralization is widespread. Gold, uranium and beryllium occur.

Comparison with other recorded Precambrian volcanics in South Australia, both in situ and diapirically emplaced, suggests that the original area of extrusion exceeded 30,000 sq. miles. A general comparison is made with volcanics similar in age and type elsewhere in Australia. A suggested possible common origin with the Gawler Range Porphyry and Moonta Porphyry in South Australia is discussed. The mineralization of the Adelaide System sediments is suggested to be exhalative-sedimentary in type.

INTRODUCTION

Between July and October, 1957, the author mapped the eastern half of the Wooltana one-inch Geological Survey Sheet, with particular emphasis on the stratigraphy and structure of the volcanic rocks and the formations overlying them. Mapping was done on South Australian Lands Department 60-chain vertical air photographs. Petrographic examination of a large number of specimens was carried out later in 1957 and a proportion of these selected by the author have been described by H. W. Fander (see p. 155 this volume).

GEOGRAPHY

The area mapped lies in the north-eastern Flinders Ranges, approximately 400 miles north of Adelaide. Wooltana H.S. (139°27′E., 30°25′S.) lies 25 miles west of Lake Frome at the foot of the ranges, about 80 miles by road east of Leigh Creek. The mapped area extends south from Wooltana for six miles along the scarp to Nepouie Creek, and north for 12 miles to East Painter Creek (Pl. 1, Figs. 1 and 2). In the north, mapping has been extended westward about five miles up the Arkaroola Creek to beyond its junction with the Wywyana, but in the south reconnaissance mapping only has been practicable south of Mount Warren Hastings.

* Published with the consent of the Hon. the Minister of Mines for South Australia.

† Geological Survey of South Australia.

This whole area consists mainly of rugged hills with relief up to 2,500 feet though predominantly between 500 ft. and 1,000 ft. At Wooltana a prominent straight craggy scarp from 300 ft. to 700 ft. high (with Mt. Jacob) overlooks the vast Lake Frome plains. This develops northward into a wider and higher

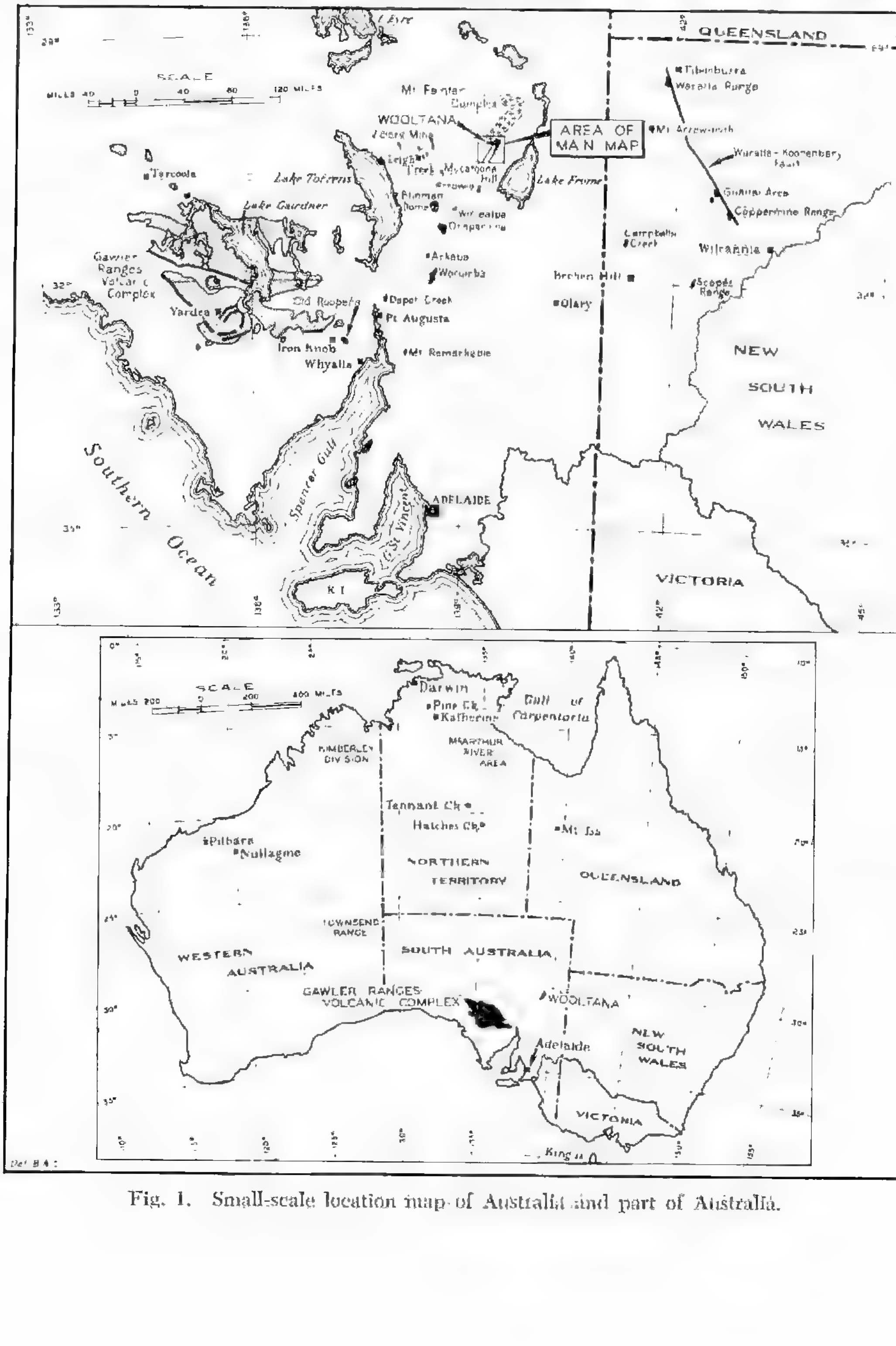

Fig. 1. Small-scale location map of Australia and part of Australia.

zone of rugged country trenched by the great winding gorge of the Arkaroola Creek. West of it is the open Munyallina valley, widening southwards, itself limited westwards by another scarp beyond which is monotonously rugged country with Mt. Warren Hastings as its highest point. To the north a most confused topography reflects a complex structure and very broken country extends west of the Barraranna gorge of the Arkaroola (Pl. 2, Fig. 1) into the granite massif of Mount Painter (Pl. 2, Fig. 2). The highest peak on the map — Humanity Seat — lies on the east side of this massif, and further east a large embayment, south of East Painter gorge, forms a triangular area of broken ground. This is limited to the north-east by the Lady Buxton Creek on the left bank of which are piedmont fans in course of dissection. Remnants of these overlie the foot of the Wooltana scarp.

The Wooltana district, in common with the rest of the Flinders Ranges, has an arid climate with low and very variable rainfall, having very hot summers and warm winters with cold nights. Rainfall is infrequent and occasionally torrential; though dissection is deep and close, no running streams exist. Streams are ephemeral. Waterholes are confined to the Arkaroola and Wywyana Creeks and are often dry.

The area covers approximately fifty square miles and contains two settlements, Wooltana H.S. and Arkaroola H.S., with the total population of less than 25, all supported by sheep grazing. No mines are active. Motorable tracks are few but a road extends along the foot of the Wooltana scarp, and a rough track connects with Arkaroola through the Munyallina Creek gap linking with a track coming north from Balcanoona.

PREVIOUS WORK

In comparison with the much more strongly mineralised granite country of Mount Painter to the north, little work has been done on the Wooltana igneous rocks; and nearly all that characteristically by Mawson, with one important paper by Woolnough. A short account, largely recapitulatory, is given in Sprigg's unpublished report (1945) on the wartime reconnaissance survey of Mount Painter. If Woolnough's sketch map of the Wooltana homestead area is excluded, no mapping of any kind was done prior to the author's except in the extreme north where observations were recorded by various Geological Survey officers working on the southern part of the Painter massif.

The first reference to volcanic rocks in the area is in Mawson's short note of 1912 in which he states that "intrusive basic igneous rocks are of common occurrence in this (NE South Australian) pre-Cambrian series. These are partly coarse- and partly fine-grained amphibolites and less altered uralitised dolerites and basalts. The latter were observed to be amygdaloidal at an outcrop on the Arkaroola Creek. . . ."

In his 1923 paper Mawson amplifies this account, especially mentioning vesicular basalts just north of the gorge, and adding that "other parts of the formation were brecciated in a manner which suggested a possible tuffaceous character. The metamorphism which these rocks have undergone obscures their features" (p. 380). A coarse-grained amphibolitic rock from the same area is compared with the copper-bearing actinolite-rich rocks of Yudnamutana. More space is given to vesicular lavas — "amygdaloidal melaphyres" — from Paralana station (now a northern part of the Wooltana property) which he had not seen in the field. These he considered to be recrystallised amygdaloidal basalts and noted their close resemblance to chloritised basalts from the Blinman South mine described by Benson (1909).

The 1926b paper of Mawson is the most important, but suffers from lack of a geological map; by chance the chosen line of section crossed what is now known to be the northern end of an outcrop of post-volcanic pre-glacigene sediments, reduced at this point to a thin representative of an arkosic conglomerate. Here it is peculiarly difficult to distinguish in the field either from one of the many varieties of glacigene beds or from an igneous agglomerate, and was classed by Mawson as the latter. He therefore concluded that the volcanics were "either contemporaneous with the glaciation or preceded it with no great intervening time break" (p. 200). This was a reasonable inference from an examination of the section alone but it is odd that in crossing from Wooltana H.S. to the eastern end of the section line Mawson failed to investigate the prominent crags of the folded sediments immediately overlying the volcanics, and the angular unconformity made by these sediments with the glacial sequence, there most beautifully displayed. Even after further visits, one of which is mentioned in the only succeeding paper (Sturtian Tillite of Mount Jacob and Mount Warren Hastings, 1949) the very existence of these beds seems to have been unrecognised, in spite of the fact that the area immediately north of the homestead is the one place along the scarp where they form the whole of the lower part of the scarp and where no volcanics outcrop.

W. G. Woolnough spent a short time at Wooltana in 1926 principally in reconnaissance of the Lake Frome basin in search of salt on behalf of Brunner, Mond & Co. He was evidently unaware of Mawson's discoveries and separately described the Precambrian geology with particular emphasis on the volcanics. He, too, regarded them as directly under Sturtian glacials and drew a rough geological sketch map of the area in the immediate vicinity of Wooltana H.S. He noted the existence of bedded dolomites north-west and south-west of the homestead, both of which he grouped with the volcanics, regarding the latter as a merely local interruption of an essentially sedimentary series, and confined the volcanics to the area west of the homestead.

GENERAL STRATIGRAPHY AND STRUCTURE

Introductory — Geological Environment

The Northern Flinders Ranges are defined here as those north of Blinman. They form a wide zone of tightly folded Precambrian and Cambrian rocks, with a triangular outcrop, widest in the north. The essential structure is of east-west folds in the central zone, with north-west folds in the west and north-east folds in the east, all characteristically asymmetrical. Much associated faulting, including major thrusts, complicates the picture. It is further complicated by the presence in the north-east of the outcrop of the oldest rocks, which form the Mount Painter-Freeling Heights massif and its extension north. The shape of the outcrop of this massif and the alignment of the boundaries between the Archaean sedimentary and granitic bodies within it further demonstrate the dominance of north-easterly trends; but clearly it has acted as a block more resistant to deformation than the Proterozoic and Cambrian beds wrapped around it, and has had a strong influence on the details of their deformation.

On the west and south of the massif upper Proterozoic rocks overlap it unconformably. West of Freeling Heights in the Yudnamutana area these are predominantly sediments, though strongly metamorphosed. Near Umberatana calc-silicate rocks with possible volcanics appear. In the south the sequence is essentially volcanic with subsidiary sediments. It is this southern section which is known as the Wooltana Volcanic Belt.

Lower Stratigraphic Boundary of Wooltana Volcanic Belt

It is not proposed here to discuss the Painter massif, the mapping of which has recently been completed by the author's colleagues and in which he has played a negligible part. It has now been shown that everywhere on the south side of the massif quartz-feldspar and quartz porphyries outcrop over a belt usually 1-2 miles wide. They are regarded as of Archaean age, and extend from the Arkaroola Creek above its junction with the Wywyana to the Arkaroola Bore and Humanity Seat, the contact with the Wooltana rocks being tectonic and marked by very strong development of pegmatites and a gigantic quartz reef. The contact is broken by a major thrust – the Paralana fault – being stepped north on the east side and emerging from the ranges north of East Painter Gorge. The eastern part of this stretch is an unconformity, and the contact can be traced through a small outcrop two miles east on the piedmont slope, where it appears again to be non-tectonic.

South and east of the Humanity Seat area no lower boundary can be traced on the ground because of overlap by poorly exposed Mesozoic beds and an extensive further overlap of Cainozoic sediments. No relevant information is obtainable from the wide network of bores on the plains, and it must be assumed that the downfaulting to the east is on a major scale.

Upper Stratigraphic Boundary of Wooltana Volcanic Belt

The accompanying geological map shows that stratigraphically there are marked differences in the thickness of the sequences on either side of the Paralana fault. On the east side the igneous rocks form a belt widening northward and lying east of, and stratigraphically below, a strong development of the lower glacial sequence which is accepted as of Sturtian age. The map shows also, however, that overlying the volcanics there is an arenaceous-carbonate sequence present only near Wooltana in the south, but extending from the area east of Eagle Crag northwards for several miles. Both at Wooltana and at Woolnough Crag this is seen to be folded, and unconformably covered by the glacial sequence. Although very variable in facies along the strike, and varying a good deal vertically, it is demonstrably arenaceous in its lower part, with a characteristic dark arkosic grit and dolomitic in its upper part.

The volcanics and this arenaceous-carbonate sequence are therefore clearly pre-Sturtian in age.

Towards the Paralana Fault intense folding, faulting and crushing make mapping difficult, but the essential features remain, though the arenaceous part of the sequence increases in thickness very greatly.

West of the fault all the rocks are much more metamorphosed and thicknesses are again increased. The author's interpretation on the map is based on a recognition of the Sturtian boundary, two miles up the Wywyana Creek from the Arkaroola-Umberatana track; the great arkose immediately north of the track being correlated with the arkosic grit of Wooltana and the equally massive wide outcrops of dolomites south of the track with the overlying dolomites. The phyllite sequence below the Arkaroola arkose is, therefore, a thickened and metamorphosed equivalent of thin purple shales and quartzite found locally at Wooltana and north of Groan Creek; and below it are dark green schistose rocks with amygdaloidal lavas, much metamorphosed but undoubtedly equivalent to the Wooltana igneous rocks.

The more metamorphosed rocks of the Humanity Seat area are much less readily identified by lithology and they are structurally almost completely separated from those to the south. On the evidence of the unconformity north of East Painter Gorge they might be expected to be the equivalent of the volcanic sequence and the overlying rocks. The author, approaching them first from the east, saw little resemblance; but careful mapping from the south across the Barraranna Gorge showed that the arenaceous sequence extends north into the gradually mylonitised rocks of Humanity Seat itself, and a lithological boundary in phyllitic beds has been mapped to the east of the peak. Still lower in the sequence is an actinolitic marble almost certainly equivalent to one low in the volcanic sequence. The author has since discovered that "possible ash beds" were recorded within the lower less phyllitic sequence by Sullivan (according to Sprigg, 1945).

The Use of the Term "Willouran"

In the past, the whole sequence below the glacial beds would have been described as Torrensian. In recent years the term Willouran has been used for rocks in the Copley-Witchelina area which are stratigraphically below the Copley Quartzite. This is regarded as equivalent to the great arkose of the Arkaroola H.S. area. While such a division is easily applicable to that part of the Wooltana Volcanic Belt lying west of the Paralana Fault it is less easily applied to the area to the east.

In the west a considerable thickness of phyllites, apparently conformable with the arkose, lie between it and the volcanics. The boundary between the phyllites is in part faulted but in any case metamorphism makes recognition of its character difficult. In the tightly folded central and northern area, east of the fault, the phyllite sequence is little less thick and its base is again difficult to interpret. But south of the triangular area between the Lady Buxton Creek, the fault running south-west from the Lady Buxton Mine, and the Torrensian outcrop (i.e. what is hereafter described as the "triangle of volcanics"), and in the whole of the scarp zone, the arkose is itself very much thinner, rather less persistent, and is underlain by apparently conformable thin quartzites or shales which rest on an eroded surface of the volcanics. Thus the marked break is here within what is strictly a Willouran sequence.

It would therefore have been easier to place all the rocks below the Sturtian in one group, but to avoid confusion in relation to published maps a division into Willouran and Torrensian has been introduced and the break placed at the base of the arkose as elsewhere.

Willouran Series: Wooltana Volcanic Group

The Wooltana Volcanic Group in its "type" area, the Mount Jacob scarp zone, comprises lavas, tuffs and agglomeratic tuffs with associated quartzites and shales. The lavas are almost entirely sodic trachytes; some andesite occurs. Tuffs are much less common than lavas and are mostly found in the south, where a porphyritic sodic rhyolite bomb rock is locally common enough to produce agglomeratic tuff. Tuff has been recorded which is indurated, though not welded.

Dykes are rare. Rocks having the appearance of dykes in outcrop, but in reality well post-volcanic and associated with later tectonic movements, being either clastics or vein-rocks, are very common.

Associated sediments are of minor importance. In a sequence of approximately 400 ft. south of Wooltana H.S. green shales occur, maximum thickness 30 feet, at or towards the top of the sequence. One mile north of the H.S. and again north of Copper Mine Creek very characteristic red, often current-bedded quartzites occur. These are lens-like in the south but in the north can be traced for long distances. They are everywhere less than 20 feet thick. (Since the map was drawn a bore at Wooltana H.S. has shown 200 ft. of red quartzitic sandstone under the volcanics.)

Subdivision of the Wooltana Volcanic Group is thought to be impracticable, because of rapid horizontal and vertical variability.

In this scarp zone alteration of the rocks is very common and while the type of alteration is usually clear, the pattern shows nothing but a consistent irregularity. The typical unaltered trachytes are Mawson's "amygdaloidal melaphyres"—hard, dense, fine-grained, dark purple rocks with salmon pink or white amygdales, or occasionally vesicular. They outcrop prominently, forming scarp edges and minor gorges. Rocks mineralogically little different, but physically altered, occur as a purplish-grey or greenish-grey crumble on lower ground between the outcrops of unaltered but brecciated trachyte cemented by pink and white quartz veins, which is common near the major faults and in the south-east part of the "triangle".

The small outcrop of igneous rocks south of the Barraranna Gorge has similar rock types, though near the fault they are mylonitized.

West of the Lady Buxton Fault lavas are confined to a small area near the Barraranna Gorge. Most rocks are green, fine-grained and tuffaceous, with increasing scapolitization northwards. The proportion of shaly material is difficult to estimate. The sequence contains argillaceous limestones near the base, which become actinolitic marbles to the north, and a red quartzite higher in the succession which may be correlatable with one of those of the scarp zone. North of East Painter Gorge chlorite-magnetite schists occur.

West of the Paralana Fault metamorphism, tight folding, and faulting make determination of original rock types very difficult. True lavas are known to occur only in a small area in the south-west. Green schists are common, some with quartz blebs possibly amygdaloidal in origin. The evidence suggests a predominantly tuffaceous sequence between two actinolitic marbles which coalesce westwards and open again west of the Arkaroola Water Hole revealing another, smaller, outcrop of metamorphosed, mostly tuffaceous volcanics.

The Humanity Seat rocks are phyllites, with very minor volcanism.

Overlying Sediments of Willouran and Torrensian Series

In the scarp zone these rocks outcrop in two distinct areas: a short section of the scarp between Mawson Bluff and Wooltana H.S. and a much longer section extending from a point half a mile south east of Woolnough Crag northwards around to the tighly folded Barraranna Gorge area.

The short outcrop thickens from nil at the south end of Mawson's Bluff to about 200 ft. at the maximum in the first creek north of the homestead, west of which it is lost by folding under the Sturtian. The basal member is a red quartzite (shaly at Wooltana) rising in the south through purple shales and current bedded quartzitic sandstone to an arkosic conglomerate grit which in the north rests disconformably on the basal quartzite. Above this very characteristic grit (which is equated with the basal Torrensian to the west) bedded dolomites outcrop in the south; in the thickest section they have a light brown mudstone at the base. There is much minor horizontal variation.

The sequence rests on an eroded surface of volcanics.

The longer outcrop has essentially the same characteristics, with similar horizontal variation within a general sequence beginning with quartzite passing up into purple shales and arkosic grit. Above the arkosic grit and north of Woolnough Crag a sequence of shales, flaggy sandstone, shales with minor dolomites becomes regular, with the flaggy sandstone very thick in the north-east. The overlying beds, purely dolomitic in the south, contain much shaly and silty material. Pre-Sturtian folding in the Woolnough Crag area results in Sturtian resting unconformably on arkosic grit in the bed of the Arkaroola Creek.

Accurate subdivision in the Barraranna Gorge area is not easy, especially north-east of the Gorge where there is tight folding and much faulting. The flaggy member above the arkosic grit is apparently much thicker here and dominates the outcrops. In the tightly folded but unfaulted area south-west of the Gorge the sequence can be established, though very careful mapping was necessary as squeezing of incompetent members is common. Towards the north characteristic purplish ribbon-banded, ripple-marked quartzites become dominant below the thickened arkosic grit (and form the rocks in the sharp bend of the Gorge itself) and can be followed across the Arkaroola immediately east of the Paralana Fault into the Humanity Seat area; slightly further north in the immediate vicinity of the peak they are mylonitized and no very obvious lithological correlation is possible.

West of the Paralana Fault the very much thicker Willouran sequence of monotonous phyllites rises to a still stronger development of the Torrensian arkosic grit well displayed in the gorge of Boulder Creek immediately east of Arkaroola H.S. The homestead itself stands on shales and westward the thicker equivalent of the flaggy sandstone outcrops as another massive scarp. Beyond this is a very thick sequence of carbonate beds mapped in detail only along the Wywyana.

Sturtian Series

No detailed study of the Sturtian Series has been made, but its outcrop has necessarily been mapped and much information about the lower and upper parts of the sequence was recorded.

The Series was examined for the first time in this area by Mawson (1949), who gives detailed descriptions along an east-west section near Mount Jacob. It is necessary to add that much lateral variation in lithology occurs, and that Mawson's belief in the significance of the colours of tillites seems misplaced.

In the scarp zone the Series varies a great deal in rock type. In the southernmost area a basal boulder tillite is found, beautifully displayed in a narrow gorge a quarter of a mile west of Merinjina Well (Pl. 1, Fig. 5), rising into what is probably a fluvioglacial conglomerate with sub-rounded pebbles and boulders almost entirely of quartzite, and mostly of about 6 in. to 1 ft. in size. The basal tillite is strongly purplish or green due to its content of volcanic detritus.

At Wooltana the same sequence is seen, but immediately to the north and for several miles to beyond the Arkaroola Creek the lowest member is invariably a tillite very rich in rectangular blocks of dolomite, with other erratic material quite subordinate or absent. This highly characteristic rock is the material forming the massive feature named by the author Mawson Bluff, which appears in the photograph in Mawson's 1926b paper. At this point the member is thickest (100 ft.) and is a yellowish or buff tillite weathering dark brown. In the creek on the north side of the Bluff it rises into a purple tillite containing a much higher proportion of non-dolomitic material with the red bomb porphyry very prominent. (In all the lower tillite containing volcanics, the bomb porphyry is predominant among volcanic erratics; most of the other volcanic types have contributed principally to the matrix.) This member shows much box weathering and is less prominent in outcrop. Above it is greener in colour and gives way to about 300 ft. of green and whitish shales. These are capped by the massive fluvioglacial conglomerate, forming great scars on the crest of the range. The matrix of this is mostly quartz sand (rather than rock flour) and the boulders nearly all fine-grained or medium-grained quartzites, usually purple-stained with prominent current bedding. The rock is so indurated that commonly the joint planes cut cleanly through the boulders.

North of Woolnough Crag, which is formed of it, this latter member occupies nearly the whole sequence; the outcrop is all high ground.

In general, the fluvioglacial conglomerate forms the major part of the Sturtian outcrop, but the uppermost Sturtian along the eastern side of the Munyallina valley is again a definite tillite, with magnificently facetted boulders. In the north it is intensely brecciated, and at the "tear-off" north of Boulder Creek, where the top and the bottom of the Series approach very closely, so much so that it is almost unrecognizable.

The Sturtian west of the Paralana Fault is confined to the area south of the Arkaroola H.S. Umberatana track. It has been examined in detail by the author only along a section up the Wywyana Creek, where there is no sudden onset of massive glacial beds but an introduction of thin tillitic beds repeated and gradually giving place to massive fluvioglacials which to the south are more developed and form the rugged mass of which the highest point is named Mount Warren Hastings.

DETAILS OF STRUCTURE

Paralana Fault System

The major structural feature of the area mapped is the Paralana Fault. This is a break which produces an almost complete repetition of the sedimentary and igneous formations, bisecting the area approximately meridionally.

It is a complex fault. Because for much of its length it is a duplicated strike fault its existence was not clearly established until the wartime reconnaissance survey when air photographs became available for the first time. Previously, recognition was much more difficult because the area of major topographic change on the west side of the Munyallina Valley, which was, of course, noted both by Mawson and Woolnough, coincides with the eastern member of the fault, west of which is a narrow repetition of carbonate beds of similar lithology to some of those in the valley; this together with similarity of strike and dip allayed suspicion. Neither Mawson nor Woolnough in 1926—both crossing westwards—so much as suspected the existence of a fault.

In Mawson's 1948 paper the existence of the fault is recognised and it is shown on Sprigg's reconnaissance map (1945) though the Wooltana Volcanic Belt on that map is left very much in the air in relation to the rest of the area.

Here we may regard the Paralana Fault System as beginning in the south at Italowie Gorge (see Fig. 2) on the Balcanoona 1-mile G.S. sheet where a double fracture throws the lower glacial mass on the west against upper Sturtian on the left bank of the emerging creek, with repeated upper Sturtian between the two fault members. Here they dip at a high angle. At this point

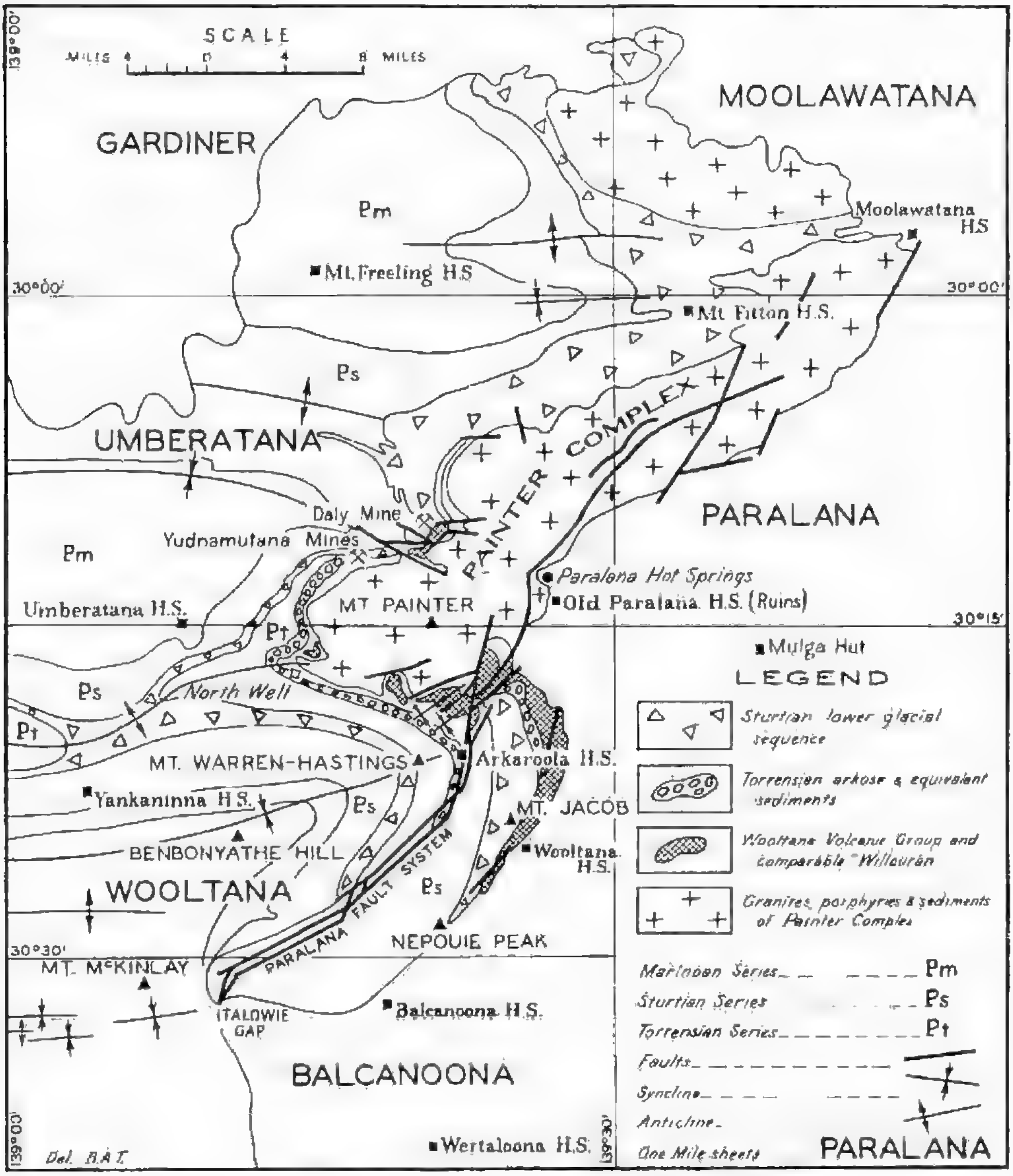

Fig. 2. Larger scale location map of Northern Flinders Ranges.

the main mass of Sturtian lower glacials on the west side is torn off, re-appearing in the area north-east of Arkaroola H.S.—a tear with an offset of 20 miles. Calculations based on cross sections drawn through the centre of the Munyallina valley show that the throw-down to the east is of the order of 25,000 ft. assuming a dip of the fault plane of 70°, and 22,500 ft. at 80°.

The eastern fault member is clearly exposed on the north bank of the Balcanoona Creek four miles west of Balcanoona H.S., 250 yards north of the track to Grindle's Hut, immediately east of where the creek leaves the gorge through the tillite. Here it is a low angle thrust, but a quarter of a mile further west the western member is a high angle reverse fault, throwing Lower Glacials against upper Sturtian (on the east). The western splinter is much steeper and less clearly exposed.

North of Balcanoona Creek the north-easterly trending fault system is offset westwards by north-south splinters which isolate Mount McTaggart. From there the eastern member extends for seven miles in a straight line, with the western member about half a mile from it in the south but approaching more closely northwards. This is the area where Mawson and Woolnough made their reconnaissances, the "Cave Hill dolomite" of Mawson (1934) lying between the faults and forming a very prominent east-facing scarp. To the east are upper Sturtian beds which in the south include the upper glacial sequence. West of the double fault the lower glacials are very near in the south but the unconformity between them and the upper Torrensian swings away northwards leaving a wide outcrop of the latter beds east of Mount Warren Hastings.

A mile north of the point where the Wooltana-Arkaroola track cuts through the "Cave Hill dolomite" the faults are again splintered, with a direction change to north-north-east to north. For several miles north the fault is a single high angle stretch thrust (dip 70°-80°) but in the vicinity of Boulder Creek and to the south a narrow zone of upper Sturtian is duplicated, and at the north end of this duplication massive quartz-iron "blows" occur on the left bank of Boulder Creek.

From here north the fault system as a whole is much more complex because of intense splintering and wrench faulting on the east side and to a smaller extent on the west side in the reverse direction. The Paralana Fault proper, however, remains exceedingly clear-cut extending across the Arkaroola Creek upstream from the Barraranna Gorge into the Humanity Seat massif, passing west of the peak, north of which it peters out into a complex system before developing *en echelon* as the Paralana Fault of the "type area" from north of East Painter Gorge to the Yudnamutana Gorge mouth and Paralana Hot Springs. At the point it crosses the Arkaroola, the break is so clean cut and lacking in any local brecciation (and this is true of much of its length) that it is not surprising that Mawson failed to see it (Mawson, 1923); here by relative northward displacement of the eastern block against the Painter massif volcanics of similar facies on each side of the fault approach very closely.

Splinter-Faults and Thrusts—Folds

Associated with the Paralana Fault System are several major splinter-faults and thrusts, which cannot be discussed without the associated folds.

The most important of these faults extend as a fan in a north-east quadrant from the tightly folded area one mile north-east of Arkaroola H.S. Here, a tremendous compression on the east side of the Paralana system has been relieved by—

(a) overthrusting by the volcanics in the axial core, and the overlying arenaceous-dolomitic Group, on to the upper Sturtian;

(b) development of three tight anticlines with squeezing-out or severe thinning of the less competent (largely calcareous) beds in the arenaceous-carbonate Group;

(c) (in the southern part of the Barraranna Gorge) minor over-thrusting from the north-west, with petty wrench faults (all too small to show on the map);

(d) overturning of the quartzites of the Barraranna Gorge at their contact with the volcanics at its northern end.

This is the situation in the "corner" of the structure. Beyond, the faulting and folding extends well north of East Painter Gorge and affects the area around the upper reaches of Groan Creek. The major thrust, (a) above, is probably continued north-eastward as the Lady Buxton Fault (unless that fault is *en echelon* to it). On the west side of this the volcanic group is very tightly folded anticlinally with an overturned east limb. On the east side the volcanics of the "triangle" are for the most part folded more openly but in the south-west corner of the "triangle" the arenaceous-carbonate group is tightly folded anticlinally, with a curious shallow synclinal keel of quartzite between the principal anticline and a subsidiary lying east of it, the two amalgamating north-eastward. Strong wrench faults with very prominent slickensides showing horizontal movement are associated with this folding.

To the east and south of this complex system of folds and faults numerous wrench faults affect the remainder of the country mapped. These are nearly all dextral on the west side of the lower glacial outcrop (some of these carry through to the east side) and sinistral on the east side; further south sinistral faults become dominant. Many extend for several miles and have little throw, but cumulative throw is considerable. They have caused narrow zones of intense brecciation. Only the major faults have been mapped. Innumerable minor wrench faults exist and explain the ubiquitous brecciation in the volcanics. In the glacials they lead to much weathering-out of the rounded pebbles and boulders of the fluvioglacial beds, where they are not so indurated as to form one solid mass. In the arenaceous-dolomitic group the effect is seen in the shattering of the quartzites and in the dolomites shattering on an almost microscopic scale is everywhere apparent.

As described below in the Woolnough Crag-Vermiculite valley area these wrench faults are associated with what appear to be normal faults in turn may be associated with the major downthrow limiting the ranges to the east.

Folding in this eastern area is much less common, the only important example being in the upper reaches of Groan Creek, where the dips in the upper Torrensian arenaceous beds suggest a syncline plunging west. It is not certain whether this is not partly to be explained by local thickening of the arenaceous beds. The faulting on the north-east side of this area is also abnormal in its north-westerly alignment, but this again may be connected with the faulting limiting the ranges, which elswhere is offset by north-westerly trending faults.

North of the Barraranna Gorge another major thrust, also duplicated, develops from a fold in the upper Torrensian and extends parallel to the Lady

Buxton Fault to East Painter Gorge entrance and beyond. This dips much less steeply than the Paralana Fault (and the Lady Buxton Fault); brecciation is common and intense in the vicinity of East Painter Gorge. At the southern end of this structure the phyllites of the Humanity Seat block are extremely tightly folded and overturned

To the north the actinolitic marble of the Humanity Seat block appears to be faulted against the higher beds; there is a marked difference of strike. Beyond, structures in the East Painter Gorge area are very confused.

West of the Paralana Fault very strong faulting occurs along the southern margin of the Painter Complex, principally along NE-SW lines. Tremendous quartz blows exist. A crude *en echelon* pattern of wrench faults affects the volcanics and sediments. Tight folding has taken place. Two major synclines in the upper Torrensian are clearly established. (These fade southwards and there is no good evidence to date them, even in part, as pre-Sturtian.) A little north-east of the junction of the Arkaroola and the Wywyana folding is extremely sharp and excellent boudinage is seen. Strong cleavage, elsewhere not prominent, leads to weathering of the phyllites into angular blocks. The zone between these two synclines is far from simply anticlinal, however, and repeated examination on the ground and of air photographs has failed to establish a satisfactory detailed structure. Variations in thickness of the volcanics and metamorphism make this difficult.

Further west, structures are simpler. They are finally cut by overlap of the higher beds on to the Painter Complex.

A minor splinter east of Arkaroola H.S. may partly account for the gold mineralisation at the Golden Rule Mine (Lively's Find).

Dyke-like Features

Two types of dyke-like features occur both of which are regarded as of tectonic origin.

The first are brown-weathering linear wall-like bodies which occur in two areas, the southern part of the scarp zone and the eastern part of the area west of the Lady Buxton Fault, both north and south of East Painter Creek. (In the latter area some confusion may arise if it is not recognised that for about half a mile south of the Lady Buxton mine one has in fact been used as a wall, with debris of similar material piled on top or built on to the end as a dry stone wall extension. This is apparently an early shepherd's work.)

In the scarp zone these bodies are 5-20 feet wide and extend continuously (or with minor breaks) across the area in a north-north-easterly direction irrespective of the formations outcropping. They reach 15 feet in height, usually 5-10 feet, and form strong landscape features. They are apparently vein bodies of calcite, dolomite and quartz, rather ferruginous. No other mineralisation had been noted.

In the Lady Buxton area the bodies are similar but north of East Painter Creek they are folded.

In both areas the bodies are regarded as veins developed along wrench faults or associated fractures (including, perhaps, north of East Painter Creek, gaps between tightly folded formations).

The second type of dyke-like bodies is confined to the southern end of the scarp zone south of Wooltana H.S. These are bodies with no differential relief, usually only 5-10 feet wide, and dark or light grey in colour. In places these cut the tuffaceous shales, i.e. they post-date at least the lavas of the south. They are not, however, volcanic, though they contain much altered volcanic material. Of two example collected (T.S. 5272 and T.S. 5275) one is obviously a deeply altered rock, largely calcite and chlorite; the other a strongly mylonitized rock which Fander thinks might originally have been agglomerate or conglomerate. At the time that these rocks were being examined, other rather similar rocks were collected by R. C. Horwitz from the Arrowie 1-ml. G.S. sheet where he has demonstrated diapiric squeezing of lower Torrensian material through younger rocks along the eastern side of the ranges. It seems possible that these are related bodies, essentially tectonic.

LOCAL DETAILS OF STRATIGRAPHY AND STRUCTURE

Wooltana H.S. Area—Southern Limit of Volcanics to Mawson Bluff

This is the area of volcanics most easily seen, the Volcanic Group here forming a narrow linear outcrop no more than a few yards wide in the extreme south to a little over half a mile in the north. The outcrop is broken immediately north of Wooltana H.S. by the overlying Torrensian arenaceous-dolomitic group.

In this area, especially that part of it south of Wooltana H.S., faulting is a major feature. In addition to major wrench faults, associated with which are numerous massive vein structures cutting the outcrops with strong relief, there is a thorough shattering. The area is also folded more intensely than any other part of the scarp zone. Much of the volcanic material is therefore highly brecciated and is weathered more than elsewhere. Effects due to deuteric alteration are not easily distinguished from alteration consequent upon tectonic shattering and later weathering. Near the eastern edge of the outcrop rock types are commonly difficult to identify.

The scarp here is not more than 200 feet above plain level in the south, but rises to about 700 feet in the north.

As the map shows, the area is structurally divided into three parallel zones by what appear to be wrench faults. Each zone is anticlinal, with mild plunge variation, so that several isolated outcrops of volcanic rocks occur. The relationship of this folding and faulting which affects both the Torrensian and the Sturtian, to that immediately north-west of Wooltana, which affects only the Torrensian, is not absolutely clear; but there is no doubt that the latter is older: no effect on the tillite north-west of Wooltana can be seen, but to the south it is very definite. This folding and faulting with north-easterly or north-north-easterly trends is connected with the major flexing which limits the Flinders Ranges as a whole.

The most characteristic rock type is exemplified by T.S. 3229, an amygdaloidal sodic trachyte (Pl. 1. Fig. 3). This is macroscopically an unusually striking rock, a dense fine-grained dark purplish-grey lava with amygdales commonly filled with salmon-pink microcline and usually with white quartz.

Vesicular lavas of similar type occur, more especially in the south. Such lava tops are common but not traceable for more than about 50-80 yards; they are repeated vertically many times. Because of such rapid variations and variably intensive weathering and alteration counting of flows is impracticable. There is a confusion of numerous minor flows.

The fresh, unaltered trachyte commonly outcrops adjacent to a crumble of altered rock containing much secondary material. T.S. 3107, for example, is a *trachyte* containing colourless to pale green amorphous material and calcite. From field evidence there is no doubt that this is essentially the same rock as T.S. 3229, and a gradual change from the one to the other often occurs over a distance of 20 yards.

The third characteristic rock is the epidotised material, e.g. T.S. 3099. This occurs as sharply angular fragments about 6 ins. long resembling unweathered talus, much less often as massive outcrops. This is the host rock for tremolite veins up to 4 ins. wide, which are commonly stained green with epidote and are sometimes crumpled.

The many brecciated areas commonly show a rock consisting of a trachyte similar to T.S. 3229, but broken up into very irregular, sometimes crudely rounded masses cemented together by quartz which is often stained and associated with haematite. This material was at first regarded as an agglomerate produced close to its source and altered but once the intense and ubiquitous brecciation was recognised it was appreciated that much of this type of rock is merely a recemented brecciated trachyte; some, however, is associated with what are almost certainly small vents. The frequency of occurrence of this material makes it difficult to be certain of the existence of pillow lavas, as the only two places where such pillows have been thought to possibly exist are in areas of brecciation. Immediately behind Wooltana homestead strongly cleaved red shales appear to overlie the lavas, but they appear to be disconformable. The shales rise through a current-bedded sandstone and shales (40 feet) to the very characteristic arkosic conglomeratic grit.

To the south there is a generally low but very irregular area much cut by thick veins of calcite, dolomite and quartz; further south the ground is higher and is capped by tillite.

A clearer sequence is seen at Merinjina Well, one mile south of Wooltana H.S. The last wide curve of the creek before entering the plain below Merinjina Well windmill shows very elegantly the swinging outcrop of the folded volcanics under green tuffaceous shales. (These shales resemble part of the Sturtian glacial sequence and there was at first some difficulty in distinguishing them in the field.) The faulting of the volcanics against these is clearly seen on the left bank. Upstream for 800 feet is a fine succession of dark purplish-grey lavas with vesicular and amygdaloidal tops, all dipping west at 30°-40°, and showing the characteristic crumbly grey and green epidotic variants; these lavas are of the order of 100-150 feet thick. At the repeated boundary with the tuffaceous shales a very fine section is seen on the left bank, from which a suite of specimens was obtained. A sketch of this is given (Fig. 3).

The basal member is a fresh, hard, dark, greyish-green rock, non-vesicular, very constant in colour and texture, and with a smooth upper surface. This is a micro-diorite (T.S. 5269) slightly coarser-grained and more basic than the trachytes.

It is covered by a succession of interbedded tuffs and clayey sediments and in the lowest tuff is a bomb of porphyritic sodic rhyolite, T.S. 5265, with characteristic glomeroporphyritic chequer-albite.

This rhyolite occurs elsewhere to the south and is very common as debris at the extreme south of the volcanic outcrop; it occurs rarely north of Wooltana but it is widespread as an erratic in the Sturtian glacial beds.

The matrix around the bomb is a lapilli-tuff (T.S. 5266) but the immediately overlying material is an argillaceous siltstone (T.S. 5270) succeeded by a tuff (T.S. 5268) with similar constituents to T.S. 5266. Overlying these are tuffaceous shales with pebbles of gritty sandstone, and a boulder of current-bedded quartzitic sandstone.

In the extreme south a rock which appeared in the field to be a dyke (T.S. 5272) cutting the volcanics immediately west of the major limiting fault is strongly altered but most probably a volcanic which has been squeezed up through tension cracks associated with the major faulting. A rock thought to be a bomb is described by Fander as a brecciated and mylonitized lapilli-tuff or conglomerate (T.S. 5275). The only other volcanic characteristic of this area is a very dense red jaspery-looking intensely hard rock (T.S. 5271) which is a tuff occurring repeatedly among lavas and owing its colour to

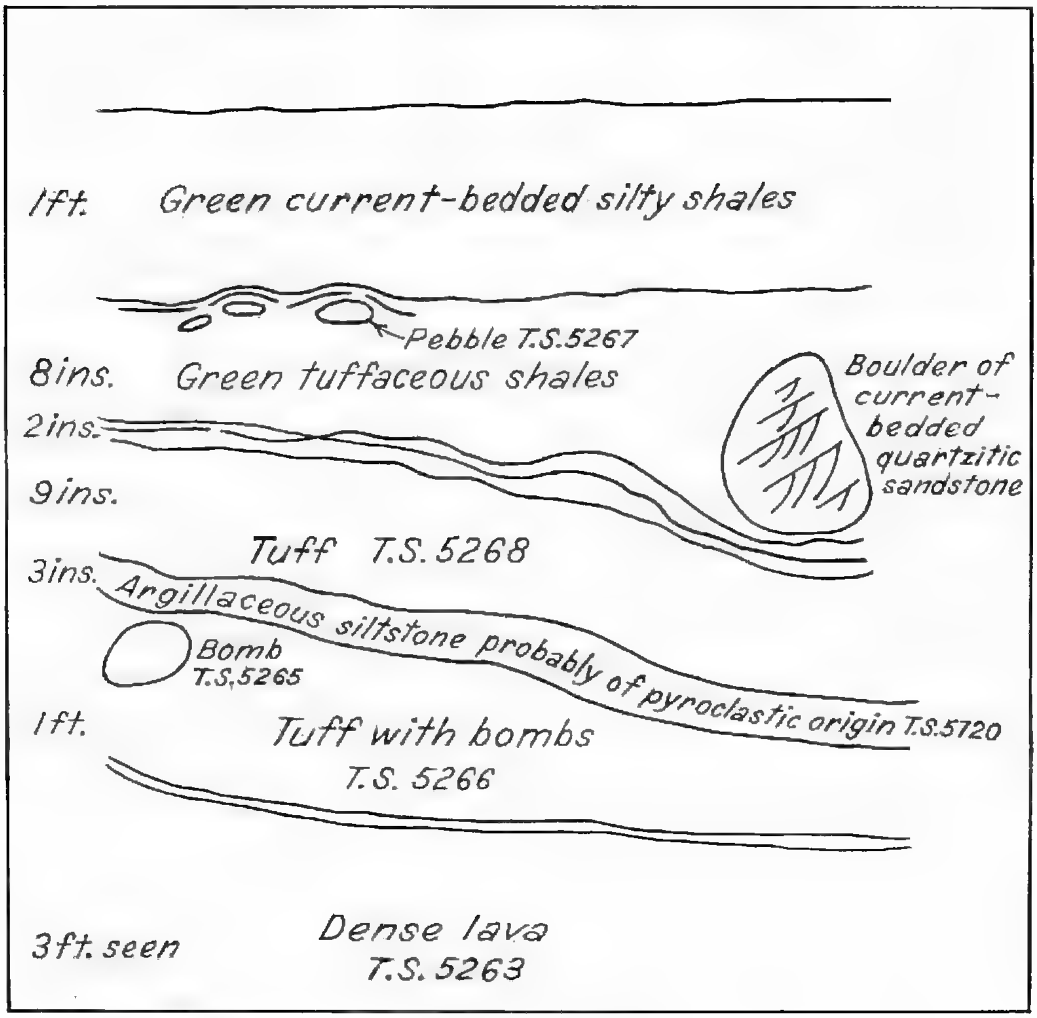

Fig. 3. Sketch of occurrence of bomb porphyry at Merinjina.

abundant haematite. This rock has not been seen in the northern part of the Belt, but much of the tuffaceous material there is comparable though less haematitic.

Between Wooltana H.S. and Mawson Bluff is the area first described by Mawson (1926b). On the low ground north of the hills occupied by the upper Torrensian the volcanics outcrop poorly under piedmont debris. The reddish sandstones and chocolate shales described by Mawson as below the main igneous formation have not been seen. Eastwards the boundary of the volcanics and the overlapping ?Cretaceous conglomeratic gravels is indefinite. The first major creek to the north-west offers a poor section in the volcanics (though a fine one in the higher beds). Further north the outcrop of the volcanics widens at the expense of the upper Torrensian and the three characteristic rock types mentioned earlier are well seen, in their equally characteristic irregular distribution. The strike is generally north-westerly with a dip south-west of 20-25°, in sympathy with the synclinal folding of the upper Torrensian. In this area interbedded sediments are rare, except in the extreme north where quartzite lenses appear.

Mawson Bluff to Copper Mine Creek

This area has been examined in most detail in the south, where the stratigraphy is apparently most complex. A typical section is seen in the creek running from the amphitheatre of Mount Jacob down on the north side of Mawson Bluff.

The southern part is apparently more disturbed than the rest and has much more interbedded sediments, mainly red shales, purplish-grey conglomeratic shaly sandstones and minor quartzitic sandstone. As in the south, repeated lava flows are common. The relation between the Sturtian and the volcanics is here apparently only disconformable because of similarity of strike and dip. Immediately north a tight syncline forms a steep hill, volcanics in the hill being faulted against sediments in the creek to the north.

In Red Bank Creek a hard dense unusually reddish rock was noticed near the Sturtian boundary. It is an indurated tuff (T.S. 3213).

The only other rock examined which resembles this is T.S. 3143 from the isolated outcrop of volcanics adjacent to the Paralana Fault between the Barraroona Gorge and Arkaroola H.S., a resemblance not obvious in the field, as the rocks in the latter area are much brecciated and squeezed. In the author's opinion the two types are different, T.S. 3213 being probably indurated by superincumbent strata or baked by overlying lavas, and T.S. 3143 being a tectonically metamorphosed volcanic.

The area between Red Bank Creek and Woodnamoka Creek presents no unusual features, having a little sedimentary material and numerous typical flows. It has two prominent hills, outcrops of massive dense red-brown rock which in the field resembles T.S. 3213, but which has not been examined microscopically.

At Woodnamoka Well typical vesicular and amygdaloidal lavas are beautifully exposed. Epidotized rock is common here, e.g. T.S. 3228 (Pl. 1, Fig. 4).

Above Woodnamoka Well similar rocks are repeated across all the outcrop.

North from Woodnamoka Well to Copper Mine Creek there is a greater regularity of outcrop, but insufficient time could be devoted to the area to determine whether this is due (as further north) to an increased proportion of intercalated sediments or to some other reason, e.g. linear fissure eruptions as against the confused and apparently more explosive conditions of the Wooltana H.S. area. It is probable that both causes combined to give this effect.

Vermiculite Valley and Groan Creek Area

This is a large area of westerly-dipping lavas with minor sediments, with clearly defined faults — either normal or reversed, but not wrench faults — markedly affecting the landscape and producing the fault-angle depression of Vermiculite Valley. It has been subjected to two periods of folding. The first period of folding is illustrated by the existence of a tiny outcrop of volcanics occurring west of the upper Torrensian outcrop, and is unconformable under the Sturtian. The whole of the north-east is gently arched along the north-south axis as is revealed by the present disposition of the Mesozoic (Cretaceous) cover. This latter folding is insufficient to alter the general westerly dip of the volcanics.

Rocks typical of the Wooltana area occur. The typical amygdaloidal lava is most easily seen where the old Paralana mail track crosses the Arkaroola. On the south side up the creek for a quarter of a mile is a beautifully exposed succession of lavas many of which are amygdaloidal sodic trachytes (e.g. T.S. 3220, Pl. 5), and the recemented brecciated variety is very common a quarter of a mile to the south-west (e.g. T.S. 3094).

On the west of this lava belt of minor rugged hills a continuous outcrop of a thin dark red very dense recrystallized quartzitic sandstone limits the eastern edge of Vermiculite Valley. Two specimens of this have been examined (T.S. 5277 and T.S. 5278), are almost identical and resemble red quartzites from the "triangle" and the area west of the Lady Buxton Fault. Though it would be unwise to assume that they are all necessarily synchronous, they enable the stratigraphy and structure to be disentangled in the three separate areas, in which the outcrop is continuous or almost so.

Vermiculite Valley itself is a generally flat-bottomed valley strewn with debris of piedmont material (which caps some of the volcanic hills) and much weathered volcanic rock. It is an enigma, being like no other part of the volcanic outcrop except the eastern part of the triangle, where, similarly, much weathered volcanic rock exists. One is tempted to regard it as perhaps at one time very temporarily a lake, since drained by a right bank tributary of the Arkaroola about half a mile above the Paralana mail track crossing. A high-level lake Frome (and there is much unpublished evidence of such a former high-level) would fill the valley and have marked effects on the rock weathering.

A curious depression, reminiscent of an old mine shaft and dump area so completely washed by rain as to be almost unrecognizable, occurs in the centre of the valley about 100 yards east of a sizeable fault scarp. The material in the "dumps" is a crumbly crust of grey-green weathered volcanic rock and was sampled as a possibly activatable clay. Mrs. N. Chebotarev examined this and found it to be mostly aggregated vermiculite with much secondary iron mineral. The rock at the foot of the fault scarp to the west (T.S. 5276) was found to be a completely altered fine-grained volcanic.

North of the Arkaroola, Groan Creek is a major left bank tributary, east of which most of the volcanic outcrop is strewn with younger debris: in the south the volcanics are better exposed but very much lateritized on the crests.

This is an interesting area not examined in detail. T.S. 3225 from the central part of a flow towards the north end of Groan Creek south-east of its exit from the upper Torrensian is a slowly-cooled trachyte. This rock type is very common in the area, together with typical amygdaloidal trachytes.

"Triangle of Volcanics"

A relatively small but highly confused area of volcanics exists as a triangular area between the Lady Buxton Fault, the upper Torrensian, and the Lady Buxton Creek. This contains all types of volcanics previously described, but tight folding in the south-west, and deep weathering towards Lady Buxton Creek, made identification occasionally difficult. The south-eastern part is intensely brecciated and contains some isolated knobbly hills which are probably vents.

A typical lava (T.S. 3224) from the southern margin is a sodic trachyte; T.S. 3199 from the eastern edge is similar but coarser grained.

A rock from one of the knobs considered to be possible vents is T.S. 3194, another trachyte.

South-westwards these rocks give way to green fine-grained rocks with quartz blebs suggestive of elongated amygdules. Half a mile south-west of the Lady Buxton mine an altered andesite was collected (T.S. 3232).

The northern and north-western part of the triangle has been shown to be anticlinal by following the outcrop of a quartzite comparable with those described above.

The proportion of tuffaceous material increases in the north-west, so that the succession tends to resemble that of the area west of the Lady Buxton Fault.

Area South of Barraranna Gorge

A small outcrop of volcanic rocks occurs immediately east of the Paralana Fault on the west side of the track running north from Boulder Bore. This is an anticlinal core of rocks brought up by plunge variation. The volcanics are typical Wooltana-type amygdaloidal trachytes with minor tuffs but adjacent to the fault they have been mylonitized.

Area West of Lady Buxton Fault and East of Humanity Seat Thrust

A rugged area between the "triangle" and the Humanity Seat mass extends from Barraranna Gorge to East Painter Gorge. North of the entrance to East Painter Gorge a smaller area of similar rocks exists. This is the northernmost recorded outcrop of the Wooltana Volcanic Group.

These rocks (a) are generally much more tuffaceous than those to the east and south; (b) contain more persistently bedded sediments – dolomites, actinolitic limestones; (c) are tightly overfolded in an anticline along a narrow zone parallel to the fault; and (d) show increasing metamorphism from south to north.

True lavas are seen only in the extreme south next to the overturned sandstones through which the Barraranna Gorge is cut. Most of the area shows bedding on the air photographs.

Three rocks from the south centre of the area are T.S. 3191, a strongly altered basic rock, T.S. 3192, probably an altered trachyte and T.S. 3144 (from the foot of the thrust in the south-west) an extensively altered fine-grained igneous rock.

The rocks of the northern part of the area are very much scapolitized and the question of the existence of spilites was considered. An example is T.S. 3184, a thoroughly scapolitized rock. No detailed study has been made of these rocks but they are at present regarded as comparable with those to the south, altered mainly by regional metamorphism with accompanying metasomatism. Another related rock from about 200 yards north-west of the Lady Buxton Copper Mine was described in the field as a "scapolitized intrusive or ?spilite" (T.S. 3098). Petrographically this resembles the albite-tremolite rock from Groan Creek (T.S. 3225).

North of East Painter Creek chlorite-magnetite schists are characteristic (T.S. 3149). In the extreme north amphibolitic material appears which is not certainly part of the Group, being possibly part of the Painter Complex.

Area West of Paralana Fault

This area, much less readily accessible, has been studied in less detail than the rest. It is intensely folded. True amygdaloidal lavas have been observed in the south-west. The rest of the outcrop would best be described as green schistose calc-silicates, but green quartz-blebbed dense rocks occur in the north which are regarded as metamorphosed amygdaloidal lavas, e.g. T.S. 3214.

Still further west, beyond the Arkaroola Water Hole (i.e. 1-1½ miles west of the Wywyana Creek) similarly metamorphosed rocks occur, and one specimen from an outcrop surrounded by actinolitic limestone belongs to the amphibolitic facies (T.S. 3174), a very characteristic pink and green feldspar-tremolite rock.

These rocks—which are Mawson's (1948) Arkaroola Series—are cut off westwards by the unconformity of higher horizon rocks on the Painter Complex but are thought to be the equivalent of amphibolites near North Well, east of Umberatana H.S., which are at a comparable stratigraphic horizon.

Humanity Seat Area

The Humanity Seat area is quite different from the others described, being much higher, more rugged, and essentially an area of phyllites. However, there is little doubt that these phyllites are stratigraphically equivalent to the Volcanic Group on mapping evidence. None of the volcanics noted by Sullivan have been seen by the author, as Sprigg's report on the area, in which this occurrence is quoted, was not seen until field work was completed. The existence of an actinolitic limestone east of the phyllites suggests equivalence with those highly folded in the area west of the Lady Buxton Fault and similar limestones west of the Paralana Fault; and the uppermost very mylonitic rocks adjacent to the Paralana Fault can be followed along strike southwards into upper Torrensian beds.

MINERALIZATION

Mineralization is widespread in the volcanics and along structures. The observed minerals of economic interest are those of copper, gold, uranium and beryllium, and asbestos (tremolite). Magnetite occurs in the north and the volcanics are everywhere very rich in haematite. The gold is not certainly associated with the volcanics, but is of much interest. Cave guano and ammoniacal cave deposits are known in the carbonate rocks.

Copper

Minor malachite and azurite showings are numerous, mostly along or near faults. The largest occurrence is at the Lady Buxton mine where mineralization is associated with strong overfolding and thrust and wrench faulting. Magnetite occurs here also, and a quarter of a mile further north.

Woodlamulka mine on Copper Mine Creek has less obvious mineralization. Six shafts were sunk along a shear which is probably related to the wrench faulting described above. The Oraldana, Great Boulder (Great Boulder and Welcome) and Wheal Hancock Mines were all in the vicinity of Boulder Bore, near the Paralana fault and Golden Rule gold mine (q.v.). Several other minor diggings and more showings exist east of Groan Creek, in the high ground west of Vermiculite Valley, in the triangle, and in the "tear-off" area north and north-east of Boulder Bore. The old shafts two miles north-east of Boulder Bore are at the junction of the Sturtian glacials with the overlying slates, here a fault. These may be the old Kingsmill Mine. Other minor shows are seen in the Barraranna Gorge (southern part) where they are clearly related to faulting, though Woodmansee and Johnson (1956) suggested that some may be derived from leached volcanics. The same authors recorded bornite in vesicles near the Arkaroola Bore.

The O'Donoghue's Castle mine was on the Paralana fault about six miles south-east of Arkaroola H.S. The Nepowie mine (never developed) was adjacent to Nepouie Peak, probably on a wrench fault.

Asbestos

Tremolite has been dug for at two sites near Wooltana H.S. and most occurrences of tremolite in the scarp zone have obviously been prospected. They are clearly related to faulting, often occurring in fault planes. No important deposits have been seen, though if the occurrences were near to Adelaide some might prove workable.

Gold

In 1949 three prospectors discovered gold about three-quarters of a mile east of Arkaroola H.S. (Lively's Find; Golden Rule Mine). This is sited almost exactly on the Paralana Fault. 158·85 fine ounces was produced from 77·1 tons of ore dug to 1952. The last working took place in 1954.

The 20 ft. shaft has not been descended by the present writer, and the statement by L. L. Mansfield (Mining Engineer) that the material excavated appears to be a decomposed and faulted dyke has not been verified; only shales having been seen. Petrological examination of this material by A. W. G. Whittle in 1948 and 1949 indicated that the material might be of primary origin, and a report by F. L. Stillwell in 1949 on a specimen described it as a fine-grained syenite aplite. This suggests that it is either an altered thin remnant of volcanic material preserved along the Paralana fault plane or similar volcanic material as debris in a conglomerate of upper Torrensian age; or mylonitic volcanic material squeezed up locally along the fault plane. Volcanics outcrop a quarter mile north.

Uranium

Woodmansee and Johnson (1956) refer to scattered evidences of uranium mineralization in small amounts in the area west of Paralana Fault, in the actinolitic marbles, associated with copper mineralization. They regarded it as unimportant.

Beryllium

A specimen from the dumps of the Lady Buxton Mine has been described by H. W. Fander as containing massive magnetite with veinlets of malachite and partly altered crystals of phenacite.

Wooltana Cave

References are often made to the Wooltana Cave. This is the Ammonia Cave of Mawson (1934, map, p. 188) and Ammonia Mine of Woolnough (1926). The cave is in massive dolomitic limestone immediately west of the Paralana Fault (east member), near the Wooltana-Arkaroola track and when visited by Woolnough in 1926 contained quantities of liquid wallaby dung. Near the entrance a great heap of bat guano was seen, in which the remains of a large extinct bat-eating bat were discovered, demonstrated to the Royal Society of South Australia by Wood Jones in 1925. The floor of the cave was covered with ammoniacal material later dug for manure, and last worked in 1933.

COMPARISONS WITH OTHER AREAS

Areas on Margin of Painter Complex

As pointed out above (General Stratigraphy and Structure), upper Proterozoic rocks overlap unconformably the Archaean rocks of the Painter Complex on the west side as well as on the south.

Near Umberatana, rocks occur two miles north-east of North Well (which is on the Arkaroola track six miles east of Umberatana) and have been mapped by Thatcher as calc-silicate rocks. Some of these were seen by the author and appeared very similar to the westernmost Wooltana Volcanic Group rocks. They are in a comparable stratigraphic position, below the thick arkose. No detailed examination of the rocks has yet been made.

At Yudnamutana, eight miles east-north-east of Umberatana, copper mineralization has long been known to be associated with basic rocks. Mawson (1923) described altered basic intrusives "post-dating the great quartzite" which at that time he equated (with some hesitation) with that of the Bolla-Bollana (Burrarunna) Gorge. He noted much actinolite and tremolite. Recent mapping by Campana, Coats, Horwitz and Thatcher places these rocks in the Willouran; but they are, of course, a horizon equivalent to that of the Wooltana volcanics. One is described by Mawson as a diabase. A specimen collected by R. P. Coats during mapping has been described by A. J. Marlow as amphibolitic marble, and another from two miles east as a pyroxene marble.

A little further round the periphery of the complex, altered basic intrusives were recorded in the vicinity of the Daly (Mawson, Daley) mine, four miles east-north-east of Yudnamutana. Mawson described some as "slightly vesicular", and intruded into "slaty and calcareous beds", adding that the intruded rocks "include a remarkable development of actinolite rock and spotted slates in which tremolite is seen to be forming at scattered centres, crystallizing in radial fibrous forms". This association of rocks is almost identical with that on the opposite side of the massif at the entrance to East Painter Gorge. Again, recent Geological Survey mapping places these rocks in the Willouran. Two miles east of the Daly Mine a scapolitized basic rock was recorded at the Shamrock Mine.

Arrowie One-Mile Sheet

In late 1959 mapping by R. Horwitz on the Arrowie one-mile sheet 40 miles south of Wooltana revealed basic rock in breccias apparently squeezed up along the marginal fractures of the ranges near Tea Tree outstation and St. George's Bluff. Three specimens collected by Horwitz were described by Fander as a dolerite, a uralitized dolerite and a sheared uralitized gabbro and it seems likely that these are of Willouran age. They are fragments diapirically emplaced in Marinoan and Cambrian rocks. Other similar associations have been mapped in the area to the west.

Blinman Dome and Other Diapiric Structures in the Central Flinders Ranges

The Blinman Dome is a prominent structural feature of the Central Finders Ranges. Howchin (1907) recorded basic rocks in "volcanic dykes and necks" near Blinman, where a rich copper deposit was found in 1862 and worked till 1918. Specimens were described by Benson (1909). Howchin (1922) gave further details and also referred to basic intrusions at Big Hill, Wirrealpa, 15 miles east. Dickinson (1911, 1953) described the mine and accepted Howchin's "intrusions", suggesting that they were, however, separated from the upper Proterozoic and Cambrian by an unconformity and that they predated the diastrophism which produced the Dome. Howard (1951) studied the district and regarded the structure as an "early form of ring-dyking" and thought the basic rocks were intrusions following a late stage of the Cambrian to post-Cambrian folding and faulting. He found no unconformity. He did suggest that Benson's "melaphyres" predated the dolerites and were interbedded with shale and sandstone.

Webb (1960, 1961) recognised diapiric structures in the Flinders Ranges of which the Blinman Dome is one of the largest. Most of the rocks in the diapiric centre are of Willouran type and include lavas. Subsequent detailed mapping by Coats and Webb shows that many of these lavas though often very similar to Wooltana type lavas are rather more basic.

Comparable diapiric structures occur 15 miles east of Blinman near Wirrealpa H.S., 20 miles south near Oraparinna H.S., 40 miles south near Arkaba H.S., and 55 miles south near Worumba H.S. Of these, that at Oraparinna includes large outcrops of amygdaloidal trachyte identical with some Wooltana trachytes. The Worumba area was described by Spry (1951) who recognised uralitized and saussuritized dolerites and basalts. The present author (1959) noted diorite in crushed dolomitic limestones near Arkaba.

Leigh-Creek-Angepena Area

Benson (1909) refers to a dyke at the Victory mine, 10 miles east of Leigh Creek, Northern Flinders Ranges, and describes a specimen as amygdaloidal melaphyre. This was probably from the "dolerite plugs" mapped by Parkin, Reyner, Pitman and Johns (1953) on the Serle one-mile sheet as intruding the Sturtian south-east of the Victory mine. Similar dolerite plugs are mapped on the Angepena sheet to the south, by Sprigg and Wilson (1953) at Camp Hill Springs—almost on a fault—and in a great "crush zone", possibly diapiric, north of Mucatoona Hill; and east and north of Leigh Creek and at a node on the North-West Fault near Termination Hill by Parkin and King (1952) on the Myrtle Sheet.

Willouran Ranges-Witchelina H.S. Area

Howchin (1924) described Sturt tillite in the Willouran Ranges west and south-west of Hergott Springs (now Marree). Mawson (1927) gave further details of the geology. Howchin noted no igneous rocks in situ, but saw many varieties as erratics in the tillite.

Mawson (p. 387) mentioned that a microscope slide of a conglomerate of a "peculiar type" at Breaden's Hill showed a fragment of a much-altered ophitic basic igneous rock, suggesting that it may have originated in a dyke located amongst the strata half a mile to the west. He described the beds to the west and named them the Willouran Series, noting a calc-silicate rock between Breaden's Hill and Hogan's Well and a large ophitic dolerite sill, uralitized and epidotized, "extending for a great distance to the north-north-west" (from near Breaden's Hill). This, he said, "it quite like some of the basic igneous types of Wooltana and Blinman". He noted also vanadium mineralization (as well as copper).

The published Geological Survey sheets do not cover this area but a specimen collected by R. K. Johns from four miles east of West Mount, Witchelina one-mile sheet (and 25 miles south-west of Marree) is an extensively altered medium-grained volcanic similar to those of Wooltana. Specimens from Willouran rocks near Callana H.S. mapped by B. P. Webb include vesicular dacites and microdiorites.

Port Augusta-Iron Knob-Whyalla Area

Forty miles north of Port Augusta, Brunnschweiler (1956) recorded amygdaloidal lavas in Willouran rocks at Depot Creek, Southern Finders Ranges. These are identical with the typical Wooltana trachytes.

Early in 1960 B. P. Webb, visiting the Whyalla area with R. Whitehead, geologist of Broken Hill Proprietary Ltd., collected similar lavas from a sequence interbedded with sediments unconformably overlying Archaean at Douglas Point, on the coast of Spencer Gulf south-west of Port Augusta.

In mapping the Middleback Ranges, Miles (1955) recorded "younger dolerite dykes and possible sills or flows" on the General Geological Map which accompanies his Bulletin. His own descriptions refer only to dykes cutting the Iron Monarch orebody, and he quotes G. H. Taylor's description of a specimen as a "pyroxene dolerite". On the map, however, there is shown an outcrop three miles by two miles around Old Roopena H.S. (10 miles east of Iron Knob) and in an appendix Taylor describes three specimens from this area as vesicular basaltic lavas. Specimens since collected are scarcely distinguishable in the hand specimen from the most common amygdaloidal trachyte of Wooltana and have been described by Fander as exact equivalents of the Wooltana rocks, but far less affected by subsequent changes. The lavas are overlain by a conglomerate mapped as Corunna conglomerate, containing pebbles of volcanics.

Mount Remarkable

Mount Remarkable, 30 miles north-east of Port Pirie, forms a precipitous scarp, 2,000 feet above the Willochra Plains. Its structure was examined by Howchin (1916) and found to be complex, there being strong meridional faulting and crushing, the sudden ending of the range being attributed to east-west faults.

In the "Foot Hills" between the southern end of the scarp ridge and the town of Melrose at its base to the east is an area of crushed limestones and ribbon slates (above a tillite) in which Howchin stated that numerous small plugs and pipes of basic igneous rock, with a few acid types, occur over an area about one mile by half a mile.

E. O. Thiele (1916, in Howchin, 1916) described these rocks as of three types: (i) altered dolerites, (ii) quartz porphyries (including "quartz-ceratophyre"), (iii) aplites. He compared the first group with the Blinman basic rocks. From his descriptions it seems likely that the "quartz-ceratophyre" very strongly resembles the porphyritic sodic rhyolite of Wooltana.

It is suggested here from a review of the published evidence that the Mount Remarkable igneous complex is diapiric.

Olary Province

Jones, Talbot and McBriar (1962) suggest that rocks mapped on the Plumbago one-mile sheet of the Geological Survey of South Australia by Campana as "amphibolites, epidotes and skarn rocks" in Archaean rocks are volcanic and that the sequence "probably represents a spilite-keratophyre assemblage with interbedded shales". They refer it to the Archaean. The authors kindly showed specimens to the writer: they closely resemble the more metamorphosed Wooltana rocks. It is suggested here that these rocks are of Willouran age. Those near the southern boundary of the Plumbago sheet occupy a syncline and are mapped by Campana as overlying his uppermost Archaean, and unconformably covered by Sturtian. Those of the larger outcrop extending east-north east from Hughes prospect could be intrusive into Campana's Archaean and are mapped as unconformably covered by the Torrensian Series.

New South Wales

Barrier Ranges. According to B. P. Thomson discontinuous outcrops of lavas occur in Adelaide System rocks (Torrowangee Series) from about 30 miles north of Broken Hill for a distance of at least eight miles, continuing to the north (King and Thomson, 1953, p. 547 and personal communication). These occur along a folded and locally faulted zone, which could explain the discontinuity. They were described as altered amygdaloidal and vesicular basalts. A specimen kindly presented by Mr. Thomson was described by M. J. Bucknell as an amygdaloidal quartz andesite.

The lavas overlie thin beds of limestone, sandstone and grit which themselves unconformably overlie the Willyama Series. The contact between the lavas and an overlying tillite (which contains erratics of volcanics obviously of local origin) is disconformable.

West Darling District. In Kenny (1934) lavas (feldspar-porphyry and rhyolite), interbedded with sediments which according to Thomson (pers. comm.) are probably of Adelaide System age, are recorded in the Gnalta-Grasmere area (80 miles north-east of Broken Hill). Specimens collected by the present author in 1961 include some closely resembling Wooltana lavas. Green tuffaceous sandstones of similar age are recorded near the Coppermine Range (100 miles north-east of Broken Hill). Porphyry and felsite lava flows occur in the Cootawundy Hills to the south of the Coppermine Range. The distribution of these outcrops has a north-west trend in sympathy with a regional fault direction (the Waratta-Koonenberry Fault of King and Thomson p. 555) which is associated with gold and copper mineralization.

At Mount Arrowsmith (125 miles north of Broken Hill) andesite and amygdaloidal basalt were recorded by Kenny (p. 51) "and appear to be arranged as lava flows about a centre of volcanic activity more or less contemporaneous with the upper beds of the Torrowangee Series. These ancient basalts have undergone considerable alteration, epidote being very common in veins and irregular masses within the basic lavas. The general trend of the main structures is north 30 degrees west", parallel to the general direction of the Waratta-Koonenberry Fault.

In the Waratta Ranges (180 miles north of Broken Hill) Kenny recorded flows of felsite and porphyry interbedded with sediments and equivalent in age to those previously mentioned. Possible volcanics of similar age occur in the Scopes Range (50 miles east of Broken Hill).

It is noteworthy that tillites were recorded in the Koonenberry Gap close to the top of the Torrowangee Series.

Far North of South Australia—Indulkana Ranges

In the extreme north of South Australia Proterozoic outcrops are rare, but west of Granite Downs H.S. in the Indulkana Ranges an area of "vesicular basalt and melaphyre" has been mapped south of Chambers Bluff by Sprigg, Wilson and Coats (1956) on the Chandler one-mile sheet. These are shown as overlying Sturtian tillite. A smaller area is mapped 20 miles east, near Wantapella swamp, at a similar horizon.

Northern Territory

Proterozoic volcanics are widespread in the northern Territory. Hossfeld (1953) gave the name Agicondi Series to rocks assigned to this age, and stated (p 114) that they consisted originally of "arenaceous and argillaceous sediments with a considerable amount of tuffaceous material and very few calcareous deposits", the tuffaceous material having been subsequently metamorphosed to schist. Hossfeld regarded certain rocks at Hatches Creek as of this age; these contain amygdaloidal lavas. Tuffs of the Pine Creek district he regarded as suggestive of "original lavas of intermediate composition, dacites or andesites, but probably the latter".

Regional mapping by Bureau of Mineral Resources geologists has since confirmed the widespread occurrence of Proterozoic amygdaloidal rocks. Examples of these collected from the Edith River volcanics (Katherine-Darwin region) were stated to resemble Willouran volcanics (Webb, 1959). As Fander points out in the accompanying petrological notes, volcanics collected by Bureau of Mineral Resources geologists in the McArthur River Basin on the south-west side of the Gulf of Carpentaria are practically identical with the Wooltana rocks.

Noakes (1957, table, p. 224) refers the Wollogorang volcanics of the Gulf of Carpentaria-Barkly Tableland area to a Willouran-Torrensian horizon.

Western Queensland-Mount Isa

Knight (1953), discussing the regional geology of Mount Isa, mentions amygdaloidal rocks and tuffs in the Greenstones Group. This is the lowest Group of the Mount Isa Series according to Jones (1953), who places it in the Proterozoic.

Western Australia

David and Browne (1950) correlated the Nullagine Series of Western Australia with the upper Adelaide Series (System) of South Australia. The basal bed, 300 feet thick at Nullagine, they accepted as fluvioglacial, quoting a correlation with the Sturtian by Becher in 1898.

Browne states (p. 73) that in the Pilbara Goldfield "contemporaneous volcanic activity is strongly represented by acid, intermediate and basic lava-flows and pyroclastic rocks. These are in places at the very base of the series, but may be interbedded with the sediments on more than one horizon. . . . Thick felsite flows are present. . . . Numerous volcanic vents have been found, surrounded by coarse agglomerates, tuffs and vesicular and amygdaloidal lavas."

In the Townsend Range a series of that name, equated with the Nullagine Series, includes altered vesicular lavas in its lower part, and lavas are common in the Kimberley Division Nullagine Series. Noakes (1957) refers the Mornington volcanics of the Kimberley Plateau to a lower Torrensian horizon.

CONCLUSIONS

Wooltana Area

Mapping of the Wooltana Volcanic Belt shows that at least 2,000 feet of lavas and associated pyroclastics of Willouran age outcrop over an area about 15 miles by 5 miles. In the immediate district it seems probable that northwards and westwards they thin and a change to a more sedimentary facies is masked by metamorphism. Southwards and eastwards there is insufficient evidence to state whether they are concealed or absent. The major part of the outcrop lies along an important lineament forming the eastern limit of the Flinders Ranges.

The volcanics are overlain disconformably by Torrensian sediments which, near Wooltana, are thin or absent but which thicken rapidly to the north and west. These are unconformably overlain by the Sturtian lower glacial sequence, which near Wooltana rests directly on the volcanics.

The area is bisected by a major meridional structure, the Paralana Fault, which has a throw of over 20,000 feet. Intense splinter-faults, wrenches and thrusts are associated with this and caused ubiquitous brecciation. Tight folding occurs in the north and west.

Petrographic examination of the volcanic rocks show that they are mostly trachytes, with very subsidiary porphyritic rhyolite and some andesite. The trachytes are sodic and unusual in being rich in haematite and are often amygdaloidal or vesicular.

The presence of interbedded though thin sediments of shallow-water type suggests that some flows at least were submarine. No pillow lavas have been found and most of the volcanics are of sub-aerial deposition. Some filled up shallow waters and others were temporarily submerged and covered by water-deposited sediments.

The Wooltana volcanics appear mostly to have been extruded from fissures, of which the main lineament along the Wooltana scarp foot was probably much the most important. Central vents are few and small.

The association of volcanics with lineaments often known to be faults, together with the combination of predominantly sub-aerial effusion with some shallow water sedimentation has been explained experimentally by E. S. O'Driscoll (pers. comm.). In producing domes and basins by shear folding techniques he has demonstrated that the hingeline is a nodal line which combines the zone of maximum weakness with the meeting point of ground, air and water. Further, it defines the locus of maximum shear, maximum deformation and maximum rate of change of attitude, with all the attendant maxima of sedimentation rate, turbidites, fracture, brecciation and, in the inclined shear, overturning and thrusting.

The fissure effusion of the volcanics could, therefore, be associated either with a prominent scarp due to block faulting or with a lineament showing no marked relief. Any present day relief along such a lineament would have, of course, no necessary relevance to the environment at the time of effusion.

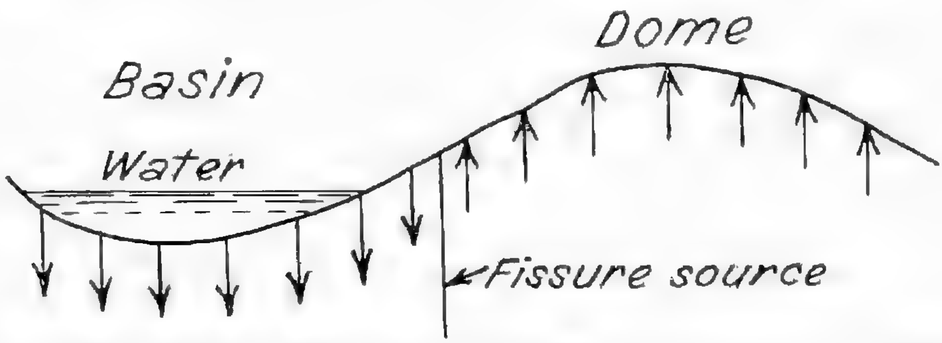

Fig. 4. Sketch showing relationship of volcanic fissure of Wooltana type to hinge-line between dome and basin.

Adelaide Geosyncline

The known occurrence of similar rocks *in situ* and in diapirs elsewhere in the Adelaide geosyncline suggests that either the original area of effusion was very much larger, or that other scattered occurrences exist, mostly now concealed. Because the erosion during and immediately preceding Sturtian time was intense but apparently local, the second suggestion seems more probable.

Even if only the northern half of the geosyncline is considered (i.e. about as far south as the southernmost known related rocks at Mount Remarkable) an area of 30,000-40,000 square miles may have been affected. Whether this was ever a complete cover of lavas or was in discontinuous but extensive spreads from local centres is uncertain. The Wooltana occurrence could itself be such a local centre, related to the known linear weakness along the Wooltana scarp foot. This could apply also to the Depot Creek (Wilkatana) occurrence, itself on a major fault. The almost invariable occurrence of Willouran volcanics in numerous diapirs at first sight suggests a complete coverage. But as the age of the beginning of doming at Blinman has been shown by Coats (pers. comm.) to be probably contemporaneous with Sturtian deposition, and as this doming may be the first surface expression of diapirism, it is possible that the diapirs are located on centres of volcanic activity which started in Willouran time and continued long after it, rather than local revelations of what lies everywhere below. Although there is no evidence of post-Willouran vulcanism at Blinman, other occurrences exist, e.g. at Chambers Bluff (Indulkana sheet) which could come within this category. There is also no certainty that some necks at Wooltana are not post-Willouran.

Wider Australian Correlation

The occurrence of precisely similar rocks at similar stratigraphic horizons in various distant localities, including Tennant Creek, N.T. (800 miles north-north-west of Wooltana) and Bauhinia Downs, N.T. (950 miles north) as well

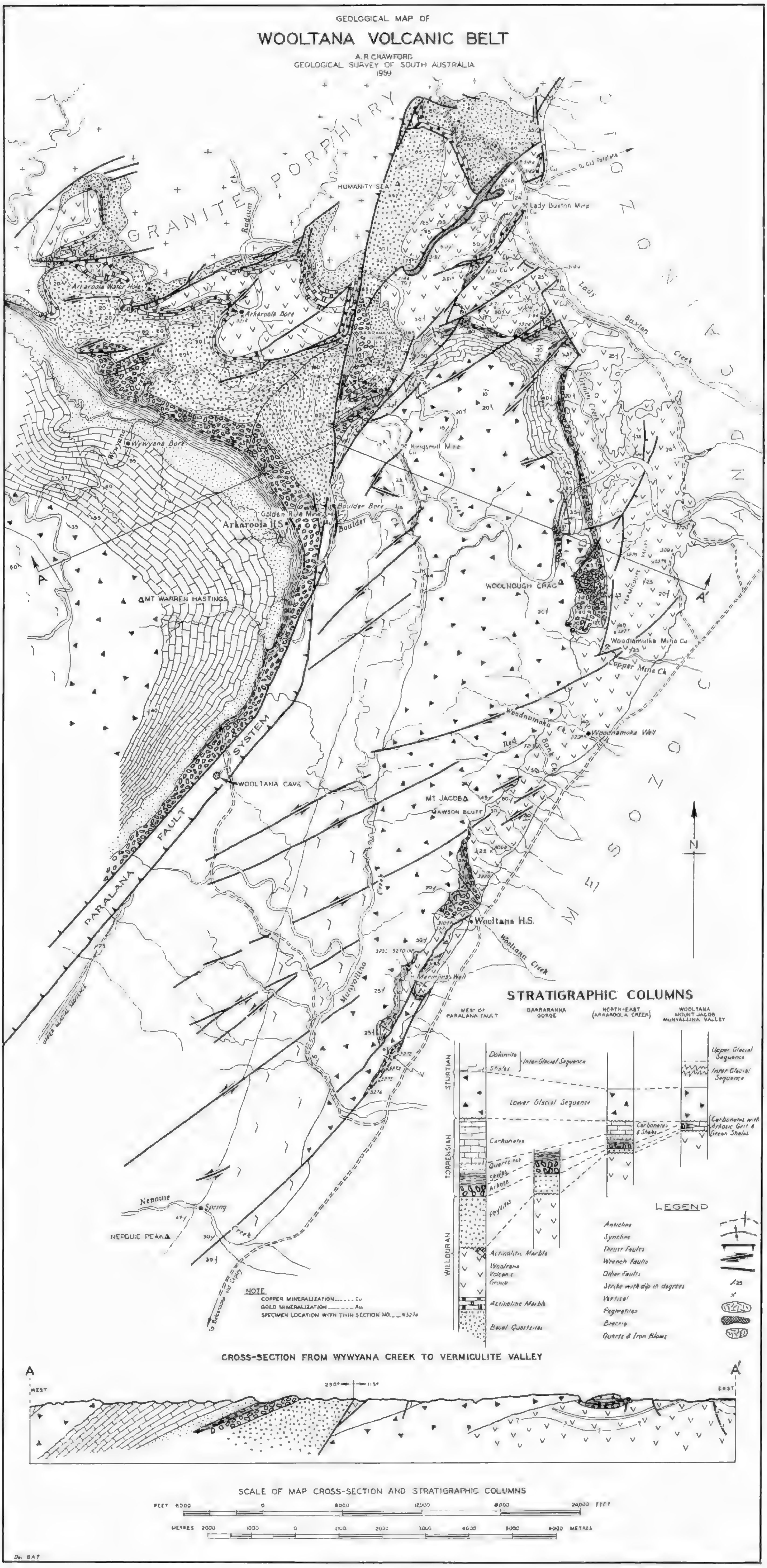

Fig. 5. Geological Map of Wooltana Volcanic Belt.

as very similar rocks from almost certainly the same horizon over large parts of Western Australia, western New South Wales and western Queensland is of great interest. Making due allowance for erosional losses in a well-authenticated Australian-wide Upper Proterozoic glaciation and a widespread Permian glaciation, it seems reasonable to postulate an effusion of Proterozoic volcanics of Willouran age comparable, if not so continuous in extent, with the classic flood basalts such as the Deccan Traps, Drakensbergs and Keeweenawans.

Restricting discussion to South Australia and the adjacent areas, lack of knowledge of the basement geology of the great sedimentary basins and of those parts of the massifs masked by Quaternary deposits prevents even an approximate assessment of the real relationships with (for example) western New South Wales.

A major problem in South Australia is the age and structure of the vast area of igneous rocks known loosely as the Gawler Range porphyry. This not only forms the Gawler Ranges as shown on most maps, but extends far to the north and is known near Kingoonya, at Tarcoola, and for 100 miles north. Jack (1917) regarded it as an effusive lying on the Archaean gneisses. No study of the porphyry itself has yet been made. Much confusion about its age has arisen because of the discovery by Jack, repeated by Mawson (1947) of pebbles of Gawler Range porphyry type rocks in an arenaceous formation (Corunna conglomerate) lying east of the porphyry mass and of uncertain relation both with it and with other rocks in the geosyncline, where Sturtian glacial beds contain erratics of similar porhyry; and the discovery by Johns and Solomon (1953) of intrusions of Gawler Range porphyry in that same arenaceous formation.

At the time this paper was submitted in its original form as a thesis the problem was unsolved. The author suggested then a genetic relationship between the Gawler Range porphyry and the Wooltana and other equivalent volcanics. At that time he was particularly struck by the similarity between the sequence of events in the Erongo complex of South-West Africa (Cloos, 1919) and a possible though unproved sequence in northern Eyre Peninsula. This, together with the petrographic similarity of the "bomb porphyry" of Merinjina, Wooltana (T.S. 5265) and specimens of Gawler Range porphyry led him to suggest that the Gawler Range porphyry is "an effusive mass formerly covered by, and possibly lying on, a lava of which the Wooltana and other volcanics are local remnants of the floods spreading further out (possibly, at Wooltana itself, locally more abundant extruded). This porphyry-lava complex could be . . . a larger version of the Erongo complex of South-West Africa (Cloos, 1919). It would since have been deprived of its outer skin on the upper surface by erosion. The relatively minor occurrences of porphyry at Wooltana and their apparent equivalents (e.g. at Mount Remarkable) having been derived from a similar ultimate source". It was further suggested that the intrusions of the Gawler Range porphyry into the Corunna conglomerate were a late phase (it should be noted that these lie well east of the main outcrop of the porphyry) and, following Jack, that the Moonta Porphyry was also genetically related, and was possibly a deeply eroded feeder.

The economic importance of a study on these lines was emphasized, the Wooltana volcanics having copper and gold mineralization, and considered with the Gawler Range Porphyry to be the ultimate source of the widespread copper mineralization of the Flinders Ranges, and the Moonta Porphyry being known to be the host rock for very rich copper lodes. While the mineralization actually in the Wooltana volcanics and the two porphyries is, of course, magmatic (if often structurally controlled) it is suggested that much of that in the Adelaide System sediments is of the submarine exhalative-sedimentary type (Oftedahl, 1958). The widespread distribution of copper and other minerals in sediments known to occur in extensive basins crossed by numerous lineaments along which volcanics occur suggests that gas emission accompanying the volcanic lavas and tuffs caused chemical reaction with sea-water which by marine circulation led to mineral deposition far beyond the emission areas.

In 1961 a sinuous traverse of the Gawler Range porphyry outcrop and surrounding areas was made with B. P. Webb and J. Johnson. The discovery that the rocks at Roopena included by Miles in his "Younger Dolerite" suite are identical with the typical Wooltana amygdaloidal trachytes gave immediate encouragement. The discovery of definite extrusive rocks (volcanic breccia, volcanic glass and tuff) at one of Johns and Solomon's intrusions and elsewhere followed. It was immediately evident that the "Gawler Range porphyry", though possessing a very strong identity in that red porphyritic sodic rhyolites are by far the commonest rocks, is nevertheless a great volcanic complex.

In a report on this reconnaissance the fact that the gold and tin mineralization at Glenloth and Tarcoola is closely associated with variants of the typical Gawler Range porphyritic rhyolites was emphasized.

The author's later discovery of huge intersecting circular structures up to 35 miles in diameter (possibly 50 miles) and definite central vents parasitic to these, both associated with major straight lineaments suggests that both circular and straight fissures were the major sources of a vast but quiet effusion of rhyolite lava in the Gawler Ranges, with local explosive central vents. The relationship of this to the Wooltana, Oraparinna, Roopena and other trachytes, though certainly genetic, needs further study.

ACKNOWLEDGMENTS

The author thanks his Geological Survey colleagues R. P. Coats (who has mapped much of the rest of the sheet), R. C. Horwitz, D. Thatcher, B. P. Thomson and B. P. Webb. H. W. Fander has been especially helpful in the petrology. Professor A. R. Alderman has been an understanding supervisor. Miss A. K. Brook, Mr. W. Rossini and Mr. B. Tink produced elegant copies of the author's original maps. Acknowledgment is due to Mr. and Mrs. J. Ford of Wooltana for hospitality. The author thanks the Director of Mines, South Australia, for permission to submit Departmental work for publication.

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APPENDIX

Analyses of Wooltana volcanic rocks by H. W. Sears, Australian Mineral Development Laboratories. Specific Gravities by Geophysical Section, Geological Survey, of South Australia.

	Epidotized trachyte Wooltana: Woodnamoka Well (TS.3228)	*Trachyte* Wooltana: Triangle of Volcanics (TS.3194)
	%	%
SiO_2	53·2	59·2
Al_2O_3	12·3	11·2
Fe_2O_3	10·92	12·07
FeO	0·73	nil
MgO	2·36	0·73
CaO	15·8	2·02
Na_2O	0·16	0·24
K_2O	0·15	10·2
H_2O −	0·31	0·17
H_2O +	0·84	0·50
CO_2	0·71	2·22
TiO_2	1·42	1·02
P_2O_5	0·13	0·10
SO_3	Nil	Nil
Cl	Nil	Nil
MnO	0·14	0·44
F	0·03	—
Specific Gravity	2·86	2·75

Fig. 1. Air view, looking south, over Wooltana Volcanic Belt.

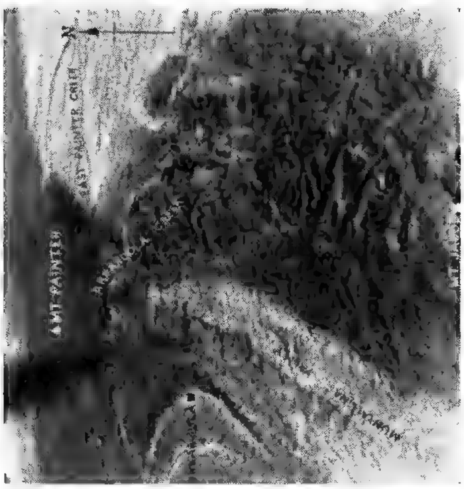

Fig. 2. Air view, looking north, of central and northern part of Wooltana Volcanic Belt and Painter Complex.

Fig. 3. Typical amygdaloidal trachyte, immediately west of Wooltana H.S.

Fig. 4. Vesicular and amygdaloidal trachyte Woodnamoka Well.

Fig. 5. Massive trachyte, Arkaroola Creek at old Paralana mail track crossing.

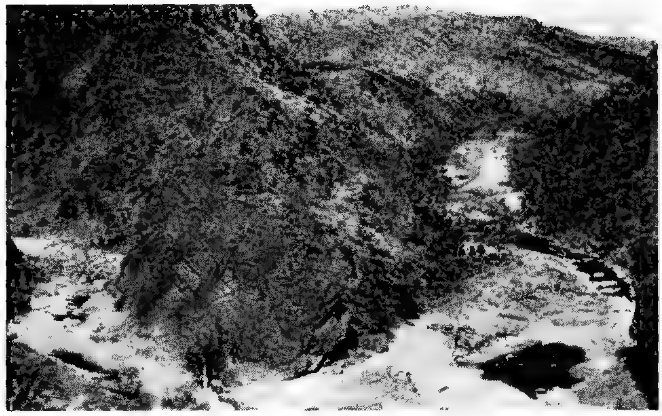

Fig. 1. Barraranna Gorge. South end looking east.

Fig. 2. View of area west of Paralana fault looking north to Mount Painter (the prominent monadnock).

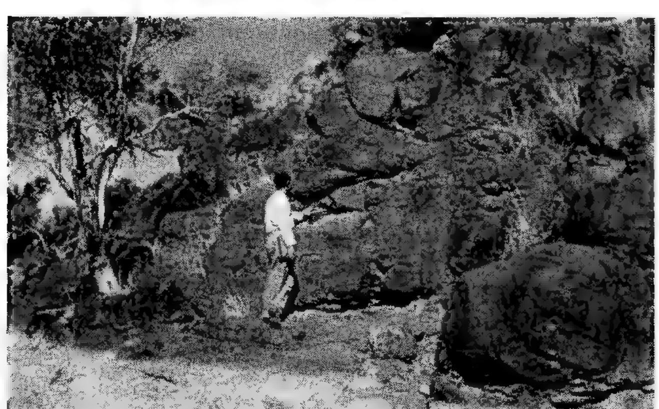

Fig. 3. Close-up of Sturtian lower glacial formation, Merinjina Creek.

THE WOOLTANA LAVAS

BY H. W. FANDER

Summary

The geological setting of these rocks is described elsewhere by A. R. Crawford. The petrography of the Wooltana lavas is unusual and distinctive, and is given in detail. Comparisons are made with similar rocks from other localities in South Australia, and some evidence is presented showing correlation between the Wooltana rocks and similar material occurring in widely scattered parts of the Northern Territory and New South Wales.

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[Read 11 April 1963]

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INTRODUCTION

The Wooltana lavas present problems of classification, owing to their unusual texture and constitution. Compositional variations and successive stages of alteration have further obscured the picture. However, the distinctive nature of these rocks has aided their comparison and correlation with certain other rocks occurring at Roopena (10 m. east of Iron Knob) and at Depot Creek (Southern Flinders Ranges). The pyroclastic deposits associated with the Wooltana lavas contain fragments of sodic rhyolites strikingly similar to some of the Gawler Range Porphyry types; this fact opens up interesting possibilities of petrogenetic links between all the areas concerned. The Gawler Range Porphyry itself shows compositional variations ranging from andesite through trachyte to sodic rhyolite.

1. THE WOOLTANA ROCKS

The main rock-type represented in the igneous sequence in the Wooltana area is a red to black or purplish, amygdaloidal extrusive rock. The amygdales often have a selvedge of pink feldspar and are filled with quartz. The macroscopic appearance of the rock is thus quite distinctive.

In thin-section, the freshest samples of the lavas consist of laths of feldspar, randomly embedded in massive, fine-grained hematite. The feldspar has been carefully studied by mineralogical means and by X-ray diffraction, and is thought to be a member of the sanidine-anorthoclase series, probably in most instances nearer to the anorthoclase end. The usual range of dimensions of laths is between 0·04 mm. × 0·20 mm. and 0·08 mm. × 0·40 mm. In some thin-sections, pseudomorphs of iron-ore and antigorite occur which by their shape and constitution suggest that they represent completely altered microphenocrysts of olivine. The amygdales are typically lined with euhedral crystals of reddish microcline and filled with quartz and calcite. In some instances, pure albite or chlorite occurs as fillings, but a microcline lining is almost present.

* Australian Mineral Development Laboratories.

More altered rocks show replacement of feldspar laths by quartz, in patches showing simultaneous extinction unrelated to the orientation of the laths. In other instances, particularly in more scoriaceous types, the microcline has veined the rock and partially replaced original feldspar, as well as lining the amygdales.

Secondary or late-stage introduction of minerals, which postdates the filling of the amygdales, has occurred in successive stages. An earlier stage involved the introduction of muscovite and quartz, accompanied in some instances by little tourmaline and phlogopite. This is a siliceous, potassic phase. A later stage was dominantly calcic, introducing fibrous tremolite, calcite, sphene, epidote, and finally scapolite. The tremolite, epidote and scapolite occur in the body of the rock, but the other minerals are to be found in the amygdales. In places, the tremolite, scapolite and epidote have so obliterated the original structure that very little resemblance between the altered and the fresh rocks remains.

The texture of the fresh rock is distinctive and unusual. Although the rock must be classified as a trachyte on the grounds of its mineral composition, its texture is not trachytic; flow-structure is conspicuous by its absence. The texture could more accurately be described as slaggy, consisting of random to sub-radiating laths of feldspar in hematite; the amygdales are often rimmed with massive hematite containing practically no feldspar. This is probably due to more rapid cooling adjacent to the original, unfilled vesicles. The slaggy texture, brought about by very rapid chilling of the rock, is in keeping with other considerations such as the general absence of primary ferromagnesian minerals, and the presence of the high-temperature feldspar (anorthoclase). The probable former presence of olivine is also significant in this regard, since this mineral does not normally occur in acid to intermediate rocks except in the rapidly-cooled extrusives where the natural sequence of Bowen's Reaction Series has been arrested.

The hematite which forms such a large part of the trachyte is considered to be primary; it occurs as dense aggregates and swarms of very small euhedral to subhedral crystals, usually denser adjacent to amygdales. Nowhere does the hematite replace feldspar or any other mineral. It does not occur in the amygdales, nor in veins. It is not associated with the potassic, siliceous or calcic secondary minerals described above.

Minor variants of the Wooltana trachyte include slightly coarser-grained microsyenites, and more calcic varieties classified as microdiorites. Hematite is abundant in all these. They are not usually amygdaloidal, and they reflect a slower cooling history and slight differences in the composition of the magma.

The associated pyroclastic rocks are lithic tuffs and lapilli-tuffs. They contain fragments of Wooltana-type trachyte and of sodic rhyolite remarkably similar to a widespread member of the Gawler Range Volcanic Complex. Inclusions of both these types in the pyroclasts indicates their extrusion prior to at least some of the volcanic activity giving rise to these deposits.

2. COMPARISONS AND CORRELATIONS

a. *The Gawler Range Volcanic Complex*

This comprises a range of igneous rocks, predominantly extrusive, extending from trachyte and andesite to sodic rhyolite and obsidian. This vast complex is characterized by the conspicuous and uniform reddening (sometimes termed "magmatic reddening") of its various representatives due to finely-divided hematite. Extensive but as yet incomplete studies of the Complex strongly indicate, on petrogenetic grounds, that the Wooltana Lavas quite probably represent a local variant of the parent magma responsible for the whole Complex. The presence of Gawler Range rhyolite fragments in Wooltana lithic tuffs considerably strengthens this contention.

b. *Depot Creek Volcanics*

These rocks strongly resemble the Wooltana Lavas in every feature, being only slightly coarser-grained and less hematitic. The nature and mineralogy of the alteration is closely similar to that of the Wooltana rocks. There is very little room for doubt that both rocks had a common origin.

c. *Roopena Lavas*

These rocks are remarkably similar to the Wooltana rocks in every detail. Secondary alteration is far less prevalent, being mainly confined to secondary or late-stage muscovite. In some parts of the rock, the amygdales are lined with pale chlorite, but the characteristic euhedral microcline is very widespread. Occasional microphenocrysts of probable sanidine-anorthoclase occur. There is no doubt that the Roopena and Wooltana lavas have a common origin.

d. *Gnalta Area, N.S.W.*

Porphyritic sodic rhyolites and trachytes occurring in this area may be petrogenetically linked with the Wooltana lavas. Little is known about these rocks as yet and thus detailed comparisons must be made at a later stage.

e. *Northern Territory*

Rocks very closely resembling the Wooltana lavas in petrogenesis and petrography occur in the Borroloola area, the Hodgson Downs and the Bauhinia Downs four-mile areas. There is a possibility that volcanic rocks at Tennant Creek and Hall's Creek may also be related. Extensive further investigations are needed to explore this concept which extends from Arnhem Land to Eyre Peninsula.

Fig. 1. The photomicrograph shows sheaves of fibrous tremolite and a pseudomorph after olivine composed of antigorite and geothite. x 35.

Fig. 2. Portion of a vesicle, showing fibrous, cloudy microline; twinned, clear albite; and quartz. Crossed polarizers. x 100.

Fig. 3. Wooltana trachyte, showing feldspar laths and hematite. Note concentration of hematite surrounding microcline-filled vesicle in centre. x 35.

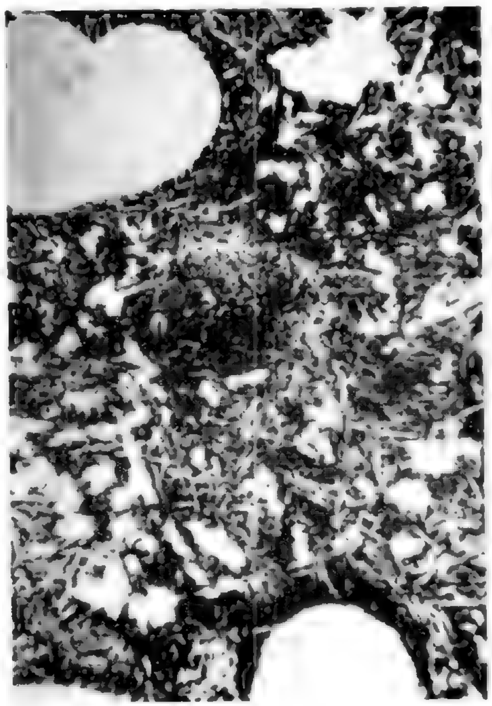

Fig. 4. Typical texture of Wooltana trachyte. Laths of feldspar and patches of serpophitic alteration products embedded in hematite. x 35

STONYFELL QUARTZITE: DESCRIPTIVE STRATIGRAPHY AND PETROGRAPHY OF THE TYPE SECTION

BY *G. R. HEATH*

Summary

A detailed study of the Stonytell Quartzite in the type area disclosed the presence of *830'* of dominantly arenaceous sediments, The principal rock types are poorly sorted, somewhat calcareous, felspathic greywackes and clean, well sorted and subarkoses. The sediments occurring through the type section show sufficient variation to justify some reclassification and subdivision of the Stonyfell Quartzite as a stratigraphic unit.

STONYFELL QUARTZITE: DESCRIPTIVE STRATIGRAPHY AND PETROGRAPHY OF THE TYPE SECTION

by G. R. Heath

[Read 11 April 1963]

SUMMARY

A detailed study of the Stonyfell Quartzite in the type area disclosed the presence of 830′ of dominantly arenaceous sediments. The principal rock types are poorly sorted, somewhat calcareous, felspathic greywackes and clean, well-sorted arkoses and subarkoses.

The sediments occurring through the type section show sufficient variation to justify some reclassification and subdivision of the Stonyfell Quartzite as a stratigraphic unit.

INTRODUCTION

The Stonyfell Quartzite is the sixth Formation in the Torrensian Series of the Adelaide System (Mawson and Sprigg, 1950). It outcrops along the western edge of the Mount Lofty Ranges, east of Adelaide, as a series of "blocks", which are the faulted remnants of an original continuous occurrence. These outcrops are generally less than eight square miles in area and are separated by faults which have a variable, roughly north-easterly strike.

To the west, the occurrences are terminated by the Eden Fault, producing the well-defined scarp which forms the western limit of the Ranges south of Hope Valley.

Of the fault blocks, the one forming the prominent east-west ridge above Stonyfell has been chosen as the type occurrence of the Formation (Mawson and Sprigg, 1950).

TYPE SECTION

The type area does not contain an uninterrupted, well-exposed section through the Stonyfell Quartzite, due to the deep weathering which has affected the ridge tops in this area. In order to obtain relatively unaltered samples throughout the unit, the type section was measured in two parts.

The lower beds were studied along a spur, about half a mile east of Stonyfell Quarry (lat. 34°55.25′S., long. 138°41.5′E., grid reference 692831 to 693831, Adelaide 1:63,360 Military Sheet). The upper part of the sequence is well exposed in the south-east wall of Slapes Gully (lat. 34°57′S., long. 138°41′E.), and was measured between grid references 690821 and 690820.

Stratigraphic Summary

Top-416′ Thinly-bedded, well-sorted and rounded subarkoses with minor, shaley felspathic greywacke partings.

416-681′ Schistose, felspathic greywackes interbedded with somewhat calcareous subarkoses.

681-829′ Two quartzite sequences (681-738′: subarkosic, 790-829′: arkosic) separated by schistose greywackes similar to 416-681′.

Detailed Stratigraphy

Top-215′ Subarkoses; off-white to pale yellow-brown; medium-grained; fairly well sorted; friable to sub-quartzitic, with minor (less than 20 p.c.) arkoses. The clean arenites, which are 2 in. to 2 ft. thick, are separated by ½ in. shaley felspathic greywackes. Bedding is irregular, and frequently shows lensing and "pinch and swell" structures. Low dip, planar cross-bedding is common. Strength of outcrop is generally poor to fair.

215-335′ Off-white to red-brown subarkoses, similar to 0-215′, with abundant 1 in. interbedded shaley felspathic greywackes. Bedding as 0-215′. Generally crops out poorly.

335-416′ Subarkose; off-white to pale yellow-brown; medium-grained; fairly well sorted; dominantly sub-quartzitic to quartzitic. Bedding is usually thin and irregular, but is difficult to see because of the homogeneity of the unit and absence of parting. Cross-bedding is common. The unit forms prominent outcrops, which show good rectangular jointing and are commonly case-hardened.

416-467′ Subarkoses; dominantly quartzitic; off-white to pale red-brown; fine- to medium-grained; poorly sorted. Thinly interbedded with felspathic greywackes; light grey to grey; fine- to medium-grained; poorly sorted; friable to subquartzitic; schistose; somewhat calcareous. Bedding (less than 1/10 in. to 9 in. thick) is usually irregular in thickness and is commonly obscured by superimposed schistosity. Subarkoses make up about two-thirds of the sequence. Strength of outcrop is fairly strong, due to the absence of well-developed joint systems to assist mechanical disintegration.

467-524′ Interbedded subarkoses and greywackes. Similar to 416-467′, but all beds contain some calcite as matrix or cement. Subarkoses make up about one-third of the sequence. The greywackes frequently contain irregular argillaceous laminae (? mud flakes) and show irregular easterly dipping schistosity. The unit generally crops out poorly.

524-557′ Calcareous (average calcite content is about 15 p.c.) interbedded subarkoses and felspathic greywackes, generally similar to 416-467′. Forms fairly prominent outcrops, which have a "blocky" appearance (due to the etching of jointed quartzitic beds). Subarkoses make up about two-thirds of the sequence.

557-627′ Interbedded greywackes and medium-grained subarkoses, generally similar to 467-524′. Argillaceous laminae are common in the greywackes. Subarkoses make up a quarter to a third of the unit. Generally crops out poorly. However, a more quartzitic bed near the middle of the unit crops out fairly prominently in Slapes Gully.

627-681′ Arkoses; pink to purplish-grey; fine- to medium-grained; generally quartzitic, interbedded with felspathic greywackes; calcareous, grey to grey-green; schistose. Bedding, ranging up to 3 ft., is generally thicker than in the underlying units. Cross-bedding is almost ubiquitous, although obscured by crude, easterly dipping schistosity in some areas. Foresets range from less than 1 in. to 40 or 50 ft. in length. The unit crops out strongly in the vicinity of the type section, but is not as well exposed further east.

681-738′ Subarkoses and lesser arkoses; pale pink to light brown; fairly well to well sorted; very fine- to medium-grained; sub-quartzitic to quartzitic. Bedding ranges from less than 1 in. to 3 ft. in thickness, but is difficult to see due to the gradational variations in lithology. Rectangular parting and jointing are very well developed. The unit forms very prominent outcrops; the whole thickness commonly being exposed as a vertical cliff face.

738-790′ Subarkoses; calcareous; off-white to pinkish; fine- to medium-grained; poorly sorted; sub-quartzitic to quartzitic. Interbedded with felspathic greywackes, grey; schistose; calcareous; fine- to medium-grained; poorly sorted; friable to sub-quartzitic. This sequence is similar to the interval 416-681′. Bedding is generally thin and irregular. Cross-bedding is abundant. The unit is generally well exposed due to the protection afforded by the enclosing resistant beds.

790-829′ Arkose; off-white to yellowish-brown and occasionally pink; homogeneous; fine- to medium-grained; fairly well sorted; sub-quartzitic to quartzitic. Similar in appearance to 681-738′. Bedding is generally 1 in. to 3 ft. thick and shows "pinch and swell" structures. Jointing and parting are well developed, but less perfectly than 681-738′. This unit crops out strongly in the type area where it is commonly exposed as a sub-vertical cliff face.

PETROGRAPHY

Principal Rock Types

Petrologically, the rocks of the Stonyfell Quartzite fall into two well-defined classes. Very few specimens show intermediate characteristics.

The most common rock type is a "clean" generally fairly quartzitic subarkose, with an average mineral composition of 79·5 p.c. quartz and 20·5 p.c. potassic felspar (determined by grain count). Grains are well sorted, well rounded and frequently have high sphericities. The most common cement is silica, which has been deposited as optically continuous envelopes in the voids between quartz grains. Calcite cement was observed only in samples from the middle of the formation.

The other common rock type is a poorly sorted felspathic greywacke, which is often somewhat calcareous and usually shows well-developed irregular schistosity. The average mineral composition is 58·7 p.c. quartz, 12·0 p.c. felspar (potassic varieties, with a fairly large proportion of sodic plagioclase in the finer grain sizes), 20·7 p.c. matrix and 8·6 p.c. calcite (determined by modal analysis). Grains are usually angular and have low sphericities. Packing tends to be very open, the interstices being filled with very fine-grained quartz-sericite-chlorite matrix. Plate 2 is a photomicrograph of a thin section cut from a typical felspathic greywacke.

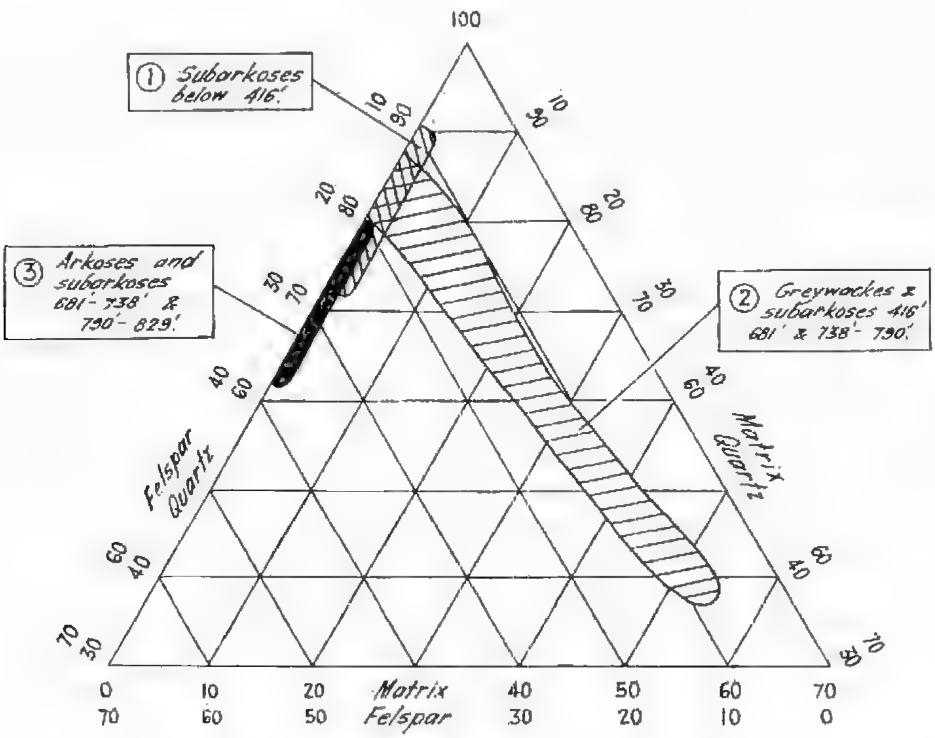

Fig. 1. Mineralogical composition of samples from the Stonyfell Quartzite.

Grain Size Characteristics

Thin sections were used for all grain size studies, as samples could not be effectively disaggregated for sieve analysis (Krumbein, 1935).

The average of the arithmetic mean grain diameters for all samples studied (corrected for the random intersection of spherical grains by the plane of the thin section) was 0·345 mm. Fig. 2 shows that this value is substantially constant throughout the section, although deviations are most marked near the top of the formation.

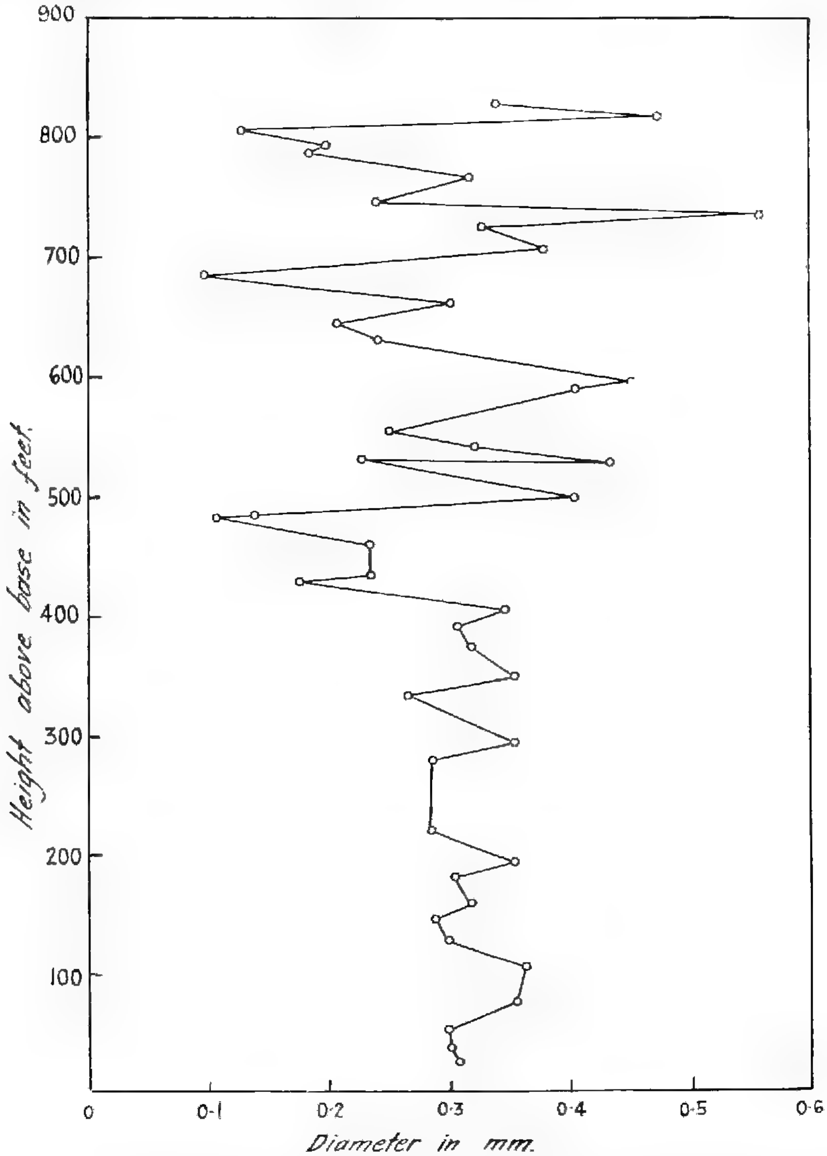

Fig. 2. Graph of variations in the corrected arithmetic mean grain size of samples from the type section of the Stonyfell Quartzite.

The degree of sorting in samples from the two main rock types is markedly different. The "clean" arenites (subarkoses and arkoses) have an average standard deviation of about 0·6 Wentworth grades, whereas the value for the greywacke is about 1·0. Cumulative curves for two typical clean arenites (A and B) and two greywackes (C and D) are reproduced in Fig. 3. The greywacke represented by curve "C" is one of a number showing a distinct bimodal grain size distribution. Fig. 4, a histogram for the same sample, shows this property more clearly.

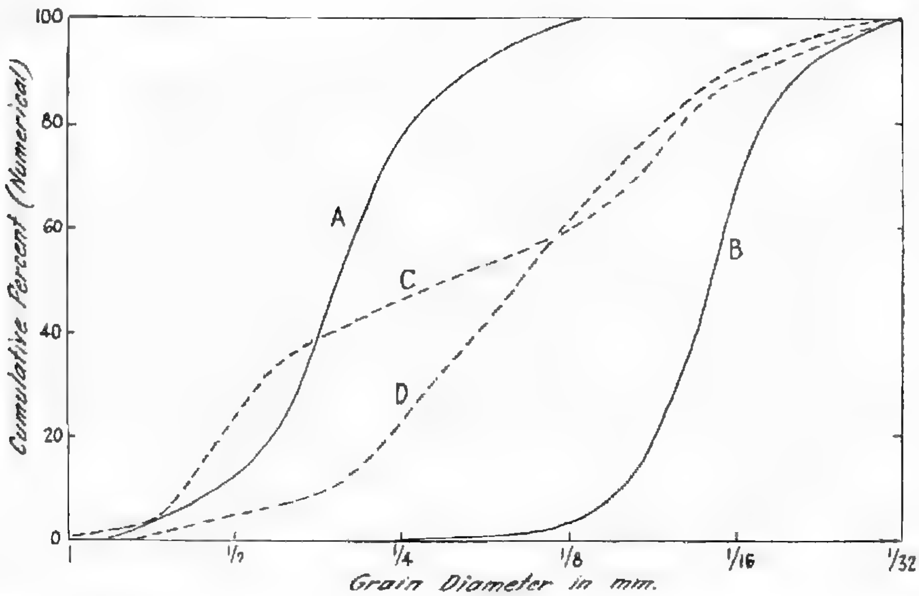

Fig. 3. Cumulative curves of grain size distribution in samples from the Stonyfell Quartzite.

Heavy Minerals

Heavy mineral grains were arbitrarily defined as those which sank in tetrabromoethane (S.G. 2·96). Non-opaque minerals covered by this definition constituted 40 to 1,300 parts per million of the samples studied.

Six opaque and nine non-opaque minerals were identified. In addition, optical properties were used to subdivide rutile grains into three groups, zircons into three groups, and tourmalines into 13 groups (Krumbein, 1946).

The opaque minerals identified were haematite, ilmenite, leucoxene, limonite, magnetite and pyrite, all of which were quite common. Of these, only the ilmenite, magnetite and portion of the haematite and pyrite are considered to be original detrital constituents.

The non-opaque minerals identified were andalusite, garnet (dominantly almandine, with rare grossularite), monazite (rare), rutile (pale yellow, orange and deep red varieties), sphene, spinel (rare), topaz, tourmaline (13 varieties, including iron-, magnesium-, sodium- and lithium-rich, as well as intermediate and zoned varieties) and zircon (the most abundant non-opaque heavy mineral, usually pale pink, with a few highly spherical colourless and deep pink, pleochroic grains). These minerals are all considered to be original detrital constituents.

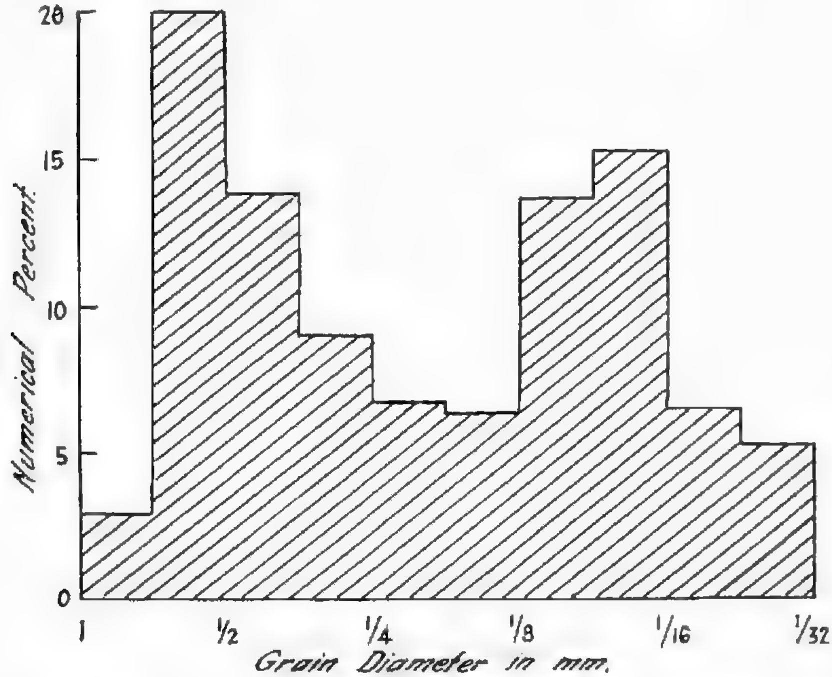

Fig. 4. Histogram of grain size distribution in a typical greywacke from the Stonyfell Quartzite.

CONCLUSIONS

The Stonyfell Quartzite, in the type area, consists of 830 ft. of dominantly arenaceous sediments.

This sequence has been defined as a Formation by Mawson and Sprigg (1950) and has subsequently been mapped as a single unit in the Adelaide area (e.g. on Adelaide and Echunga 1-mile series geological maps).

However, within the type area (which was mapped in detail to facilitate the choice of a well-exposed section for detailed study), the sequence consists of three well-defined units, with several quite persistent sub-units. These three main units, as well as some of the sub-units, are also recognizable in other Stonyfell Quartzite outcrops, which have been examined by the author since studying the type section. In general, the cleaner, more quartzitic arenites are recognizable over a considerable area, whereas the schistose greywackes tend to grade laterally to finer-grained phyllites.

As a result of these observations, the following subdivisions of the Stonyfell Quartzite (based on the type section) are proposed:

	Interval in the type section
Stonyfell Sub-Group	0′-829′
Wattle Park Formation	0′-416′
Member A	0′-335′
Member B	335′-416′
Slapes Gully Formation	416′-681′
Greenhill Formation	681′-829′
Member A	681′-738′
Member B	738′-790′
Member C	790′-829′

ACKNOWLEDGMENTS

I received assistance from several people and organisations during the period of this research. Particular thanks are due to Professor A. R. Alderman and Dr. R. L. Oliver, who supervised the project, and to Mr. L. G. Nixon, who provided many enlightening discussions.

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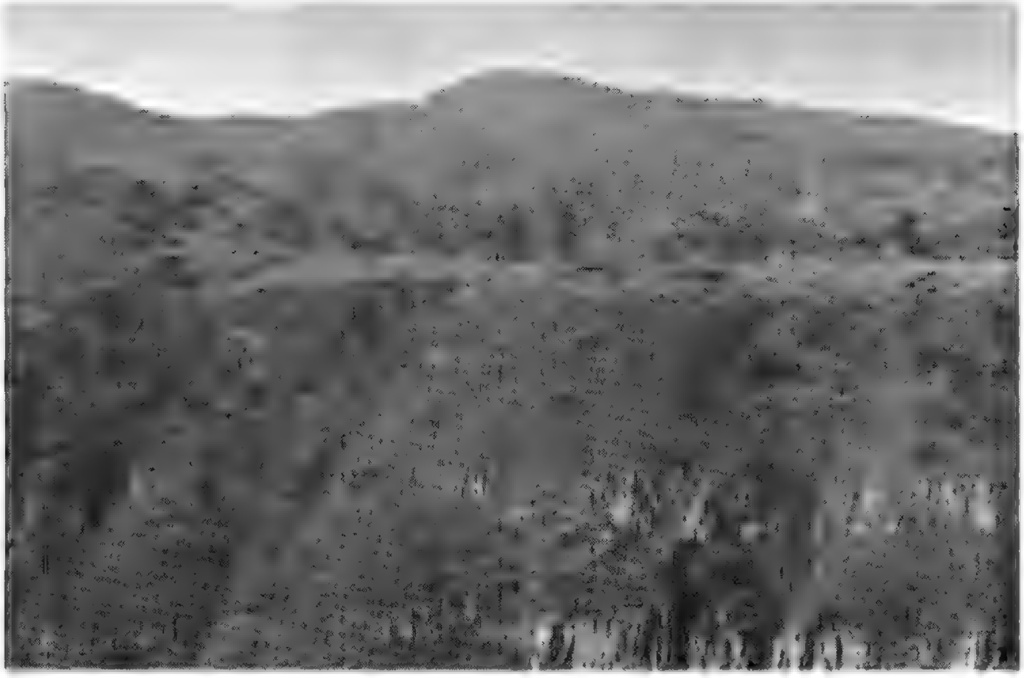

Fig. 1. Upper members of the Stonyfell Quartzite overlain by phyllites, on the eastern side of Slapes Gully. Looking east across Long Ridge to Mount Lofty, from Stonyfell

Fig. 2 Photomicrograph of a thin section from an angular, very poorly sorted, felspathic greywacke. Crossed nicols, x 120

THE GEOLOGY OF THE MOUNT CRAWFORD GRANITE GNEISS AND ADJACENT METASEDIMENTS

BY KINGSLEY J. MILLS

Summary

The Mount Crawford Granite Gneiss, a small elongate body of gneiss near Williamstown, South Australia, is considered to be the result of synkinematic granitisation of metasediments. This quartz-microcline-albite-biotite gneiss is sharply bounded against the quartz-albite-sillimanite-mica schists which it has replaced. A number of mica schist inclusions (skialiths) occur in the granite gneiss. They show structural elements parallel with those of the nearby metasediments and have gradational contacts with the gneiss. The minor heavy minerals of the granite gneiss are similar to those of the metasediments. The zircons of the gneiss and the metasediments are identical in size and shape, with a distinct lack of euhedral form. A brief summary of the petrology of the metasedimentary sequence adjacent to the granite gneiss is presented. A zone of retrograde metamorphism and hydrothermal activity surrounding the granite gneiss appears to be related in space and time to the granitisation. This zone is characterised by the presence of chlorite and sericite (alteration products of original biotite and aluminosilicate minerals), and contains the sillimanite, kyanite, clay and rutile deposits of the area. Intrusive rocks are amphibolites and pegmatites. The amphibolites (metadolerites) form steeply dipping dykes cutting both the granite gneiss and the sediments and are believed to be older than the granitisation. The pegmatites, younger and unrelated to the granite gneiss, replace both the gneiss and the metasediments. Complete chemical analyses of two garnets, a granite gneiss sample and an amphibolite sample are presented. A study of foliation and lineation in the granite gneiss and adjacent schists, and joints in the granite gneiss indicates a marked inhomogeneity of the structural elements.

THE GEOLOGY OF THE MOUNT CRAWFORD GRANITE GNEISS AND ADJACENT METASEDIMENTS

by KINGSLEY J. MILLS*

[Read 9 May 1963]

SUMMARY

The Mount Crawford Granite Gneiss, a small elongate body of gneiss near Williamstown, South Australia, is considered to be the result of synkinematic granitisation of metasediments. This quartz-microcline-albite-biotite gneiss is sharply bounded against the quartz-albite-sillimanite-mica schists which it has replaced. A number of mica schist inclusions (skialiths) occur in the granite gneiss. They show structural elements parallel with those of the nearby metasediments and have gradational contacts with the gneiss. The minor heavy minerals of the granite gneiss are similar to those of the metasediments. The zircons of the gneiss and the metasediments are identical in size and shape, with a distinct lack of euhedral form. A brief summary of the petrology of the metasedimentary sequence adjacent to the granite gneiss is presented. A zone of retrograde metamorphism and hydrothermal activity surrounding the granite gneiss appears to be related in space and time to the granitisation. This zone is characterised by the presence of chlorite and sericite (alteration products of original biotite and aluminosilicate minerals), and contains the sillimanite, kyanite, clay and rutile deposits of the area. Intrusive rocks are amphibolites and pegmatites. The amphibolites (metadolerites) form steeply dipping dykes cutting both the granite gneiss and the sediments and are believed to be older than the granitisation. The pegmatites, younger and unrelated to the granite gneiss, replace both the gneiss and the metasediments. Complete chemical analyses of two garnets, a granite gneiss sample and an amphibolite sample are presented. A study of foliation and lineation in the granite gneiss and adjacent schists, and joints in the granite gneiss indicates a marked inhomogeneity of the structural elements.

INTRODUCTION

The main object of this paper is to present and discuss the geological evidence bearing on the origin of the Mount Crawford Granite Gneiss. For this purpose an area of about nine square miles surrounding the granite gneiss was studied. The area is situated on the Cawler (1 inch to 1 mile) Geological Sheet south and west of the South Warren Reservoir, south of Williamstown on the Williamstown-Birdwood road. This area is largely Crown Land; the eastern part being the western section of the Mount Crawford Pine Plantations, the central part leased grazing land, and the western part steep virgin scrub country.

The topography has a relief variation of some 800 ft., the highest elevation in the area being Warren Hill, just over 1,700 ft. This hill forms part of a prominent north-south ridge in the centre of the area, dividing the relatively matured uplands to the east from the more rugged erosion scarp of the Kitchener fault to the west. East of the Warren Hill dividing ridge the gently undulating slopes are commonly covered with original and reworked alluvium and weathering products of the old uplifted Tertiary peneplain.

* Department of Geology, University of Adelaide.

This area was the site of the Mount Crawford Alluvial Goldfields which were active in the late nineteenth century. Harry P. Woodward (1886), reporting on the gold drifts, was the first to discuss the geology of the region. Howchin (1926) considered that the metasediments could be correlated with the lower portion of the Adelaide System, a coarse cross-bedded pebbly sandstone representing the Basal Conglomerate. Hossfeld (1935) mapped the area and regarded the cross-bedded sandstone as basal Proterozoic unconformably overlying Barossian (Archaean) schists and metasediments. He considered the granite gneiss to be the result of "pegmatisation". Alderman (1942) studied an area immediately north of the present one and presented evidence for the production by alumina metasomatism, of the massive sillimanite and kyanite rocks there. He showed that the metasomatised zone was rather local and was surrounded by metamorphosed rocks of the biotite grade of progressive regional metamorphism. Campana and Whittle (1953) have emphasised the action of metasomatism in the area with particular reference to the origin of garnet, rutile and aluminosilicate concentrations. Campana considered that alumina metasomatism has converted part of the basal sandstone to mica schist.

Few small-scale bodies of metasomatic granite have been recorded in the literature. Misch (1949) considered that metasomatic granites occur mainly on a regional scale. Granitisation on a small scale appears to have been neglected, and yet it is these small-scale examples of granitisation that are the most useful in determining the causes and nature of this type of rock transformation.

The present mapping and petrological study was carried out in 1959 and early 1960 as a research project in the Department of Geology, University of Adelaide.

STRATIGRAPHY AND METAMORPHISM

It appears that the stratigraphy of this area can be correlated with the lower part of the Adelaide System (Campana and Whittle, 1953). The rocks have reached the amphibolite facies of regional metamorphism, and intense recrystallisation of the finer sediments to schists and calc-silicate rocks has almost completely obliterated the original bedding and other sedimentary features. As a consequence no attempt was made to estimate original stratigraphic thicknesses. Sedimentary features are generally well preserved in the sandstone members of the sequence, however.

The general stratigraphic sequence may be outlined as follows:

Youngest.	Calc-silicate group.
	Mica schist group.
	Upper tremolite rock.
	Upper cross-bedded arkose.
	Thick coarse mica schist sequence.
	Lower tremolite rock.
	Lower cross-bedded sandstone.
Oldest.	Sandy mica schists.

The spatial distribution of these stratigraphic units can be seen on the geological map.

Although the metamorphic facies appears to be constant throughout the area, the degree of recrystallisation ("intensity of metamorphism", Chinner, 1955, p. 44) varies considerably. The highest degree of recrystallisation occurs in the coarse mica schist sequence near the granite gneiss and grades off towards the

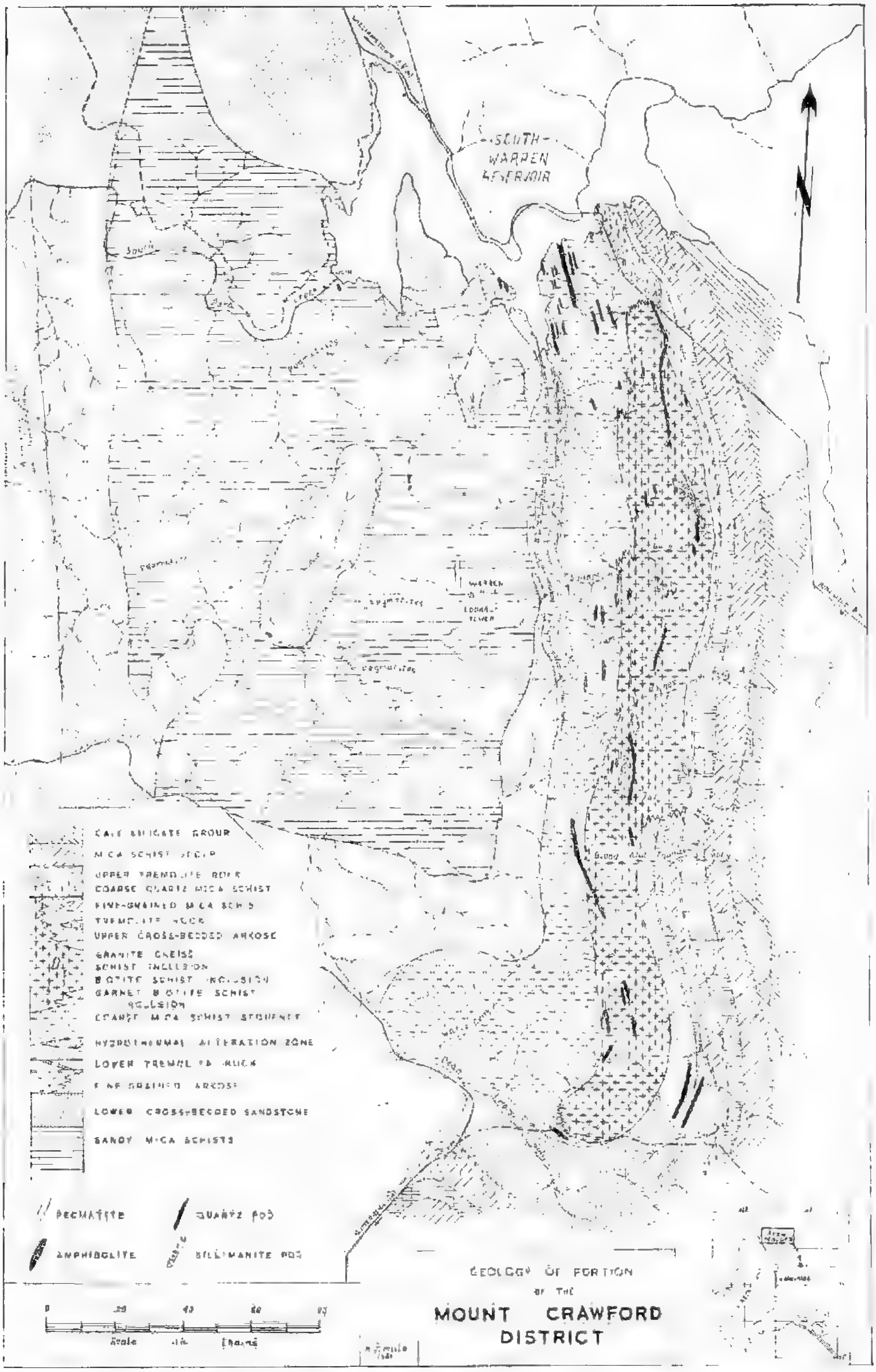

Fig. 1. Geological Map of Mt. Crawford District.

west. Metasediments above the upper tremolite bed, to the east of the granite gneiss, are much less recrystallised and this is attributed to the tremolite bed acting as a local barrier to the metasomatism.

A further complexity in the petrology of the metasediments is the presence of a zone of strong retrograde metamorphism and hydrothermal activity surrounding the granite gneiss. This zone is recognised by the alteration of biotite to chlorite, and of aluminosilicate minerals to fine-grained sericite (damourite); it extends west to the vicinity of Warren Hill, north and south out of the area mapped, and is cut off to the east by the tremolite rock bed mentioned above. The granite gneiss and the rocks at its immediate contacts, constituting the apparent centre of this altered zone, show none of these retrograde effects, the biotite in these rocks being completely fresh. It is in the northern extension of this zone of retrograde metamorphism that the sillimanite, kyanite, rutile and clay deposits described by Alderman (1942) are localised.

The Sandy Mica Schists which occupy the core of the complex anticlinal structure in the western part of the area (Figs. 1 and 2) are the oldest rocks recognised. This anticlinal structure has been named the Lookout Tower Anticline (Campana, 1955). Although sedimentary structures have been almost completely obliterated in these schists, grit bands containing detrital haematite and occasional layers of pebbles define the bedding. The minor folding is best displayed at the reservoir weir where it has affected beds with alternating thin quartz-feldspar-rich bands and more micaceous layers.

The sandy mica schists vary from biotite-muscovite-rich varieties to micaceous arkoses in which only muscovite is present. The latter are difficult to distinguish from the overlying cross-bedded sandstone. Although Campana (1953) regarded the sandy schists as a metasomatic facies variation of the "basal" sandstone, the present author prefers to regard them as a sedimentary facies variation which stratigraphically underlies the sandstone.

The Lower Cross-bedded Sandstone surrounds the anticlinal core of sandy mica schists, except on the eastern side near Warren Hill (Fig. 1), where the sandstone apparently lenses out. Cross-bedding, sometimes occurring in thick festoons, is common throughout the sandstone and establishes it to be younger than the sandy schists described above. The sandstone is a coarse, well-bedded, friable, feldspathic rock, with detrital haematite spread throughout as well as being concentrated in layers parallel to the bedding planes. Small, rounded pebbles are commonly found on the bedding planes. The pebbles are mostly haematitic quartzites, but rarer quartz, pegmatite and quartz-tourmaline pebbles are also present. Where folding is intense the pebbles have been flattened into thin plates or elongated into ellipsoids.

The lower cross-bedded sandstone is almost identical with the type Aldgate Sandstone with which it has previously been correlated (Howchin, 1926).

The Lower Tremolite Rock is a thin marker bed that can be traced intermittently on the eastern side of the Lookout Tower Anticline from east of Warren Hill to the reservoir (Fig. 1). Its surface outcrops are commonly replaced by massive opal. Fresh specimens consist of close-packed, interlocking, pale green tremolite-actinolite crystals. On the extreme western edge of the mapped area a fine-grained grey-blue, impure, dolomitic limestone may be a less metamorphosed equivalent of this bed.

The Thick Coarse Mica Schist Sequence crops out in a north-south belt immediately west of the granite gneiss, and is partially replaced by the granite gneiss. Most of these rocks have been affected by the retrograde metamorphism and the hydrothermal activity mentioned above, and bedding is almost completely destroyed. Although mineralogically simple, the rocks have a varied array of textures: schistose, gneissic, massive and knotted. Notable micro-structural features are coarse grain size, strong mica orientation (except in the knotted varieties), and the presence of micro-crenulations in the schistosity. The main mineral constituents are quartz, plagioclase (An_{0-15}), biotite, muscovite, chlorite and sericite, which in the various samples can occur in almost any proportion. Rarer constituents are garnet, staurolite and sillimanite. Common accessories are apatite, tourmaline, haematite, magnetite, zircon, monazite, pyrite, ilmenite and rutile. In all cases chlorite, sericite, ilmenite and rutile are the secondary alteration products of biotite and aluminosilicate minerals. Plagioclase, of albitic composition and with slight normal zoning, is far more abundant in those rocks nearer the granite gneiss. Fine cryptocrystalline sericite occurs either as fibrous knots after sillimanite (up to 2 cm. in diameter), compact blades after kyanite (?), or as rarer bands, sometimes several inches thick, of unknown origin. The latter are concentrated most strongly in a zone of intense hydrothermal alteration (Fig. 1). In the knotted varieties feathers of chlorite are often intermixed with the sericite. In a few specimens unaltered fibrous sillimanite knots seem to have originated from biotite and muscovite. Relicts of twisted and leached biotite persist among the sillimanite spindles and account for the intermixed sericite and chlorite of the altered specimens. Similar replacement of mica by sillimanite has been described by Tozer (1955), and has been attributed to metamorphic reactions in the amphibolite facies.

Rare coarse-grained staurolite, garnet and biotite-rich gneisses occur in the coarse schists and are considered to have been produced by the metamorphic recrystallisation of rocks with appropriate composition in the amphibolite facies of regional metamorphism.

The Upper Cross-bedded Arkose crops out south of the granite gneiss (Fig. 1), and apparently lenses out northwards. It is a medium-grained quartz-microcline-albite arkose somewhat resembling the lower sandstone, with heavy mineral lamination, cross-bedding and pebbles. At the granite gneiss contact the arkose develops a gneissic appearance and grades into the gneiss.

The Upper Tremolite Bed is a strong marker horizon outcropping with a north-south trend east of the granite gneiss. It consists of white to pale green, close-packed tremolite crystals up to several inches in length. This bed occasionally carries lenses of actinolitic arkose. The tremolite rock surface outcrops are strongly replaced by massive and boxwork opal which appears to be the result of slow surface weathering of the tremolite. Where deep weathering has occurred the tremolite has altered to talc.

The Fine-grained Mica Schist Group lies above the upper tremolite bed east of the granite gneiss. This unit consists of interbedded schists and thin arkoses. The schists are much finer-grained than the coarse mica schists west of the granite gneiss and some might be called phyllites. They are also not affected by the extreme alteration characteristic of many of the coarser schists. They consist of biotite, muscovite, quartz, albite, abundant microcline and rare kyanite. Some beds contain notable amounts of pyrite.

The Calc-silicate Group is the youngest bedrock unit in the area mapped. It consists of interbedded fine to coarse calc-silicate rocks and phyllitic finely knotted schists. The calc-silicate beds contain various proportions of actinolite, diopside, scapolite, oligoclase-andesine, quartz, clino-zoisite, tremolite, sphene and iron ore. Some of the calc-silicate rocks are finely laminated while others are massive and coarse-grained.

THE GRANITE GNEISS

1. *General Petrology*

The granite gneiss crops out as a single body some three miles in length and up to one-third of a mile in width. The contacts of the granite gneiss are sharply defined; the texture of the rock being readily distinguishable from the surrounding metasediments. Outcrops of the granite gneiss are abundant north of Blood and Thunder Gully (Fig. 1) but south of this watercourse the granite gneiss boundaries can be traced only by means of strongly lateritised and weathered floaters and residual soils.

Texturally the granite gneiss grades from massive varieties poor in mica to schistose varieties rich in mica. A moderately strong gneissic foliation results from preferred orientation of mica, with alternation of mica-rich lamellae with thin (0·3 mm.) discontinuous bands and lenses of quartz and feldspar. A prominent lineation due to the parallelism of elongated micas is noticeable in all outcrops. These structural features result in outcrops with a lineated bladed form. Specimens of the granite gneiss are almost invariably crumbly although the grains are fresh. The freshest specimens from the watercourses are hard and compact.

A sample of the granite gneiss was chemically analysed. The analysis, norm calculation and modal composition are presented in Table 1.

The mineralogical composition of the granite gneiss is variable. Major constituents are quartz, microline, albite-oligoclase, biotite and muscovite with accessory iron ore, zircon and apatite. The quartz (20-60 p.c.) is clear, granoblastic, free of inclusions and shows undulose extinction. Quartz grains, which average 0·75 mm., tend to be larger than the feldspar grains. Microclines, also granoblastic, show excellent tartan twinning. The microcline is always fresh and devoid of inclusions and constitutes 5-60 p.c. of the rock. Plagioclase varies from an accessory to 50 p.c. The composition of An_{0-15} is comparable with that in the surrounding metasediments. Grains are equidimensional and average 0·5 mm. in diameter. Plagioclase twinning is simple and is rare; zoning is almost absent. Perthitic textures are absent in the feldspars although occasional rims of albite at plagioclase-microcline grain boundaries may represent an advanced stage of exsolution or the beginning of replacement. Myrmekite and chessboard albite appear to be absent. Biotite is the most common mica, averaging 2-15 p.c. Its pleochroism is strong from pale yellow to dark green-black (as in the surrounding metasediments). Pleochroic haloes are common. Alteration to chlorite is absent. A rarer constituent of the granite gneiss is clear, colourless muscovite. Iron ores, haematite and magnetite are important accessories occurring in close association with the biotite and zircon. Both zircon and apatite are important accessories, the apatite occurring as small prisms in quartz and the zircons as small subrounded grains.

2. *Variations in the Granite Gneiss.*

One minor structural feature is the occurrence of a fine-grained granite phase with sharp boundaries against a coarser phase. In some cases elliptical blebs of the finer phase up to two feet in length were observed embedded in the coarser phase. In other cases the disposition of the coarse and finer phases produce a pseudo-cross-bedded appearance. In one outcrop two thin "veins" of the fine phase cut the coarse at a slight angle to the schistosity. Except for less mica in the finer phase, the composition of the two phases is similar.

In places the granite gneiss has a strong arkosic appearance, with abundant quartz, feldspar and iron ore, and lacking mica. Several beds of sheared "pebbles" were found in the granite gneiss.

TABLE I.

Analyses of rocks.

	Granite gneiss	Amphibolite
SiO_2	72·85	48·67
TiO_2	0·38	1·66
Al_2O_3	12·73	15·05
Fe_2O_3	1·29	3·12
FeO	2·13	8·70
MnO	0·04	0·17
MgO	0·63	6·63
CaO	1·32	11·49
Na_2O	2·91	2·42
K_2O	4·80	0·42
P_2O_5	0·15	0·26
H_2O+	0·46	1·59
H_2O-	0·07	0·09
CO_2	—	0·10
Totals	99·76	100·37

Modal Compositions (Approximate)

	Weight Mode	Weight Mode
Quartz	39·3	5·7
Plagioclase	32·0	22·2
Microcline	21·0	—
Hornblende	—	67·5
Biotite	6·4	—
Muscovite	0·5	—
Iron Ore	0·8	0·5
Sphene	—	3·8
Apatite, zircon	Tr.	0·3
	100·0	100·0

Normative compositions

Granite gneiss				Amphibolite			
Salic		Femic		Salic		Femic	
Or	29·0	En	1·8	Or	2·5	Hy	14·2
Ab	27·0	Fs	2·0	Ab	22·5	Di	23·6
An	6·0	Ap	0·3	An	29·5	Ap	0·5
Q	31·3	Il	0·6			Il	2·4
C	0·6	Mt	1·4			Mt	3·3
						Ol	1·5
	93·9		6·1		54·5		45·5

3. *Skialiths*

A number of metasedimentary inclusions, termed "skialiths" in accordance with the nomenclature of Goodspeed (1948), were observed in the granite gneiss. They generally have a large and indefinite shape and in all cases show a gradational contact with the gneiss. They apparently represent tracts of schist which have escaped conversion to the granite gneiss during the granitisation process. Their foliation and lineation is parallel to that in the schists outside the granite gneiss. The major skialiths have been indicated in Fig. 1.

The skialiths show a somewhat varied mineralogy which also, however, resembles that of the schists surrounding the granite gneiss. The skialiths are mainly quartz-mica schists with fibroid sillimanite knots altering to sericite. Granitisation is induced by the introduction of plagioclase of albitic composition in increasing amounts. This plagioclase has a marked chessboard twin structure which is generally regarded as peculiar to metasomatic plagioclase. Microcline is absent in the skialiths. Staurolite is a rare constituent. Biotite schist relicts often have large garnet porphyroblasts, some of which reach 2 inches in diameter. The properties of a garnet porphyroblast from a garnet-biotite skialith from the ridge north of Baynes Gully are presented in Table 2.

4. *The Contacts*

Where the contacts of the granite gneiss and the metasediments are observed parallel to the schistosity they are sharp, but they are gradational and intertongueing where traversing the schistosity. The intertongueing is represented diagrammatically in Fig. 1. The eastern contacts are nowhere visible and the contacts of the southern half of the granite gneiss are obscured by deep rock weathering and lateritisation. A thin sheet of schistose quartz-albite-muscovite gneiss constitutes part of the western margin of the granite gneiss.

There is a good schist-granite gneiss contact on a hill 400 yards south of the northern end of the gneiss outcrop where a quartz-albite-biotite-muscovite-sericite knotted schist has been recrystallised and a stronger schistosity developed. At the contact sericite knots disappear, feldspar increases in amount, microcline appears, while muscovite is greatly reduced. With these changes the rock develops the gneissic texture characteristic of the granite gneiss. Just south of this location the schists intertongue with the granite gneiss, and all gradations of schist to gneiss can be observed.

A number of amphibolite dykes cut the granite gneiss. These are considered to be older than the gneiss, and thus represent sheets of basic rocks that have resisted the granitisation. Their contacts with the granite gneiss are sharp, although in one case reaction had produced a hybrid rock type. This hybrid rock is a hornblende "granite" with hornblende, microcline, plagioclase, quartz, epidote, biotite, sphene and apatite. The plagioclase is basic (An_{50}) and strongly reverse zoned. Reverse zoning is common also in the plagioclase of the nearby granite gneiss. Unlike the amphibolite-granite gneiss contacts described by Chinner (1955) in the Tanunda Creek area, this contact rock does not contain diopside.

5. *Alumina Metasomatism*

Sillimanite-quartz pods and kyanite pegmatites of metasomatic origin occur immediately north of the granite gneiss and in the zone of intense hydrothermal alteration, but are more common north of the reservoir where they have been discussed by Alderman (1942). The alumina metasomatism is believed to have resulted from the expulsion of alumina-rich solutions during the granitisation of originally aluminous schists.

6. *Comparison with other Granite Gneisses of the Adelaide Region*

Granite gneisses of a similar character occur on a regional scale in a NW-SE trending belt several miles east of the present area. These have been studied in the Tanunda Creek area by Chinner (1955) and in the Palmer area (Rathgen Gneiss) by White (1956). Comparison of these granite gneisses with the one under present consideration indicates many marked similarities.

Both the Rathgen and Tanunda Creek gneisses have a granitic appearance with strong foliate and lineal structural features which parallel those in the adjacent schists. Also developed are the following features: a slightly strained granoblastic texture; prominent a-c joints perpendicular to the lineation; quartz, feldspar, and biotite as the major constituents; quartz showing undulose extinction; plagioclase of oligoclase composition, with rare simple twinning and clear albite rims at the contacts with microcline grains; microcline with good tartan twinning; general concordance and sharp contacts of the granite gneisses with the adjacent schists; and pre-granitisation epidiorite inclusions. All these are features which are characteristic of the Mt. Crawford Granite Gneiss.

Both Chinner (1955) and White (1956), however, observed porphyritic textures, myrmekite at plagioclase-microcline boundaries, microcline replacing other minerals, and alteration of the plagioclase to epidote and sericite — features which were not observed in the Mt. Crawford Granite Gneiss.

THE INTRUSIVE ROCKS

1. *Amphibolites*

A number of metadolerite dykes, up to one mile in length and 100 feet wide, have been mapped (Fig. 1). These sharply cut both the schists and the granite gneiss. They are fine-grained, dark, amphibole-rich schists that have, throughout the area, a uniform appearance and mineral composition. They contain dark hornblendes in parallel arrangement, zoned basic plagioclase (An_{25-60}), rarer quartz, accessory sphene, ilmenite, apatite, pyrite, magnetite and rare garnets. In one case hornblende was seen to be altering from earlier pyroxene. These metadolerites are considered to be older than the granite gneiss on the basis that joints in them have been folded during the imposition of the younger schistosity which is now seen in the granite gneiss, whereas joints in the granite gneiss have not been folded. An analysis made by the author of a typical amphibolite, norm calculation and modal composition are presented in Table 1. Similar amphibolites have been described by Chinner (1955) from the Tanunda Creek area.

2. *Major Pegmatites*

Coarse-grained feldspar-rich pegmatites are common in the whole Williamstown area, and extend in a belt southwards to the Gumeracha district (six miles south). They generally run parallel to the north-south tectonic trend, although cross-cutting pegmatites also occur. The major constituents are plagioclase (An_{10-13}), microcline and quartz, with rarer muscovite, and accessory beryl, tourmaline, garnet, apatite, monazite and zircon. In places zones of tourmalinisation border these pegmatites. According to the criteria of Chadwick (1958) the pegmatites may be considered to be of the non-mobile, replacive type. They show no visible tectonic orientation of their mineral constituents, and, because they cut both schists and the granite gneiss, they are younger than the granite gneiss. They have been produced on a regional scale and have no direct connection with the granitisation phase that produced the granite gneiss.

TABLE 2.

Analyses of garnets

Constituent	Pegmatite garnet Analysis	Pegmatite garnet Atoms on basis of 12 oxygens		Biotite schist garnet Analysis	Biotite schist garnet Atoms on basis of 12 oxygens	
SiO_2	36·67	2·881	2·918	36·96	2·948	2·967
P_2O_5	0·55	0·037		0·29	0·019	
Al_2O_3	20·48	1·896	1·957	18·85	1·748	2·033
TiO_2	0·06	0·004		0·27	0·016	
Fe_2O_3	0·67	0·057		3·14	0·269	
FeO	10·68	0·701	3·059	33·68	2·246	2·976
MgO	4·54	0·531		4·82	0·573	
CaO	—	—		0·95	0·081	
MnO	26·33	1·751		0·75	0·051	
Na_2O	0·22	0·033		0·07	0·011	
K_2O	0·43	0·043		0·14	0·014	
H_2O	n.d.			0·08		
CO_2, Cl_2	—			—		
Totals	100·63			100·00		

Compositions (Weight per cent)

	Pegmatite garnet	Biotite schist garnet
Andradite	—	2·8
Spessartite	61·2	1·7
Almandine	24·6	77·8
Pyrope	15·1	16·0
Totals	100·9	98·3

Physical properties

	Pegmatite garnet Measured	Pegmatite garnet Calculated*	Biotite schist garnet Measured	Biotite schist garnet Calculated*
Specific gravity	4·09	4·13	4·13	4·18
Refractive Index (± ·002)	1·802	1·795	1·802	1·813
Cell Size (Å) (± ·004)	11·599	11·573	11·517	11·533

*Based on date from Skinner (1956).

3. *Minor Pegmatites*

A number of small strings and veins of pegmatite, composed mainly of subhedral microcline, quartz and accessory muscovite, beryl and tourmaline occur in joints in the granite gneiss. The ends of these stringers appear to diffuse into the gneiss, and are thought to represent incipient mobilisation of the rock near the end of the granitisation period. In the surrounding metasediments pods and segregations of pegmatitic material may be similarly mobilised matter brought about by metamorphic differentiation.

4. *Other Intrusive Rocks*

Quartz veins are common in the area, especially in the zone of intense hydrothermal alteration (Fig. 1) where they contain considerable rutile.

MINERALOGY

Table 2 summarises the analyses and properties of two garnets. One is a brown spessartitic garnet from a thin beryl-tourmaline-garnet-zircon bearing pegmatite intruded into schists west of the granite gneiss. The other is a pink, almandine garnet porphyroblast from a garnet-biotite schist skialith in the granite gneiss on a ridge north of Baynes Gully. The latter garnet contained small staurolite idioblasts which were separated before analysis. Comparison of the measured physical properties with those calculated from the analyses (using Skinner's (1956) end-member data) shows agreement within the limits of accuracy of the analyses made by the author. Phosphorus and alkalies, which are not usually analysed for in garnets, were found to be present in significant amounts. Rankama and Sahama (1950, p. 587) state that phosphorus can replace silicon in the silicon tetrahedra. The high alkali content of the pegmatite garnet may contribute to its abnormal cell dimension.

It was considered that a study of the relative abundances and habits of the rarer minerals in the rocks of the area might help to elucidate the origin of the granite gneiss. Nine heavy mineral analyses were completed and are summarised in Table 3. The analyses show considerable variation in the relative abundances of minerals and that there are no assemblages peculiar to the granite gneiss. Most of the rarer minerals have recrystallised during the metamorphism, except the zircon, which, in metasediments preserves its original water-worn characteristics. Although no statistical studies were made, it is clear from Fig. 3, which compares accurate drawings of zircons from the granite gneiss, a schist skialith, and the lower cross-bedded sandstone, that the zircons from the granite gneiss are identical in size and habit with those in the nearby metasediments. In contrast zircons from an igneous, intrusive granodiorite in the Cooke Hill area (13 miles east) have a highly euhedral character. Rare rounded zircons in the Cooke Hill granodiorite may be xenocrysts. Zircons from the major pegmatites of the present area are of a distinctly different character from those of the metasediments and the granite gneiss. They are variable in size (to 3 mm.), show strong corrosion, supposedly due to alkaline solutions (Poldervaart, 1955), and have a semi-opaque, greasy, grey appearance.

STRUCTURAL GEOLOGY

Fig. 2 summarises the structural geology of the area. Folds in general are overturned slightly to the west. The main anticlinal crest in the western part of the area (the Lookout Tower Anticline) is broken by synclinal cross-folds. East of the granite gneiss the bedding S_1 is cut at a slight angle by a steeply east dipping schistosity S_2. West of the granite gneiss the schistosity is folded with the development of a new foliation S_3, and, except in the sandstones, the obliteration of bedding S_1. The refolding process has resulted in the develop-

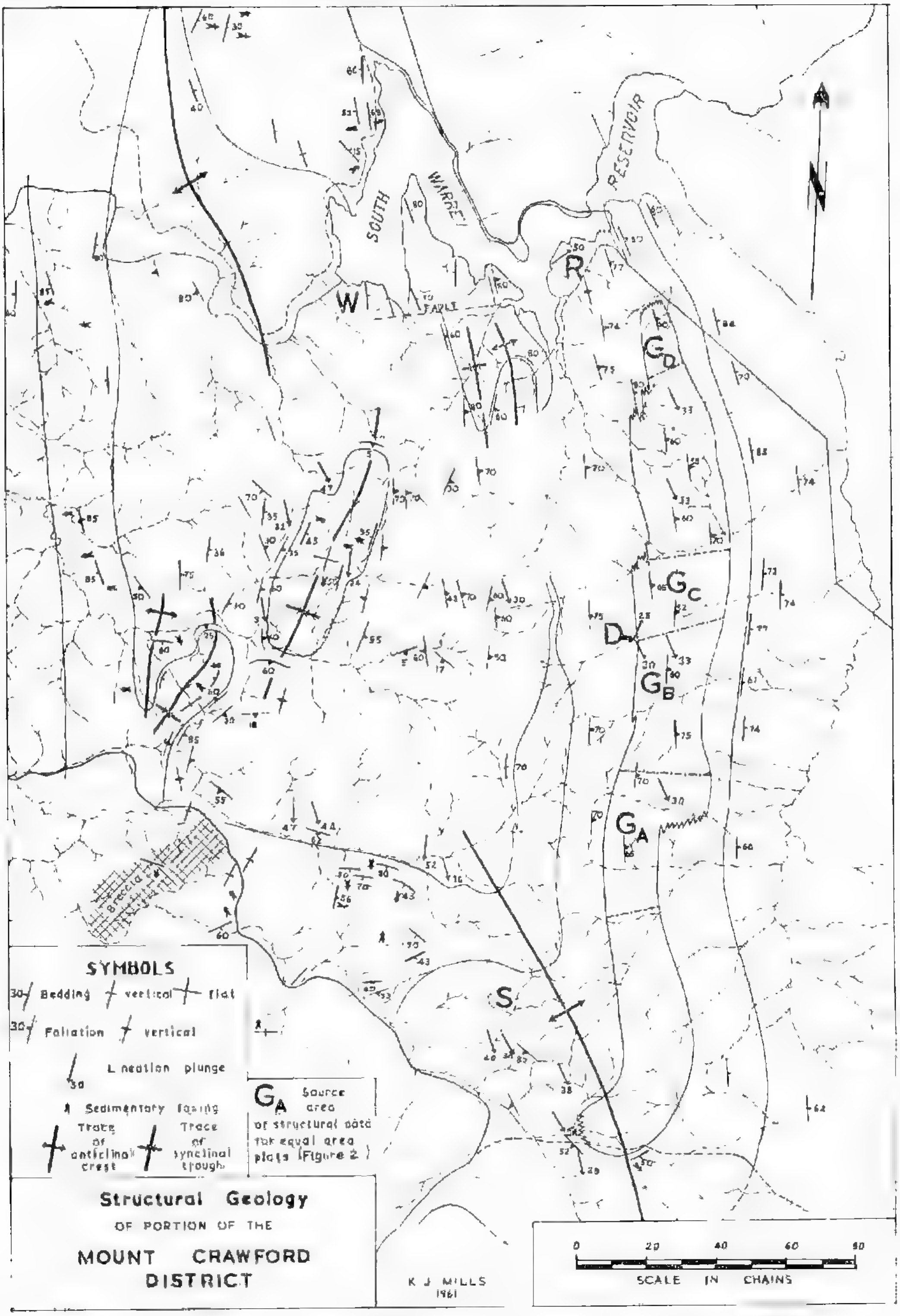

Fig. 2. Structural Geology of Portion of the Mt. Crawford District.

ment of pronounced minor folds, crenulations and lineations in the schists. Three hundred of these penetrative structures from the schists have been measured and plotted on equal area stereograms (Fig. 4 S, D, R, W). In the plots inhomogeneity of the linear structures is evident, but there is a tendency for the lineations to fall on a great circle; for which there are several possible explanations which may be summarised as follows:

A. *One period of Folding*

(1) Triaxial deformation (Roberts, 1960).

(2) The development of late stage strain slip cleavages which deform an earlier axial plane schistosity but do not intersect in the earlier fold axes (Agron, 1960).

TABLE 3.

Heavy Mineral Analyses.

		Type of Sample								
		Country Rock.		Granite.				Skialiths.		
Wt. % in sample.	Iron ore. Others as below.	A 20 n.d.	B C n.d.	C C n.d.	D VC ·01	E Tr ·05	F Tr ·05	G Tr ·075	H VC ·02	I 10 ·015
Recalculated weight percents of heavy minerals excluding iron ore and apatite.†	Zircon	92	40	51	1	42*	47*	32*	72	97
	Monazite	2	50	47		57	53	67	14	2
	Garnet	2		0·5	4	0·5	Tr	Tr		0·1
	Pyroxene	2		1·0	22	Tr		Tr		0·1
	Rutile	1·5			0·1		0·5		1	1·0
	Anatase								11	
	Staurolite		5							
	Tourmaline		2					0·7		
	Epidote			0·1						
	Sphene				73					
	Graphite							Tr		
	Others	0·5	3	0·5		0·5			2	

* Including minor amounts of xenotime.

† Apatite removed by acid leaching.

C—common, VC—very common, Tr—trace, n.d.—not determined.

A. Haematite rich feldspathic sandstone: ¼ ml. east of Warren Hill.

B. Altered coarse quartz-mica schist: ¼ ml. north of the northern end of the granite gneiss outcrop.

C. Granite gneiss: ¼ ml. south of the northern end of the granite gneiss outcrop.

D. Granite gneiss: Northern end of the granite gneiss outcrop.

E. Granite gneiss: 1½ mls. north of the southern end of the granite gneiss outcrop.

F. Granite gneiss: ½ ml. south of the northern end of the granite gneiss outcrop.

G. Coarse quartz-mica skialith: ¾ ml. south of the northern end of the granite gneiss outcrop.

H. Haematite rich arkose skialith: 1½ mls. north of the southern end of the granite gneiss outcrop.

I. Haematite rich arkose skialith: ⅜ ml. south of the northern end of the granite gneiss outcrop.

B. *Two Periods of Folding*

(1) A new foliation S_3 cuts previously folded bedding planes causing lineations to lie in S_3 (Weiss, 1959).

(2) Earlier lineations are rotated by similar folding (Ramsay, 1960).

The statistical data collected by the author is insufficient to decide which of these possibilities might apply.

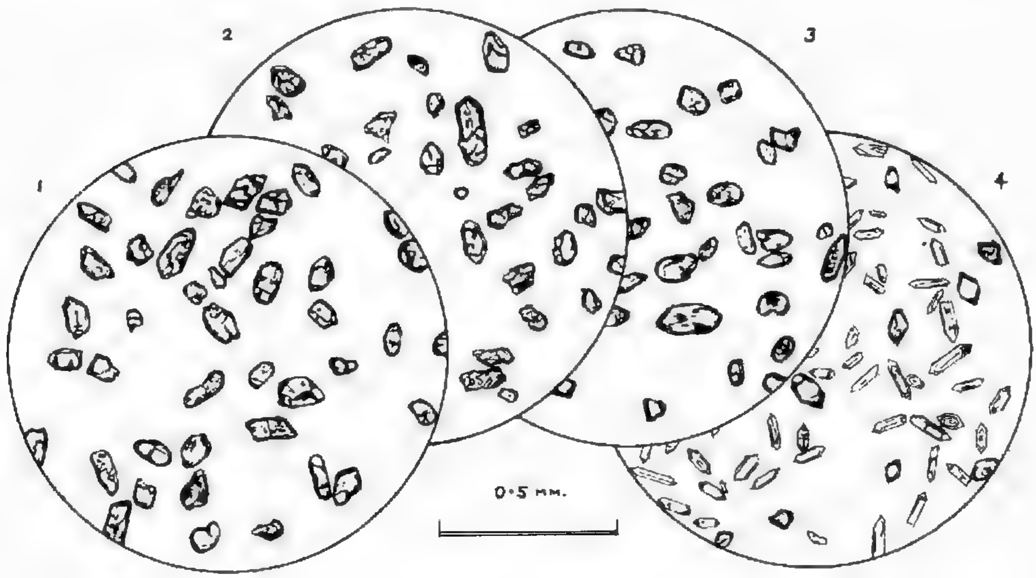

Fig. 3. Comparative drawing of typical zircon populations extracted from:

1. The Mt. Crawford granite gneiss.
2. A schist skialith in the Mt. Crawford granite gneiss.
3. The lower sandstone: quarter mile west of the Mt. Crawford granite gneiss.
4. An igneous, intrusive, gneissed granodiorite from the Cooke Hill region.

The granite gneiss displays a well-developed foliation and mineral lineation. 250 foliations and 200 lineations were measured in four sub-areas and are summarised in Fig. 4. The attitudes of these structures are consistent throughout the granite gneiss. Mineral lineations in the schists and amphibolites of the area parallel the mineral lineations in the granite gneiss. These lineations were apparently produced during or after the granitisation.

One thousand three hundred and ninety joints were measured in the granite gneiss and are summarised in Fig. 4. The joint picture appears to vary along the length of the granite gneiss with a tendency for the poles of the joints at the northern end of the gneiss to spread on a great circle (as do the minor folds in the adjacent schists).

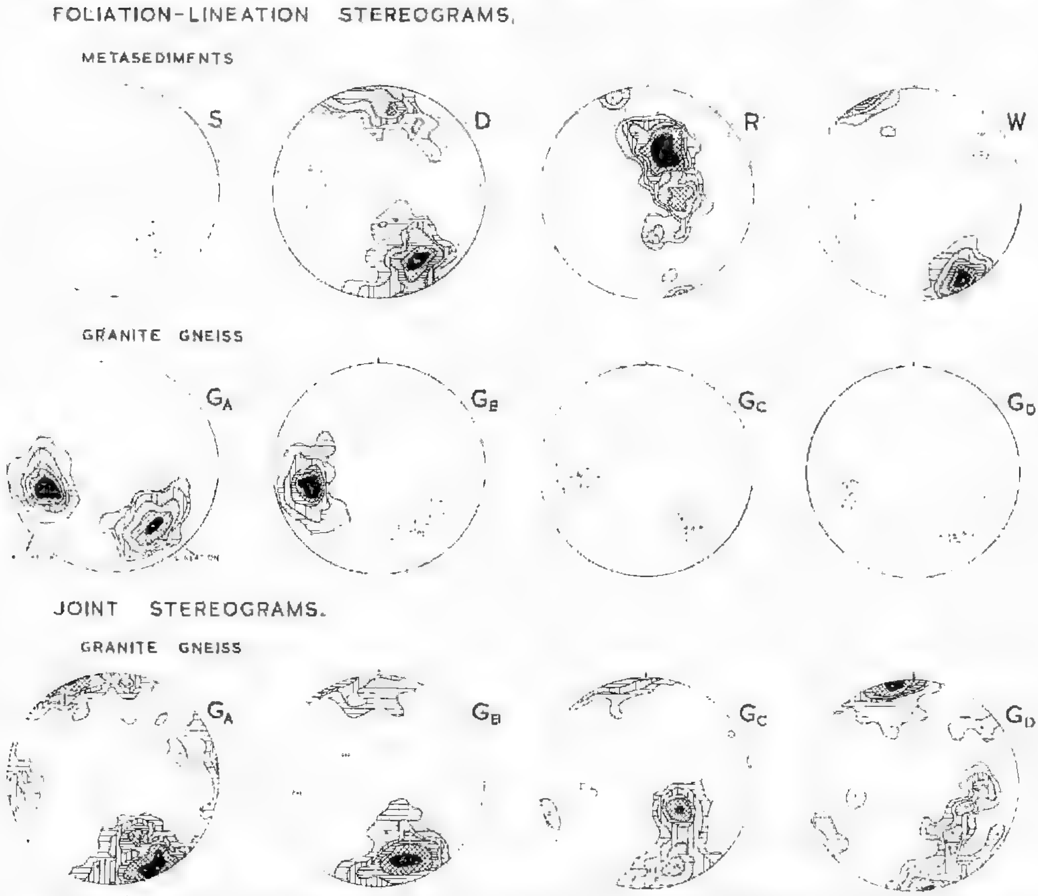

Fig. 4. Equal area projections of the poles of structure elements measured in the granite gneiss and surrounding metasediments. The letters refer to the corresponding sub-areas marked on Fig. 2.

Foliation-Lineation Stereograms

Metasediments

S 13 lineations measured in Watts Gully.

D 15 foliations and 90 lineations (contoured at 1, 2, 4, 8 and 12 p.c.) measured on a single schist outcrop above the dam in Dam Gully.

R 100 lineations (contoured at 1, 2, 3, 5 and 10 p.c.) measured in the schists immediately north of the granite gneiss.

W 26 foliations and 100 lineations (contoured at 1, 5, 10, 20 and 30 p.c.) measured at the South Warren Reservoir weir.

Granite Gneiss

G_a 101 foliations and 95 lineations (both contoured at 1, 5, 10, 15 and 20 p.c.) measured in sub-area G_a.

G_b 74 foliations (contoured at 1, 5, 10, 15 and 20 p.c.) and 37 lineations measured in sub-area G_b.

G_c 45 foliations and 41 lineations measured in sub-area G_c.

G_d 31 foliations and 25 lineations measured in sub-area G_d.

Joint Stereograms

Granite Gneiss

G_a 264 joints (contoured at 1, 2, 3, 4 and 6 p.c.) measured in sub-area G_a.

G_b 380 joints (contoured at 1, 2, 3, 6 and 10 p.c.) measured in sub-area G_b.

G_c 446 joints (contoured at 1, 2, 4, 6 and 10 p.c.) measured in sub-area G_c.

G_d 300 joints (contoured at 1, 2, 3, 5 and 10 p.c.) measured in sub-area G_d.

CONCLUSIONS

Evidences in favour of granitisation are: the complete lack of igneous textures or structures in the granite gneiss, lack of evidence near the granite gneiss for mechanical emplacement and wide variations in the relative abundances of both the major and the minor minerals in the gneiss. There are, however, no visible acid igneous rocks in the area to which the causes of granitisation might be ascribed.

The granite gneiss is concluded to be of metasomatic origin. The strongest direct evidence in support of this is gained from a comparison of zircons from the sediments with those from the granite gneiss. Poldervaart (1950) advocated the use of zircons as a criterion of the granitisation of sediments. Fander (1961), working on some local South Australian granites, showed that in most cases the origin of a granite could be indicated through zircon studies. During metamorphism zircons do not recrystallise until the highest grades are reached (Poldervaart and Backstrom, 1949). Zircons in igneous granites are almost invariably euhedral, rare rounded ones probably being xenocrysts. In the Mount Crawford Granite Gneiss none of the zircons are perfectly euhedral and there is a predominance of rounded types. Zircons in the granite gneiss are identical with those in the metasediments.

The chemical changes that occurred during the granitisation cannot be assessed without further chemical analyses. However, it is believed that only minor chemical changes would be necessary to convert the schist to granite gneiss. The major factor causing the granitisation was probably a change in water vapour pressure. Within the granite gneiss this would result in a new mineralogical equilibrium which apparently involved a reduction of the amount of mica (especially muscovite), and an increase in feldspar (especially microcline). Lower water vapour pressure and temperature outside what is now the granite gneiss resulted in a zone of retrograde and hydrothermal alteration in the schists surrounding the granitised core. The sillimanite-quartz pods and the kyanite pegmatites in this zone may have been produced by the expulsion of some of the alumina and silica from the originally aluminous schists during the granitisation. Late stage recrystallisation of the granite gneiss has almost obliterated replacement textures which might have more clearly indicated the granitisation process.

Similar granitic gneisses to the east have been considered to have a granitised origin. Chinner (1955) regarded the Tanunda Creek granite gneisses as recrystallised schists with a slight addition of alkalies. White (1956) proposed that a slight expulsion of silica was all that was necessary to convert original metasediments into the Rathgen granitic gneiss.

ACKNOWLEDGMENTS

Expenses in connection with this work were defrayed by the University of Adelaide Research Grant. The writer wishes to acknowledge gratefully the helpful advice and encouragement given by the Geology Department staff and colleagues. The assistance of Dr. R. L. Oliver and Dr. J. L. Talbot of the Geology Department in reading and criticising the manuscript is greatly appreciated.

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RETROGRADE METAMORPHISM OF THE HOUGHTON COMPLEX, SOUTH AUSTRALIA

BY J. L. TALBOT

Summary

Rocks of the Houghton Complex (?Archaean) have undergone at least three periods of metamorphism. The earliest period, as deduced by relic minerals, was at the upper amphibolite facies. The two successive periods of metamorphism were at the lower greenschist facies. Studies of the overlying Torrens Group rocks (Upper Precambrian) suggest that these last two periods of metamorphism occurred before and after the deposition of the Torrens Group respectively.

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[Read 9 May 1963]

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INTRODUCTION

Rocks of supposed Archaean age are present in several areas of the Mt. Lofty Ranges. Disconnected masses, separated by a cover of Permian, occur between Mt. Compass and Yankalilla (Fig. 1). Other inliers, surrounded by younger Precambrian, occur in the neighbourhood of Aldgate and in the vicinity of Houghton. It has long been recognized that these inliers show similar petrographic features and appear to have undergone similar metamorphic histories (Benson, 1909; England, 1935). Benson (1909) recorded that many of the high-grade rocks in the inlier around Houghton show signs of alteration, and this alteration has been discussed in more detail by Alderman (1938) and Spry (1951). Alderman concluded that the alteration was the result of dynamic metamorphism subsequent on a higher grade phase of metamorphism. Spry correlated this alteration with the deformation of the overlying upper Precambrian rocks.

It is the purpose of this paper to describe the various retrogressive changes which have affected the rocks in one of the inliers (the Houghton Complex†) and to relate these changes to the overall metamorphic and structural history of that part of the Mt. Lofty Ranges. It is only after a study of the effects of the retrograde metamorphism that the nature of the original rocks can be properly discussed.

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* Geology Department, University of Adelaide.

† The term Houghton Complex is used to describe the complex of metamorphic rocks which Howchin (1926) termed Houghtonian. This change in name is in accordance with the Australian Code of Stratigraphic Nomenclature (Anon., 1958, Article 31). The rocks which surround the Houghton Complex are part of the Torrens Group of Upper Precambrian age (Daily, 1963, discusses the nomenclature of these younger rocks).

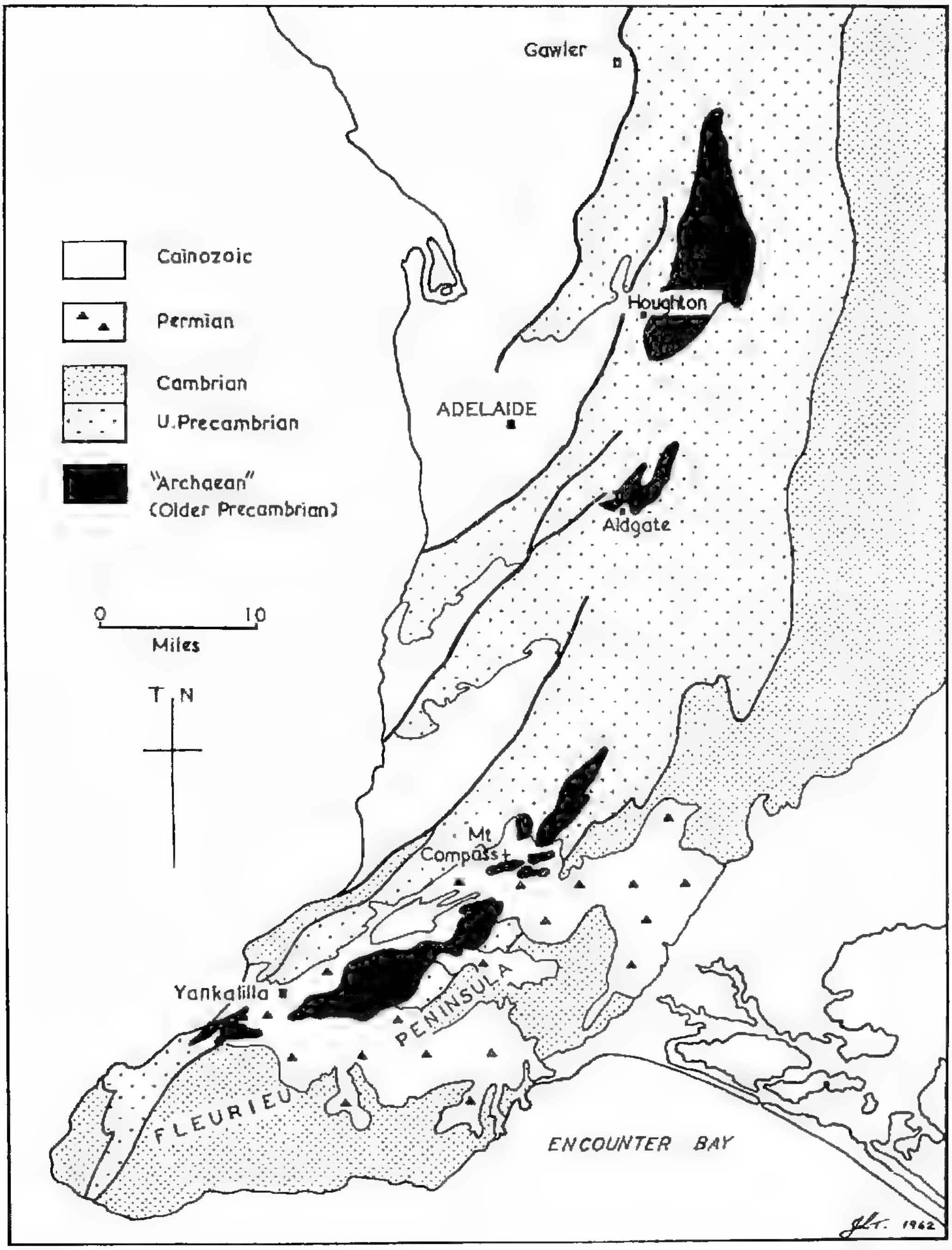
Gawler
Cainozoic
Permian
Cambrian
U.Precambrian
"Archaean"
(Older Precambrian)
Houghton
ADELAIDE
Aldgate
0
10
Miles
T N
Mt
Compass
Yankalilla
PENINSULA
FLEURIEU
ENCOUNTER BAY
JLT. 1962

Fig. 1.

THE PETROGRAPHY OF THE RETROGRADE ROCKS

The original higher grade rocks of the Houghton Complex appear to have been quite variable in chemical and mineralogical composition. In the region around Houghton and around Kersbrook (Fig. 2) are large masses of rock composed essentially of feldspar with minor amounts of amphibole and diopsidic pyroxene. In other parts of the complex, rocks richer in quartz are common and were probably quartzo-feldspathic schists and gneisses. The rocks rich in feldspar show alteration different from the other rocks of the complex, and these changes are described separately. It is realised that the differences between styles of alteration may reflect differences either in degree or type of alteration, in original composition or combinations of these effects.

Alteration of the Feldspar-rich Rocks of Houghton and Kersbrook.

The feldspar-rich rock types (diorites of Benson (1909); metasomatised sediments of Spry (1951)) show a greater number of relic features than do other rocks in the complex and the present outcrops of feldspar gneisses probably represent the least altered rocks in the complex.

Mineralogically, the feldspar gneisses consist of plagioclase and microcline in varying proportions, with minor amounts of amphibole and diopsidic pyroxene.

Plagioclase, whose composition ranges from An_5 to An_{30} is the more abundant feldspar. Perthitic relationships are common and microcline is dominantly a fine vein perthite. Antiperthites and irregular patch perthites also are common. The feldspars show differential alteration; the microcline shows less signs of alteration than the plagioclase. Even in rocks where the plagioclase is almost completely altered, microcline is commonly unaltered. In fine film perthites the albite lamellae show alteration although the host microclines are unaffected. Plagioclase shows two types of alteration. A dusty alteration to epidote resembles the normal saussuritization. The altered plagioclase shows no variation in composition within a single grain, although in different specimens the composition may range from An_7 to An_{15}.

Sericite is another common alteration product of plagioclase and its development appears to be quite distinct from the alteration to epidote. The sericite grains are commonly randomly distributed throughout the plagioclase grains. In most cases the sericite shows no obvious orientation relationship to the plagioclase, but in some specimens the flakes lie in the {001} cleavage plane of the plagioclase and less commonly in the {010} cleavage and twin boundary planes. In many specimens the sericitic alteration is patchy and the sericite may be concentrated in grain boundaries, or cross fractures or in irregular patches within single grains. In some grains the alteration may be so advanced that the nature of the original grain is hardly discernible. In contrast with the saussuritization, the alteration to sericite results in variations in the composition of the plagioclase within individual grains. Those parts of the grain which show patches of abundant sericite are more albitic than the portions relatively free of sericite.

Pyroxene always shows more or less complete alteration to actinolite. In some specimens needles of actinolite project from large diopside grains into the surrounding feldspars, but more commonly the borders of the pyroxenes are completely altered or the actinolite may occur in patches within the pyroxene. Actinolite, however, is not restricted to an association with pyroxene. Some specimens contain large discrete grains of actinolite rather than bundles of needles. Actinolite may also be concentrated in fractures and small faults. It appears that there has been considerable mobility of the actinolite constituents. It is not known whether any of the large discrete amphibole grains were original constituents of the higher grade rocks.

Epidote is another mineral characteristic of the retrograde metamorphism of the feldspar gneisses. Commonly it occurs as very small granules or dust

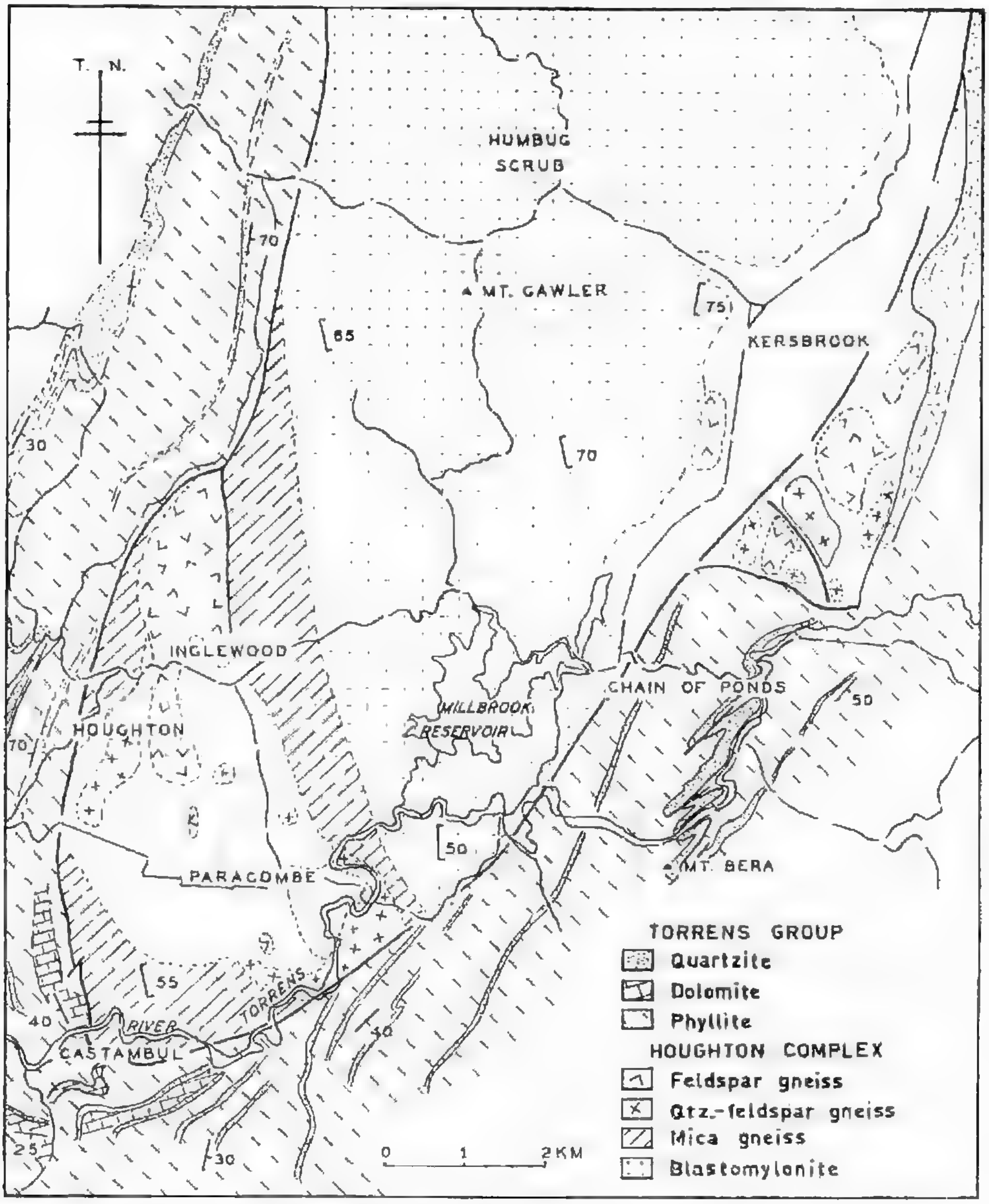

Fig. 2. Sketch geological map of southern part of the Houghton Complex.

enclosed in the plagioclase grains and presumably is a product of saussuritization. In other specimens the epidote occurs in clusters of larger grains, also enclosed in plagioclase, or as interstitial grains. Epidote is also common in some layers rich in actinolite, in which layers its concentration appears to be too great to have been derived from feldspar. Epidote also shows considerable mobility and occurs in large patches and in veins which cut across both feldspar and actinolite.

Brown biotite is a rare constituent of the feldspar gneisses and where present is commonly altered to an olive-green variety with rutile needles arranged in a hexagonal network in the basal plane. The biotite alternatively is crowded with granular opaque minerals.

Associated with the chemical changes numerous signs of deformation are observed in the feldspar gneisses. Quartz, where present, invariably shows undulose extinction or strain bands. Microcline commonly shows undulose extinction, and plagioclase twin lamellae are kinked in some instances. Recrystallization of plagioclase to fine-grained anhedral aggregates is rare. Most commonly finer-grained aggregates cutting plagioclase grains are composed of quartz (and sericite). A few specimens show coarse-grained aggregates of plagioclase and actinolite; these textures may be the result of recrystallization. The plagioclases in the Kersbrook feldspar gneisses show a texture which is commonly called chequer-albite (Gilluly, 1933; Starkey, 1959) (Fig. 1). The albite-law twins are short and alternate along their length giving a chequer board appearance to the grains (18251, 18252).* Although this texture has been considered to be the result of metasomatic replacement of potash feldspar (Gilluly, 1933), it is now commonly thought to be the result of some recrystallization process (Battey, 1955). Starkey (1959) showed that the development of chequer-albite in porphyries from New Brunswick was correlated with increasing deformation. Certainly a deformation origin would better explain the Houghton Complex occurrences. Replacement (or redistribution) textures in the feldspars of the Houghton Complex are characterized by irregular vein or patch perthite.

Alteration of Quartz-Feldspar-Mica Gneisses

Schists and gneisses rich in quartz and feldspar occur to the west of the feldspar gneisses at Houghton and in portions of the Torrens Gorge near the western border of the complex. The gneisses are characterized by good compositional layering; the Houghton examples were originally mapped as part of the overlying Torrens Group (Sprigg *et al.*, 1951), although they were later recognized as part of the older Houghton Complex (Spry, 1951). The confusion arose because of their apparently bedded appearance (excellent examples can be seen at the entrance to Houghton School, Grid ref. 757-964). The layering appears in hand specimen to be due to alternations of quartzo-feldspathic material with layers rich in phyllosilicates. In thin section the apparently micaceous layers are seen to be zones of greater alteration. The altered zones consist of a fine-grained quartz-sericite† aggregate enclosing rare relics of quartz, microcline, coarse mica and rarer plagioclase. The orientation of the layers is parallel to the preferred orientation of the coarse relic muscovite in the unaltered

* Specimen numbers refer to specimens on file in the Geology Department of the University of Adelaide.

† Sericite is an informal term used here for fine-grained white mica. The mica is a 2M muscovite.

layers. The altered layers vary in thickness up to about 5 mm. The relatively unaltered layers vary up to a few centimetres thick. The origin of the alteration or its control is not fully understood. It is possible that the alteration took place in zones which are tectonically controlled (e.g., closely spaced shear zones). Alternatively the alteration may have been selective in layers which differed compositionally from the unaltered layers. These two hypotheses cannot be distinguished on the evidence available.

Blastomylonites and Phyllonites

Over much of the complex the degree of alteration is so great that original textures and structures have been to a large extent obliterated, and the rocks have suffered more or less complete recrystallization and neomineralization.† Many of the rocks are classified as blastomylonites, a term used by Sander (see Christie, 1960) to cover all "cataclastically" deformed rocks which have been recrystallized (or neomineralized). Some of the rocks are phyllonites (Knopf, 1931) which are retrograde rocks resembling phyllites but having an origin similar to blastomylonites. Phyllonites are characterized by a microaugen structure.

In hand specimen the rocks vary greatly in appearance. In the less altered quartzo-feldspathic gneisses, a good secondary foliation is well developed, commonly parallel to the gneissic layering but in other occurrences at a distinct angle to this layering. With more advanced alteration the foliation develops into well-defined layering and the resulting rocks resemble the flaser gneisses described by Hamilton (1960). The layering varies from 1-10 cm. in thickness separated by thinner sericitic zones. In some outcrops the individual layers are uniform and are persistent over several metres; in others, the less altered portions are lensoid and irregular. With further alteration the rocks are poorly layered and possess only a foliation which is a penetrative structure affecting the whole body of rock.

Many of the rocks show augen structure. Alderman (1938) has described the augen gneisses north of the area mapped by the author. The augen are large (up to 3 cm. wide) and are composed of individual feldspar grains commonly larger than 1 cm. in size. Alderman, in a study of the chemistry and mineralogy of the augen gneisses, concluded that the augen originated by growth of the quartz and feldspar due to metasomatism. Earlier, Hossfeld (1935) concluded that the augen were crushed pegmatitic and granitic material. Spry (1951) demonstrated that the development of the schistosity associated with the augen gneisses is later than the crystallization of the augen material and concluded that the schists were not the source rocks of the augen gneisses and that the processes were more complex than that envisaged by Alderman.

The ultimate origin of the Humbug Scrub gneisses can only be partly deduced owing to the widespread sericitization, but the grain size of the quartz and feldspars is large compared with the normal grain size of high-grade rocks in the Houghton Complex. Processes involving either pegmatitization or metasomatism are reasonable origins for the particular high-grade rocks of that area. The Humbug Scrub gneisses show similarities to those seen further south, and this author would agree with Hossfeld that the development of the augen is largely determined by subsequent retrograde changes. In the area examined

† Neomineralization is a term used for crystallization under metamorphic conditions in which new minerals are formed (Knopf, 1931).

by the author the large augen characteristic of the Humbug Scrub region are rare. Smaller augen, commonly 1 cm. wide, are more common, although examples comparable in size with the Humbug Scrub augen are found in the Torrens Gorge. However, the internal structure of the augen differs from those described by Alderman. Large subhedral grains of feldspar are rare and the augen are composed of an aggregate of fine-grained quartz with strained relics of quartz, microcline and rarer albite. The rocks in which the augen are found are commonly layered with the augen forming prominences in individual layers. The rocks resemble augen schists (Lapworth, 1885) which are common in areas characterized by mylonites. The differences between the augen in the River Torrens area and those of Humbug Scrub are considered to be due to the greater degree of alteration and recrystallization in the southern part of the complex.

Two distinct textural types were produced during the alteration; one type is characterized by no distortion of the relic minerals and no preferred orientation of retrograde minerals; the other type shows evidence of considerable strain. In the first type alteration has occurred leaving the shape of the original mineral undisturbed. In this category is the alteration of feldspars to sericite with no preferred orientation of the sericite. Similarly perfect cross sections of sillimanite are preserved as a mass of non-oriented sericite, and presumably irregular patches of sericite represent this same type of complete replacement. The end product of this alteration is a rock with relics of quartz and microcline in a fine-grained quartz-sericite aggregate (Fig. 2). Euhedral tourmaline and magnetite are also found in the fine-grained aggregates and are considered to be late stage minerals. In the second type, the alteration tends to be concentrated in distinct sub-parallel zones and within these zones the sericite shows a strong preferred orientation, and relics are relatively uncommon. With an increase in the number of zones the rocks become schistose and many show the typical augen structure. The relic minerals, which in the early stages of alteration show no shape preferred orientation, in the later stages have their long axes aligned parallel to the sericitic foliation.

In extreme examples of alteration and deformation rocks resembling phyllites or roofing slates are observed (18243, 18246) (phyllonites of Knopf, 1931; see also Spry, 1951). In thin section they appear as finely laminated slaty rocks with an average grain size of less than ·005 mm., with relic elongate lenticular quartz aggregates of somewhat larger grain size (·01 mm.). Zones of true phyllonites are not common in the large area of blastomylonites and occur mainly as thin zones cutting the massive feldspar gneisses.

Commonly the oriented sericite zones cut across the areas of non-oriented patches of quartz-sericite suggesting that the orientation process is later than much of the alteration. Whether these effects are the result of two phases of alteration or parts of the same phase is not known.

Associated with the retrograde changes is a considerable degree of deformation of the relic minerals. Although deformation effects are visible even in relatively unaltered rocks, they are most apparent in the foliated sericite-rich rocks. Quartz shows a greater variety of deformation features than the other minerals and exhibits undulatory extinctions, strain bands, fracturing, marginal granulation and recrystallization. The extinction bands are parallel to the [0001] axes of quartz (e.g. Hietanen, 1938). The fractures are irregular and show no tendency to occur parallel to the extinction bands as reported by Bailey and others (1958).

Many of the large quartz grains have recrystallized to a mosaic of small unstrained grains (commonly ca. ·01 mm.). The small grains are commonly polygonal in outline and tend to meet in triple points (Voll, 1960). Where sericite is present in the aggregate the grain boundaries are modified and quartz-quartz interfaces tend to lie perpendicular to sericite {001} planes.

The distribution of small quartz grains is not constant. Some large grains show sutured boundaries which are commonly due to a single layer of intergranular polygonal grains whose orientations are closely related to the adjoining large grains (Plate 1, Fig. 3). In a few examples, stringers of polygonal grains cross single large grains of quartz (Plate 1, Fig. 4), the recrystallized grains having an orientation similar to the host grain (Fig. 3).

Fig. 3. Quartz orientation diagram of small grains enclosed in a single large grain. The average orientation of the large strained grain is shown as A. Spec. 157-172 220 grains. Contours 1-2-3-4 p.c. per 1 p.c. area.

More commonly the recrystallized quartz grains occur in aggregates and in many cases only relics of the large grains remain enclosed in a polygonal aggregate of quartz and sericite. In other cases the polygonal grains occur as tails on the larger, strained quartz grains.

The textural features described above are interpreted as changes brought about by deformation. Undulatory extinction and extinction bands in quartz have been interpreted by Bailey and others (1958) as polygonization effects resultant on deformation by bend gliding. The widespread development of fine-grained polygonal quartz is interpreted as recrystallization and grain growth from a stressed aggregate, the relics of which are still visible (Voll, 1960; Griggs and Handin, 1960). In quartz-sericite aggregates the textures suggest contemporaneous recrystallization of these minerals and possibly the widespread sericitization is contemporaneous with the recrystallization. This suggestion is supported by the generally greater degree of sericitization in the more deformed aggregates.

Structures Associated with the Retrogressive Metamorphism

As noted previously, the most common structure associated with the retrograde metamorphism is the foliation. Commonly, in the less-altered gneisses in the River Torrens region, the foliation is parallel to and accentuates what may have been original composition layering and where this layering is folded on a large scale, the foliation is also folded. However, in the more altered parts of the complex the foliation and associated metamorphic layering is not parallel to the compositional layering but forms a distinct layering which is parallel to the axial surface of small folds in the original layering. It is not possible to recognize clearly any pre-retrograde structures in the schists and gneisses and even broad folds in the feldspar gneisses have axes which lie in the retrograde foliation. The only structure which can be determined with certainty to be pre-retrogession is the layering in the feldspar gneisses.

THE METAMORPHISM OF THE UPPER PRECAMBRIAN SEQUENCE (TORRENS GROUP)

In order to discuss the relationship of the retrogressive metamorphism to the overall metamorphic history of the area a short statement of the more important aspects of the metamorphism of the Torrens Group is given here.

The Torrens Group, which Mawson and Sprigg (1950) called the Torrensian Series, consists essentially of a sequence of phyllites with prominent quartzite horizons (e.g. Stonyfell Quartzite) and dolomite horizons (e.g. Castambul, Montacute and Beaumont Dolomites). Minor quartzites and dolomites occur in addition throughout the sequence. In certain parts of the area basal conglomerates and haematite-rich quartzites rest on the rocks of the Houghton Complex. However, the relationship of the conglomerates to the overlying beds is unknown since faulting is widespread on the west side of the Houghton Complex and the outcrops are poor along the south and east of the complex.

The conglomerates contain pebbles which can commonly be matched with the adjacent Houghton Complex rock types. In the region of Houghton pebbles of a variety of feldspar and quartz feldspar gneisses are abundant (18249, Grid ref. 763-975). By comparison the conglomerate outcrops just north of the River Torrens (18248) contain much more quartz and retrograde gneiss, reflecting the more highly altered character of the Houghton Complex in that vicinity. Pebbles of retrograde gneisses and schists also are common in the conglomerates along the eastern margin of the complex.

The retrograde changes are thought to be pre-depositional, since the degree of alteration varies considerably from one pebble to another, much more than the variation in alteration observed on the same scale in the Houghton Complex. Some pebbles show retrograde effects which are as great as those in the Houghton Complex, and therefore it is concluded that much of the retrograde metamorphism affecting the Houghton Complex occurred before the deposition of the Torrens Group conglomerates.

The metamorphism of the Torrens Group appears to be of lower greenschist facies. The phyllites consist of quartz, sericite, chlorite and minor feldspar, and in some cases considerable carbonate is present. The sericite and chlorite show a distinct preferred orientation and impart a good cleavage to rocks rich in those minerals. Other rock types contain few indicators of metamorphic grade. Many of the quartzites still show evidence of the clastic nature of the grains although most of the grains are strained. Strain shadows pass through grain boundaries into the adjacent siliceous cement; thus the straining is at least partly induced by post-depositional deformation. In contrast with the Houghton Complex, recrystallization of the large quartz grains to a fine-grained polygonal aggregate is not very common or so complete. However, mylonite rocks are found in various places (Crouch's Hill and east of Mt. Gould, 18253) and in these occurrences the quartz occurs in layers of fine-grained individuals, each layer showing a marked preferred orientation, which is different from that of adjacent layers.

The dolomites are completely recrystallized, and the clastic quartz grains enclosed in them are commonly deformed. Microcline grains are subrounded to rounded and show authigenic microcline outgrowths similar to those described by Baskin (1956). The quartz grains, on the other hand, are commonly lenticular and highly strained and are elongate parallel to the local foliation where present. In some specimens (18245) the quartz has completely recrystallized with the dolomite.

THE METAMORPHIC HISTORY OF THE HOUGHTON COMPLEX

It has long been recognized that the Torrens Group rocks in the region of the Houghton Complex are of a comparatively low grade of metamorphism. Rocks of a higher grade of metamorphism occur a few miles to the east of the Houghton Complex; assemblages contain andalusite, staurolite, kyanite, garnet and sillimanite (Kleeman and Skinner, 1959). Woolnough (1908) concluded these high-grade rocks were Archaean and called them the Barossian Complex. However, it is now clear that these rocks are Cambrian or younger in age (see e.g., Campana, 1958) and that the metamorphic zoning in the Mt. Lofty Ranges is quite independent of the outcrops of the older rocks (Kleeman and White, 1956).

The Houghton Complex occurs in a zone of metamorphism where the surrounding Torrens Group is at the lower greenschist facies. The present metamorphic grade of the Houghton Complex is consistent with this grade. However, it is believed that the older rocks were essentially at this grade before the deposition of the Torrens Group. Evidence for this (as detailed previously) is contained in the pebbles of the basal conglomerates.

The Houghton Complex therefore appears to have suffered two phases of metamorphism at the greenschist facies, although no direct evidence for this is detectable in the complex itself. Spry (1951) concluded that the foliation in the Houghton Complex and Torrens Group rocks were produced at the same time. Evidence for this is limited to the demonstrably secondary nature of the foliation in the Houghton Complex and the parallelism of the foliations in both groups of rocks. This parallelism, however, could be due to the continuity of the same system of stresses over a long period (or successive periods) of time.

Evidence for earlier phases of higher grade metamorphism in the Houghton Complex is rather limited by the later retrograde changes. The rocks have a high-grade aspect, and suites which can be recognised as injection gneisses or metasomatized gneisses have long been reported (Howchin, 1906; Alderman, 1938). Of more problematical origin are the feldspar gneisses (diorites of Benson, 1909; granulites or metasomatized sediments of Spry, 1951). As far as can be determined, the feldspar gneisses were originally composed of an aggregate of plagioclase of oligoclase to andesine composition (An_{30-35} are the most calcic plagioclases observed as relics), with minor amounts of diopsidic pyroxene and possibly some hornblende. Microcline is common in some of the feldspar gneisses and is most commonly perthitic.

Quartz-rich gneisses also are common in the area around Houghton and the Torrens Gorge. These gneisses are quite distinct from the feldspar gneisses in outcrop. They appear to have consisted of quartz, feldspars and micas, and in some of them the quartz grains are in flattened spindles characteristic of granulitic fabric. Sillimanite, andalusite and garnet occur sporadically as relics throughout the complex. The mineralogy of the feldspar gneisses and the other relic rock types in the complex are consistent with an upper amphibolite facies of metamorphism (Fyfe and others, 1958).

In some parts of the complex the structure and mineralogy of the original rocks is still readily discernible. However, throughout most of the complex the nature of the pre-retrograde rocks is in some doubt. It is clear that the rocks must have been a variety of high-grade schists and gneisses, but their mineralogy and fabric have been largely changed by retrogression. Attempts to evaluate any changes which must have taken place to produce the feldspar-rich rocks from the "normal" schists (Alderman, 1938; Spry, 1951; Webb, 1953) are open to the objection that the original composition of the schists is unknown. The greater feldspar and Na_2O content of the feldspar gneisses may reflect merely the destruction of feldspar in the retrograde rocks and the simultaneous removal of Na_2O from these rocks. However, the feldspar gneisses, which may contain 100 p.c. feldspar, must have been distinct rock types as no type of retrograde change observed in the complex could result in the common rocks with coarse-grained quartz relics.

It is concluded that the original complex consisted of rocks of the upper amphibolite facies, consisting of feldspar-diopside gneisses and a variety of quartz-bearing schists and gneisses. These rocks underwent two phases of retrogressive metamorphism to produce the sericite-rich blastomylonites and augen gneisses characteristic of most of the complex. The feldspar gneisses appear to have been more massive and have resisted the retrogressive changes to a greater extent than the other rocks of the complex.

ACKNOWLEDGMENTS

The author wishes to acknowledge the advice and assistance of his colleagues in the Geology Department at the University of Adelaide. Drs. R. L. Oliver and A. W. Kleeman kindly read and criticised the manuscript.

The author is indebted to the University of Adelaide Research Fund for defraying expenses incurred in field work.

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Fig. 1. Chequer Albite. In plagioclase gneiss. Kersbrook. Spec. 18251. Crossed polars.

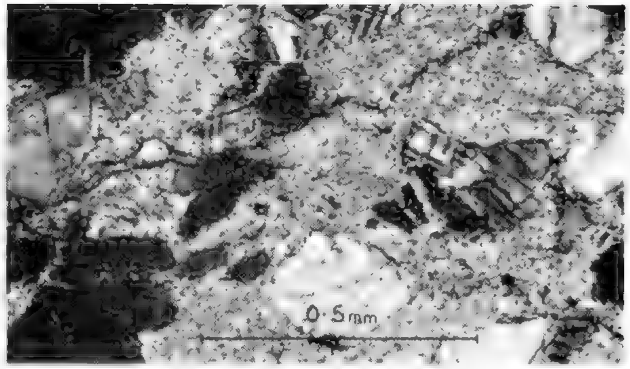

Fig. 2. Relics of quartz and microline in a groundmass of non-oriented sericite and fine-grained quartz. Spec. 18250. Crossed polars.

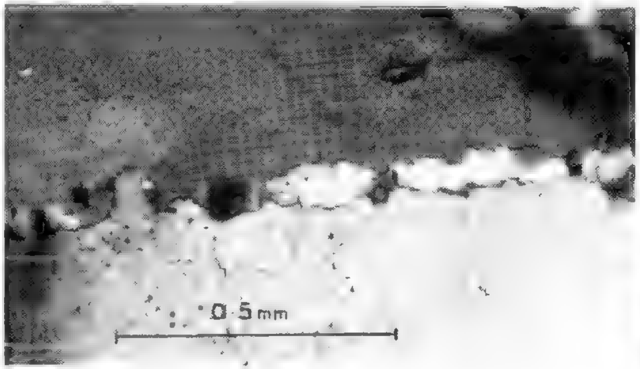

Fig. 3. Intergranular recrystallized quartz in the boundary between two large quartz grains. Spec. 18254. Crossed polars.

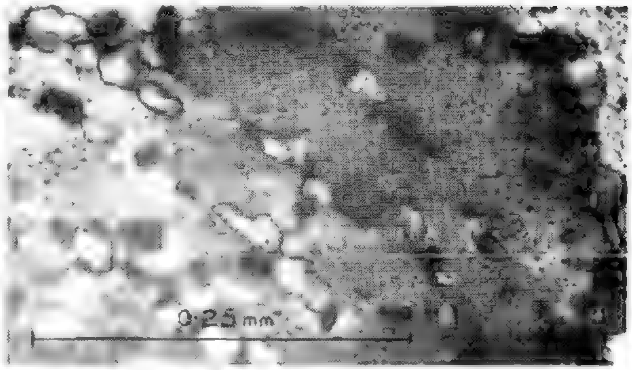

Fig. 4. Trains of polygonal quartz grains crossing a single large strained grain. Spec. 18244. Crossed polars.

AN EVALUATION OF THE CRUSTAL THICKNESS IN THE MARALINGA AREA, SOUTH AUSTRALIA

BY I. A. MUMME

Summary

AN EVALUATION OF THE CRUSTAL THICKNESS IN THE MARALINGA AREA, SOUTH AUSTRALIA

by I. A. MUMME*

[Read 13 June 1963]

International geodetic gravity measurements show that the earth's outer crust floats on an underlying substratum, which is referred to as the mantle, according to the principle of isostasy. In recent years the discontinuity between the outer crust and the mantle has been found to be a zone of seismological discontinuities and is called the Mohorovicic discontinuity.

Seismological information suggests that the mantle has a constant density of 3·32 grammes per cc., and the mean crustal density increases from a minimum value below the ocean of 2·86 grammes per cc. to 3·08 grammes per cc. beneath the high plateaus and mountains.

Although geophysical and geological work show that the earth's outer crust is the region of greatest density variations, nevertheless, the earth's crust is in a state of isostatic balance and consequently a regular relationship between crustal density, elevations of continents and their associated gravity anomalies occurs.

In determining the effective gravity anomally (which is expressed as a Bouguer anomaly) for the Maralinga area, an average Bouguer gravity value for a number of gravity stations established at approximately two-mile intervals along the 131° meridian from Fisher railway station to a latitude of 28°0′ was obtained.

A World Wide gravimeter was used in measuring the gravity intervals between the stations and because of the difficulty of access into the region a helicopter was used in establishing the gravity stations occupied.

The average Bouguer anomaly obtained was − 40 milligals, and the average elevation 570 feet.

These values were then applied in various equations and graphical methods relating elevation and crustal thickness, and gravity anomaly and crustal thickness, and are as follows:

(1) Applying Woollard's method relating elevation and depth to the Mohorovicic discontinuity, we obtain a value of 34 kilometres for the crustal thickness.

(2) Applying Woollard's method relating gravity anomaly and depth to the Mohorovicic discontinuity, we obtain a value of 36 kilometres.

(3) Applying the equation relating gravity anomaly and crustal thickness used by the Russian and Chinese seismologists: $H = 35(1 + \tanh 0{\cdot}0037 \triangle g)$, where H is the crustal thickness, and $\triangle g$ is the crustal anomaly, we obtain a value of 36 kilometres.

* Previously S.A. Mines Dept.; now Australian Atomic Energy Commission.

(4) Applying the equation relating gravity anomaly and elevation used by the Russian and Chinese seismologists: $H = 33 \tanh(0\cdot 38 \triangle h - 0\cdot 18) + 38$, where H is the crustal thickness, and $\triangle h$ is the elevation, we obtain a value of 34 kilometres.

(5) Applying Andreev's formula $H = 0\cdot 1 \triangle g + 30$, where H is the crustal thickness, and $\triangle g$ is the Bouguer anomaly, we obtain a value of 26 kilometres. The average value of these independent determinations is 33 kilometres.

The seismic observations by Bolt, Doyle and Sutton give two values of crustal thickness. From an analysis of the times of arrival of the P and S waves from an atomic explosion, crustal thicknesses of $32\cdot 2 \pm 3$ kilometres and $38\cdot 8 \pm 3$ kilometres were obtained.

It can be seen that the application of Woollard's elevation and gravity methods, and the Russian and Chinese gravity and elevation equations gives values fairly close to the average value of those obtained by the seismic observations.

Andreev's equation gives a somewhat smaller value for the crustal thickness.

The author wishes to thank Exoil Pty. Ltd. for permission to publish data obtained while conducting a geophysical survey for them, and also thank the Director of Mines for granting the permission.

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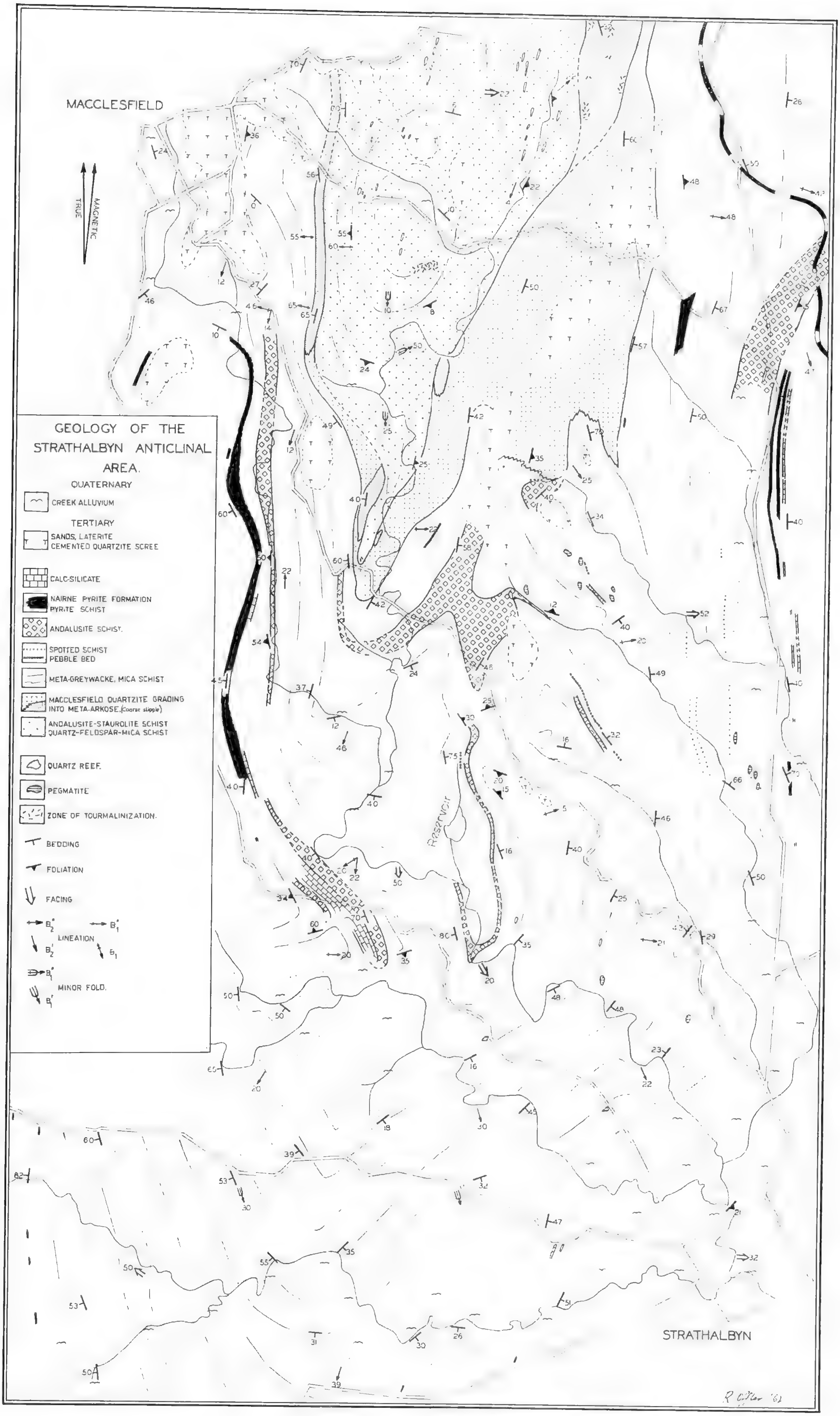

Fig. 1. Scale 2 inches to 1 mile.

STRUCTURAL GEOLOGY OF THE STRATHALBYN ANTICLINE

BY ROBIN OFFLER

Summary

Metasediments in the Macclesfield-Strathalbyn area have undergone at least two deformations. The south plunging Strathalbyn anticline with minor eastwest crossfolds have been overprinted by two sets of strain slip cleavage. Fabric relationships in the pelitic schists indicate phases of: pre-, syn- and post-tectonic metamorphism.

STRUCTURAL GEOLOGY OF THE STRATHALBYN ANTICLINE

by Robin Offler*

[Read 13 June 1963]

SUMMARY

Metasediments in the Macclesfield-Strathalbyn area have undergone at least two deformations. The south plunging Strathalbyn anticline with minor east-west crossfolds have been overprinted by two sets of strain slip cleavage.

Fabric relationships in the pelitic schists indicate phases of pre-, syn- and post-tectonic metamorphism.

INTRODUCTION

The area investigated is situated on the eastern side of the Mt. Lofty Ranges, approximately 23 miles south-east of Adelaide (Fig. 1). The rocks consist of an extensive sequence of meta-arkoses and meta-greywackes with minor calc-silicates, quartzites, pelitic and pyritic schists. They are strongly deformed and are regionally metamorphosed under conditions of the middle Almandine amphibolite facies (Fyfe, Turner and Verhoogen, 1958).

A number of workers, including Sprigg and Wilson (1954), Kleeman and Skinner (1959), and Horwitz, Thomson and Webb (1959), have examined the area on a regional scale.

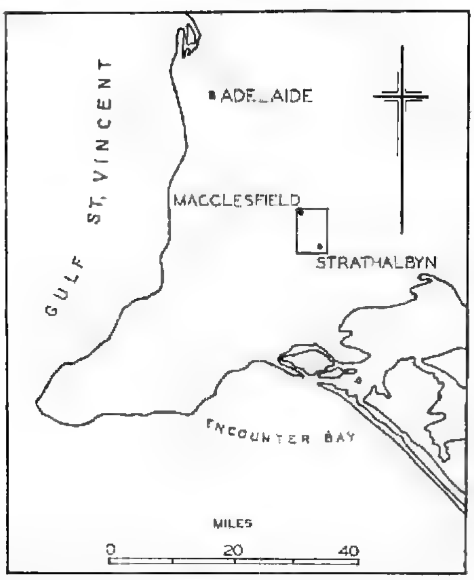

Fig. 2. Locality map showing the area mapped.

* Department of Geology, University of Adelaide.

South of Macclesfield, Kleeman observed lineations with a trend differing from that of the regional fold axis. To investigate this relationship, the author mapped this area in detail with careful observation of structural style and the various structural elements.

STRATIGRAPHIC SUCCESSION

The metasediments in this area are divided into five units and the succession is shown in Table 1. The approximate thickness of the sequence varies from 1,500 feet on the west limb to 10,000 feet on the east limb of the Strathalbyn anticline (Fig. 1). These differences in thickness are thought to be due more to sedimentary thinning than tectonic thinning.

Facies changes occur in the area. The Macclesfield Quartzite grades laterally to meta-arkose and in the upper part of the sequence the meta-arkose interfingers with meta-greywacke. The andalusite-staurolite schists commonly tongue out.

Sedimentary features such as cross and graded bedding, load casting and current ripple marks are common.

Although the author disagrees slightly with the interpretation by Horwitz *et al.* (1959) on the placement of lithological boundaries and classification of rock types, their stratigraphic nomenclature will be retained.

TABLE 1.

	Unit	Western Limb	Eastern Limb
KANMANTOO GROUP	5	Meta-greywacke with minor pyritic schists	Meta-greywacke, calc-silicate.
	4	Nairne pyrite formation	Nairne pyrite formation
	3	Calc-silicate Meta-greywacke Andalusite-staurolite schist Meta-greywacke with minor andalusite-staurolite schists	Andalusite-staurolite schist Meta-greywacke with minor pyritic and staurolite-andalusite schists, pebble beds.
BASAL CAMBRIAN	2	Macclesfield Quartzite grading into meta-arkose	Meta-arkose with minor quartzite lenses at base.
	1	Interbedded andalusite staurolite schists and quartz-felspar-mica schists with minor calc-silicates	Interbedded andalusite-staurolite schists and quartz-felspar-mica schists with minor calc-silicates.

STRUCTURAL GEOLOGY

Macroscopic Structures

The structure of the area is dominated by a large north-south trending anticline called by Kleeman and Skinner (1959) the Strathalbyn anticline (Fig. 3). The fold is assymetric with a dominantly low dipping east limb and a steep west limb. The axial surface of the anticline is sigmoidal in the central part of the area where cross folding is present.

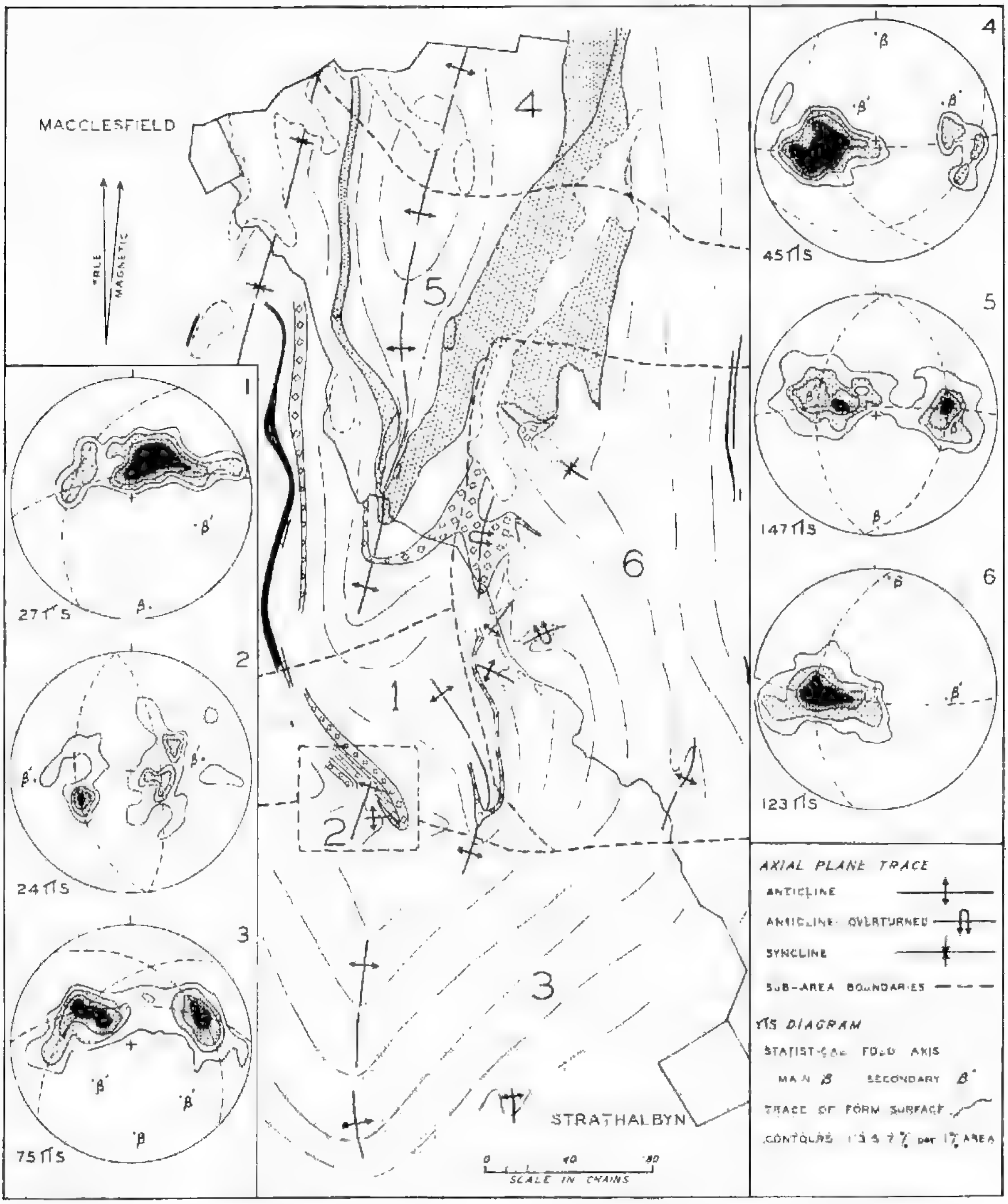

Fig. 3. Structural map showing major macroscopic structures and geometry of bedding, S.

Mesoscopic Structures

The term mesoscopic structure is adopted from Weiss (1957) and signifies a structure seen in hand specimen or single outcrop.

Bedding (S) is banding of sedimentary origin and is the most common planar structure.

Foliation (S_1) is comparatively rare. It is characterised by the preferred orientation of muscovite and biotite in planes which have a variable easterly dip (Fig. 5). In some localities, movement parallel to this foliation has ruptured quartzite bands to produce tectonic inclusions (Fig. 4).

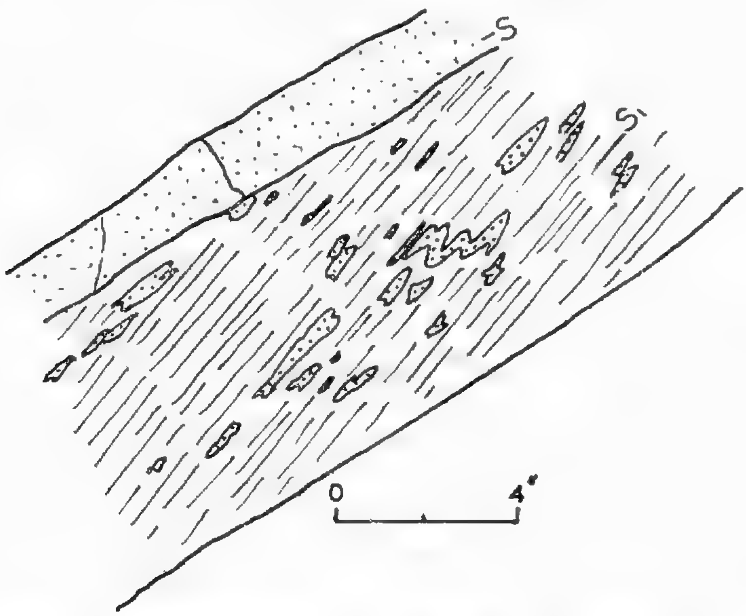

Fig. 4. Tectonic inclusions of quartzite parallel to foliation S_1.

B_1' and B_1'' are two sets of differently trending first generation folds common in the fold hinge of the anticline. Their somewhat variable axial plane attitudes (Fig. 5, Pl. 1, Fig. 2) are indicative of a fold style commonly called polyclinal (Greenly, 1919). On the limbs of the B_1' folds, B_1'' crossfolds appear. Lineations parallel to either of these fold axes are comparatively rare.

Crenulation cleavages S_2' and S_2'' are two sets of surfaces of metamorphic origin, which trend approximately north-south and east-west and parallel the axial planes of micro-crenulations in S or S_1.

Axes of micro-crenulations B_2' and B_2'' are due to the intersection of crenulation cleavage with bedding or foliation and are thought to represent the last phase of folding. The few small folds formed at this time have a similar style (Pl. 1, Fig. 1). The two lineations are commonly associated on the one foliation plane.

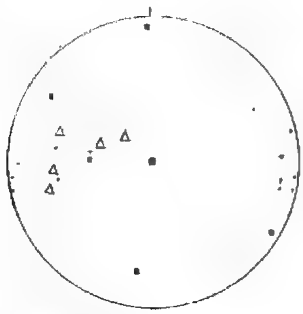

Fig. 5

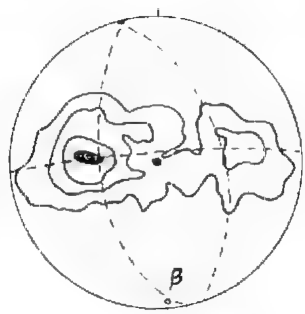

Fig. 6

Fig. 5. Orientations of S_1 (triangles), axial planes of B_1' folds (dots), and axial planes of B_1'' folds (squares)). Fig. 6. Total π S for Strathalbyn anticlinal area. 440 total. Contours 1, 3, 5, 7 p.c. per 1 p.c. area.

GEOMETRY OF S.

The π S analyses of six sub-areas is given in Fig. 3. Each sub-area diagram represents contoured equal area projections of poles to bedding (π S diagrams). β is the pole to the girdle drawn through the maxima and is a statistical fold axis for that subarea. The main geometrical features are:

(1) In all sub-areas, except number two, the bedding has been folded about a single fold axis β.

(2) Secondary girdles appear in all diagrams suggesting other fold axes (β') are present.

The collective diagram (Fig. 6) exhibits a strong girdle whose axes β plunges 6° in a direction 172° and the statistical axial plane strikes 352° and dips 84° east. S is spread along two other girdles indicating slight inhomogeneity.

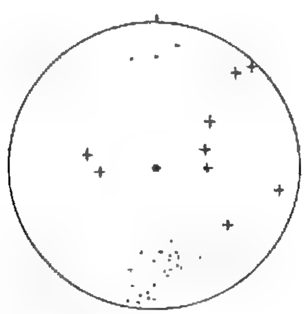

Fig. 7a

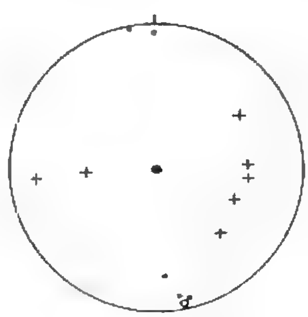

Fig. 7b

Fig. 7a. Collective diagram of B_1' fold axes and lineations (dots) and B_1'' fold axes (crosses). Fig. 7b. Collective diagram of statistical fold axes β (dots), β' (crosses), and megascopic β (small circle).

GEOMETRY OF FIRST AND SECOND GENERATION FOLDS

The geometry of the different fold axes are summarized in collective diagrams, as no significant variations resulted when individual measurements were plotted in the appropriate sub-area.

Geometry of the first generation folds (B_1' and B_1''). The orientation of B_1' is almost coincident with the megascopic fold axis β and the sub-area β (Fig. 7a, b) while the cross fold axes (B_1'') vary in plunge and trend in a similar fashion to β' statistical fold axes.

Geometry of the micro crenulations (B_2' and B_2''). The following points are noted in the collective and synoptic diagrams (Figs. 8a, b).

(1) The east-west trending crenulations (B_2'') tend to spread along a partial girdle (Fig. 8a).

(2) B_2' is close to the orientation of the megascopic β and sub-area β (Fig. 8b).

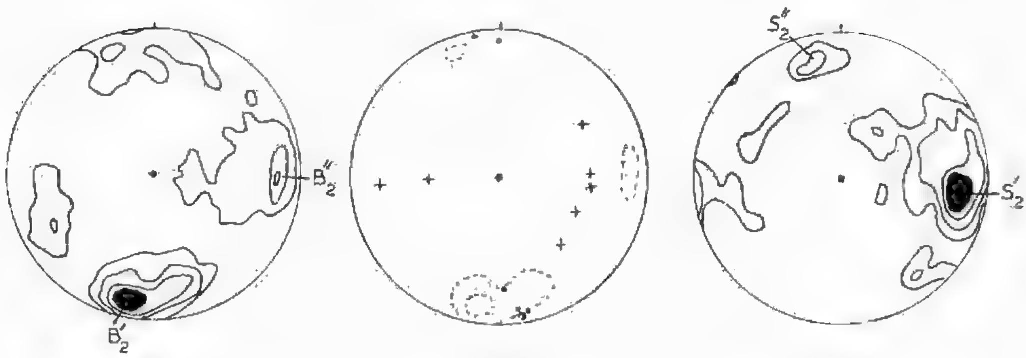

Fig. 8a Fig. 8b Fig. 9

Fig. 8a. Collective diagram of B_2' and B_2''. 158 total. Contours 1, 3, 4, 7 p.c. per 1 p.c. area. Fig. 8b. Synoptic diagram of statistical fold axes β (dots), β' (crosses) and megascopic β (small circle). Dotted lines are 3 and 7 p.c. contours from Fig. 7a. Fig. 9. Collective diagram of crenulation cleavage. 60 total. Contours 1, 3, 7, 11 p.c. per 1 p.c. area.

GEOMETRY OF CRENULATION CLEAVAGE S_2' AND S_2''

Sixty poles of crenulation cleavage are plotted and contoured (Fig. 9). The north-south cleavage is more dominant than the east-west cleavage and shows a tendency to spread along a partial girdle.

DISCUSSION

In the previous summary of meso- and macroscopic geometry, it was noted that fold axes determined from the π S analyses (β and β') were essentially coincident with the first generation, small folds B_1' nad B_1''. This suggests that the two sets of mesoscopic folds are related to the two macroscopic fold systems. Since β, the statistical fold axis determined from the collective π S diagram has a similar orientation to the B_1' small folds, it can be assumed then that they are of the same age.

Whether the B_1' folds developed contemporaneously or not with the B_1'' folds can neither be determined geometrically from the available data nor from field observations, as B_1' and B_1'' are not seen to overprint one another. The variation of B_1' axes may be due to variations in strain, superposition on an early fold system or to slight reorientation by later folding. The lack of homogeneity of B_1'' axes suggests that this minor expression owed its variability to local stress inhomogeneities.

The micro crenulations are often seen to overprint B_1' and B_1'' small folds. Weiss (1959B) has shown that the axes of second generation folds are the intersection of the new axial surface with previously folded bedding. Assuming that in the Macclesfield-Strathalbyn region, that S_2' and S_2'' (the axial planes of the crenulations), have been superimposed on the first generation folds (B_1' and B_1'') then the geometry of B_2' and B_2'' can be demonstrated diagrammatically (Fig. 10). The variation in the two sets of crenulation cleavage is represented as great circle sheaves which intersect bedding (stippled area), folded about β. Where intersection occurs, the second generation crenulations and small folds are observed. β in the diagram is the megascopic fold axis of the first generation. It is assumed that in using this orientation, the movements responsible for crenulation cleavage are only small-scale and did not affect the overall orientation of the bedding (S).

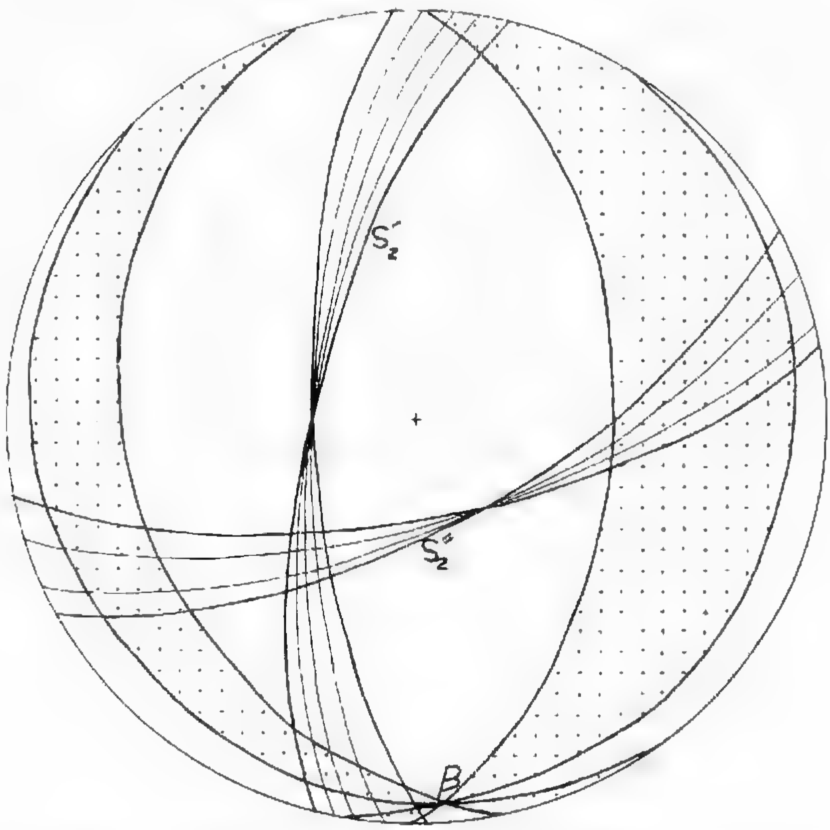

Fig. 10. Superposition of crenulation cleavages S_2' and S_2'' on bedding already folded about megascopic fold axis β.

FABRIC RELATIONSHIPS IN THE PELITIC SCHISTS

Several stages in the metamorphic history can be recognised in the pelitic schists by comparing the internal fabric (Si)* of the porphyroblasts with the external fabric (Se) (Table 2).

TABLE 2

Phase of Metamorphism		Fold Movement
Pre B_1		
		B_1
Syn B_1		
Post B_1	analagous	
Pre B_2	analagous	
Syn B_2		
		B_2
Post B_2		

Pre B_1 metamorphism as interpreted by Zwart (1960), is recognised commonly in skeletal andalusite porphyroblasts containing random inclusions of biotite, muscovite, quartz and magnetite. A later foliation (S or S_1) bends around them. In most schists, augen made up of an aggregate of quartz, biotite, plagioclase and muscovite with no preferred orientation, are found between foliae (Pl. 1, Fig. 3).

Biotite, muscovite and magnetite with strong preferred orientation parallel to either S or S_1, grew during the syn B_1 metamorphic stage. Rotated porphyroblasts (Fig. 11) and quartz-biotite augen (Pl. 1, Fig. 4) between S_1 foliae also

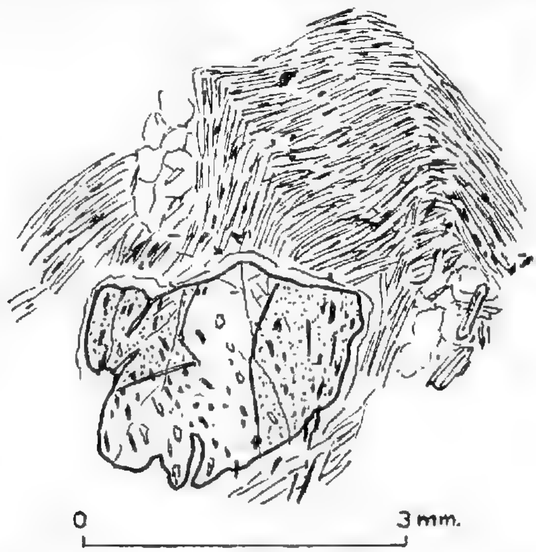

Fig. 11. Twinned, syn. B_1 staurolite porphyroblasts containing rotated magnetite inclusions. Foliation shows microfolding caused by B_2 movements. Section perpendicular to B_1'.

* After Sander (see Fairbairn, 1949).

suggest syntectonic crystallisation (i.e. syn B_1). Lineation expressed by elongated tracts of biotite formed in a few schists.

Evidence for post B_1 metamorphism can be found in staurolite and andalusite porphyroblasts which have inherited S_1. The inherited foliation, often in the form of biotite and magnetite, passes through the porphyroblasts without deviation. During later fold movements (B_2) some porphyroblasts containing S_1, underwent rigid body rotation (Pl. 2, Fig. 1).

The only positive indication of syn B_2 metamorphism is shown by biotite aggregates which have been rotated by differential movement along S_2' (Pl. 2, Fig. 2).

Porphyroblasts that have formed after B_2 folding are quite common. Idioblastic, pale pink garnet always appears to grow from earlier formed staurolite or biotite (Pl. 2, Fig. 3) while muscovite replaces andalusite. Biotite and chlorite porphyroblasts are found in most samples cutting across earlier formed foliations (Plate 2, Fig. 4). The last to crystallize is fibrolite sillimanite which replaces staurolite, muscovite, andalusite and biotite.

RETROGRADE METAMORPHISM

Retrograde metamorphism is present in all rock types. Chlorite (var. pennine) replaces biotite and the titanium oxide resulting from this breakdown forms rutile in the {001} cleavage planes.

Sericitic coronas often surround the alumino-silicates or cloud plagioclase grains. Diopside changes to deep green hornblende, while scapolite breaks down to xenoblastic aggregates of clinozoisite or epidote.

DISCUSSION

The study of the internal fabric of various porphyroblasts and their relationship to the foliations S, S_1 and S_2 suggests that metamorphism has been a continuous process before, during and after the two deformation periods. The presence of retrograde products indicates a re-adjustment of the mineral assemblages to lower pressure and temperature conditions.

CONCLUSIONS

Existing evidence has indicated that the Strathalbyn anticlinal area has been subjected to two periods of deformation. During the first period the south-plunging Strathalbyn anticline and associated cross folds formed. Lineation and a new foliation (S_1), along with a continuance of metamorphism, accompanied this deformation.

Superposed on the earlier folds are two sets of crenulations whose plunges are controlled by the intersection of crenulation cleavage with the variable attitude of bedding. Regional metamorphism continued during and after the second deformation.

ACKNOWLEDGMENTS

I am indebted to Dr. A. W. Kleeman and Professor A. R. Alderman for suggesting this problem to me as an Honours project.

Dr. J. L. Talbot and Mr. K. J. Mills were helpful with advice on problems encountered during the field work.

The manuscript was read by Dr. B. Daily and Dr. J. L. Talbot and I am grateful for their constructive criticisms.

Miss A. M. C. Swan was of great assistance with the drafting.

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Fig. 1. Profile of B_2' fold showing variable attitude of axial planes (dashed lines).

Fig. 2. Profile of B_1' fold, perpendicular to fold axis.

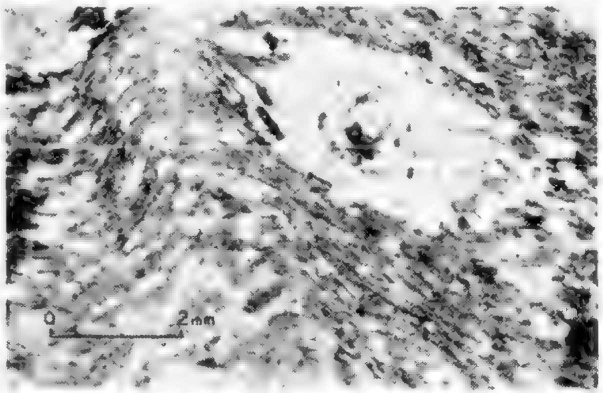

Fig. 3. Pre B_1 augen containing an aggregate of quartz, plagioclase and biotite, surrounded by crenulated S_1. Section perpendicular to B'_2.

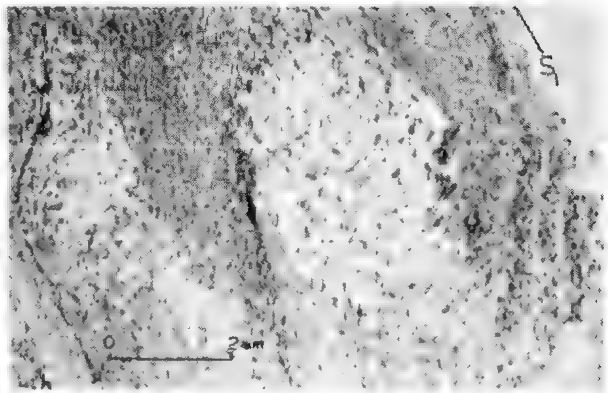

Fig. 4. Syn B_1 augen containing an aggregate of rotated biotite and quartz, surrounded by S_1 foliae. Section perpendicular to B_1'.

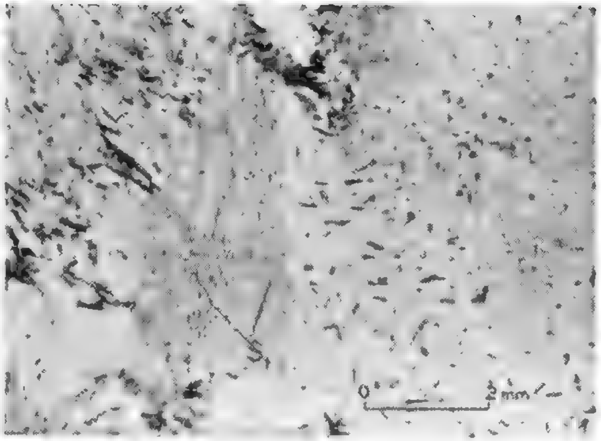

Fig. 1. Post B_1 staurolite containing magnetite inclusions parallel to S_1, which has undergone rigid body rotation. Section perpendicular to B_2'.

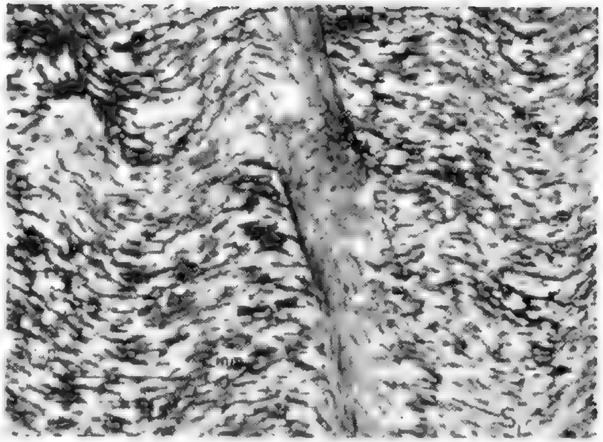

Fig. 2. Aggregate of biotite and magnetite that has undergone rotation by differential movement along S_2'. Section perpendicular to B_2'.

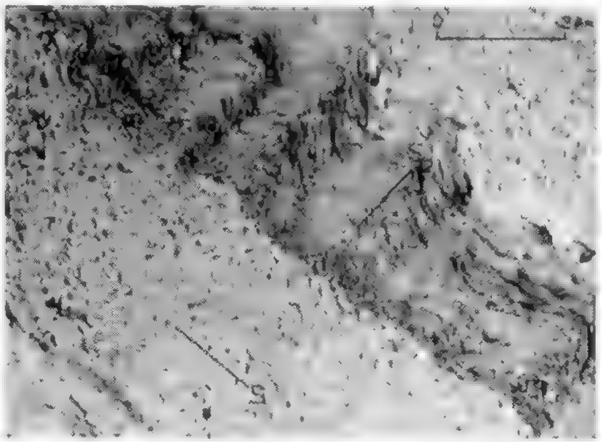

Fig. 3. Strongly crenulated biotite replaced by post B_2 garnet. Section perpendicular to B_2'.

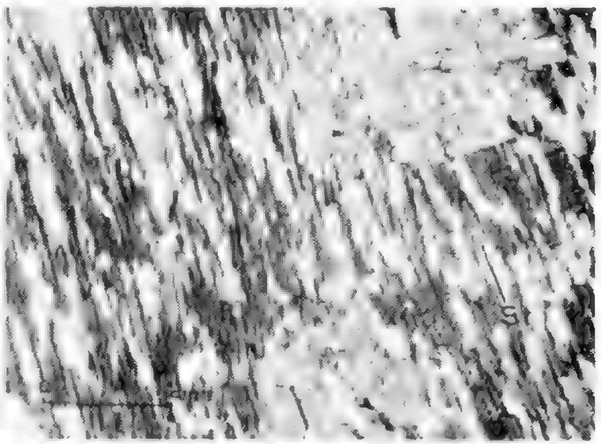

Fig. 4. Post B_2 chlorite cutting across S_1'. Section perpendicular to B_2'.

A TAXONOMIC REVISION OF THE GENUS *MILLOTIA* CASSINI (COMPOSITAE)

BY RICHARD SCHODDE

Summary

The genus Millotia Cass. (Inuleae: Gnaphaliinae) is defined as comprising four species. One species and two varieties are described as new. A key to, and descriptions, illustrations, and distribution maps of the taxa are given. The systematic relationships between Millotia and allied groups of the Compositae arc discussed, and a conspectus of the genera Millotia, Scyphocoronis and *Toxanthes* is included. The annual growth cycle (germination to senescence) is outlined, and some of its features are described in some detail.

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[Read 8 August 1963]

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The genus *Millotia* Cass. (Inuleae : Gnaphaliinae) is defined as comprising four species. One species and two varieties are described as new. A key to, and descriptions, illustrations, and distribution maps of the taxa are given. The systematic relationships between *Millotia* and allied groups of the Compositae are discussed, and a conspectus of the genera *Millotia*, *Scyphocoronis* and *Toxanthes* is included. The annual growth cycle (germination to senescence) is outlined, and some of its features are described in some detail.

INTRODUCTION

In 1829, H. Cassini described the genus *Millotia*, with one species *M. tenuifolia*, from specimens of a small annual composite collected by J. S. C. Dumont d'Urville at King George Sound, Western Australia. The characters he quoted to distinguish it were: all florets in the head tubular and bisexual; a cylindrical involucre comprising "8 to 10" free uniseriate leafy bracts with a terminal subulate point and membranaceous margins; a long, narrow, and scabrous "fruit" with a pitted neck; and style branches terminating in conical appendages.

The genus has since been maintained by subsequent authors, and a further seven species referred to it, namely, *M. myosotidifolia* (Benth.) Steetz (1845), *M. glabra* Steetz (1845), *M. robusta* Steetz (1845), *M. greevesii* F. v. Muell. (1862), *M. kempei* F. v. Muell. (1882), *M. depauperata* Stapf (1910), and *M. hispidula* Gandoger (1918). In Flora Australiensis (1867), Bentham treated Steetz's three species as synonyms of *M. tenuifolia* and Mueller's eremean *M. greevesii* as distinct. Later authors, such as A. J. Ewart (1931) and J. M. Black (1929 and 1957) of current State Floras, have corroborated Bentham's taxonomy, and perhaps followed his lead insofar as the only species generally recognised as occurring in Australia have been *M. tenuifolia*, *M. greevesii*, and *M. kempei*. *M. depauperata* Stapf and *M. hispidula* Gdgr. have not been discussed in any publication since their original description.

METHODS

Herbarium

In addition to the fine series now preserved in the State Herbarium of South Australia (AD), the collections of *Millotia* held by the following herbaria were loaned for examination: Botany Dept., University of Adelaide (AD);

* University of Adelaide and State Herbarium of South Australia for the course of the systematic work on *Millotia*; now Division of Land Research and Regional Survey, C.S.I.R.O., Canberra.

Waite Agricultural Research Institute, Adelaide (ADW); Botanic Museum and Herbarium, Brisbane (BRI); Commonwealth Scientific and Industrial Research Organization, Division of Plant Industry, Canberra (CANB); Staatsinstitut für allgemeine Botanik und Botanischer Garten, Hamburg (HBG); The University of Tasmania, Hobert (HO); Botanisches Institut der Universität, Kiel (KIEL); Laboratoire de Botanique de la Faculté des Sciences, Lyon (LY); National Herbarium of Victoria, Melbourne (MEL)—excluding types; National Herbarium of New South Wales, Sydney (NSW); Muséum National d'Histoire Naturelle, Laboratoire de Phanérogamie, Paris (P); State Herbarium of Western Australia, Perth (PERTH); Dept. of Botany of the University, Sydney (SYD); Naturhistorisches Museum, Wien (W). Dr. R. Melville also kindly submitted details of the collections of *Millotia* in the Kew herbarium (K), and a series of seven sheets of *Conyza* Less. were loaned for comparison by the Instituto de Botánica Darwinion, San Isidro (SI).

The number of herbarium sheets that have been seen, excluding duplicates and photographs, is 595: 215 sheets of *Millotia tenuifolia*, 300 of *M. myosotidifolia*, 72 of *M. greevesii*, and 8 of *M. macrocarpa*. The range of the series of specimens cannot be properly judged from the number of sheets because in most collections more than one specimen is preserved on a sheet: recent collections for the State Herbarium of South Australia, for example, comprise 10 to 60 or more specimens per sheet and are perhaps representative of local populations. Only types and selected collections which are representative or interesting in their morphological variation or distribution are enumerated as specimens examined.

The types of all taxa have been studied, except those of *M. greevesii* and *M. depauperata* which are held by the Kew herbarium. Detailed descriptions, drawings and photographs of these latter types were furnished by C.S.I.R.O., Canberra, and Kew.

Field and Laboratory

The following species were observed and collected in the field: *Millotia tenuifolia* (both varieties), *M. myosotidifolia*, and *M. greevesii* var. *helmsii*. *M. tenuifolia* var. *tenuifolia* and *M. tenuifolia* var. *nudescens* were fairly intensively sampled in the Chauncey's Line area near Murray Bridge at quarter- to two-mile intervals along two road transects six and ten miles long during August-October, 1958, a project resulting in the collection of over 2,200 individual plants. The aim of such sampling was to determine the morphological variation in each local population.

The seasonal growth cycle of *M. tenuifolia* and *M. myosotidifolia* was closely inspected in the field. For this, consistent visits were made between May and late October, 1958, to various sites on the Adelaide Plains, central Mt. Lofty Range, and western Murray Mallee, and successive growth stages were collected.

M. tenuifolia, *M. myosotidifolia* and *M. macrocarpa* were grown from germinated seedlings in glasshouses at the Adelaide Botanic Garden. No viable seed of *M. greevesii* was available. *Toxanthes muelleri* and *Quinetia urvillei* were similarly grown for purposes of comparison. The germination itself was effected on discs of moist filter paper in a series of constant temperature incubators at the Zoology Dept., University of Adelaide. Seedlings of *Millotia tenuifolia* which had been transplanted from the wild state were also grown, as in the case of var. *tenuifolia* and var. *nudescens* from Chauncey's Line. All plants grown in the glasshouse have been preserved as herbarium specimens.

While the taxonomic results of this study are based on the examination of herbarium specimens, investigations of living plants in the field and glasshouse have provided useful confirmatory evidence, and though the taxonomic descriptions are drawn from herbarium material, the characters of corolla colour, scent and cotyledon shape are taken from living plants.

TAXONOMY

Millotia Cassini, Ann. Sci. Nat. 17(1829) 31,416; Cass., Dict. Sci. Nat. 60(1830) 579,592; Less., Syn. Gen. Comp. (1832) 273, DC., Prodr. 6(1838) 161; Endl., Gen. Pl. (1838) 445; Meisn., Pl. Vasc. Gen. 1,1 (1839) 219; Walp. Rep. 2(1843) 645; ibid. 6(1846-47) 234; Hook.f., Fl. Tasm. 1(1856) 209; Benth., Fl. Austral. 3(1867) 595; Benth. & Hook.f., Gen. Pl. 2(1873) 315, Johnston, Memorand. Tasm. Bot. (1874) 24; Spicer, Handb. Pl. Tasm. (1878) 27; F.v. Muell., Trans. Roy. Soc. N.S. Wales 15 (1881) 216; Baill., Hist. Pl. 8 (1882) 177; F.v. Muell., Syst. Cens. Austral. Pl. (1882) 82; Moore, Cens. Pl. N.S. Wales (1884) 37; F.v. Muell., Key Syst. Vic. Pl. 1(1887-1888) 337; F.v. Muell., Sec. Syst. Cens. Austral. Pl. (1889) 138; Hoffm. in Engl. and Prantl, Nat. Pflanzenf. 4,5(1890) 191; Bailey, Cat. Pl. Queensl. (1890) 25; Tate, Handb. Fl. Extratrop. S. Austral. (1890) 119; Baill., Dict. Bot. 3 (1891) 361; Moore & Betche, Handb. Fl. N.S. Wales (1893) 286; Bailey, Queensl. Fl. 3 (1900) 843; Rodway, Tasm. Fl. (1903) 84; Sulman, Guide Wildfl. N.S. Wales 2 (1914) 83; Maid. & Betche, Cens. N.S. Wales Pl. (1916) 201, Black, Fl. S. Austral. (1929) 638; Ewart, Fl. Vict. (1931) 1139; Gardner, Enum. Pl. Austral. Occ (1931) 134; Lemée, Dict. Gen. Phan. 8b (1943) 885; Black, Fl. S. Austral. ed. 2, (1957) 916.

Type species: *Millotia tenuifolia* Cass.

Annual, grey to virescent, slender *herbs*, 1-20(30) cm tall. Stems, leaves, peduncles, and midribs of involucral bracts covered with a ± dense whitish lanuginose *indumentum*, sometimes with pilose or short glandular *hairs*. *Root* simple. *Stems* slender, ± branched diffusely at or near the base rarely simple, erect or ascending or decumbent. *Cotyledons* linear to almost filiform, ± evenly recurved, 2-7 mm long, glabrous though sometimes hispidulous, usually with a ± conspicuous terminal whitish cap. *Leaves* cauline, erect, alternate or becoming so, ± filiform to ± oblanceolate, (½) 1-4(6) cm long, with an obtuse reddish or yellowish glabrous mucro. *Peduncles* ± conspicuous, (½)2-8(11) cm long, and exceptionally ± absent, occasionally bearing 1 – several ± subulate herbaceous leaves 2-8(15) mm long which may grade into the cauline leaves. *Involucres* cylindrical, (3)4½-8(10) mm long, with a uniseriate or less conspicuous biseriate whorl or (3)6-14(20) linear to broad oblong free non-radiate *bracts* with herbaceous midribs and scarious margins and apices. *Receptacle* naked, pitted. *Florets* all tubular and hermaphrodite. *Corollas* tubular to funnelform, 2-5(7) mm long, creamy white to yellow, the *corolla tubes* erect or bent below the *throat* which is deflexed over the top of the involucre, usually bearing sparse minute glandular hairs. *Stamens* 3-5, the *anther auricles* with fine ciliate tails. *Pollen grains* spheroidal to spheroidal-oblate, ± 15-25 μ diam., tricolporate, with a spinous exine. *Style apices* acute to narrow obtuse and dilated dorsally with dense papillae to form expanded cone-like appendages. *Cypselae* variously papillate with the testa wall closely striate, ± linear, 3-12 mm long, brownish to dark reddish-black, with a conspicuous *beak*, and very shortly stipitate. *Pappus* dull white and various, of a ring of barbate setae, or of ± plumose setae, or of small scales, or absent.

The name "*Millotia*" commemorates Claude François Xavier Millot (1726-1785), a French historian.

Distribution and Ecology

Confined to Australia south of the tropic of Capricorn (excluding the east coast and Great Dividing Range north of Victoria), and Tasmania.

All species grow in sand or essentially sandy soils. That pollination is apparently carried out by insects may be deduced from the type of pollen grains and aromatic flower heads or herbaceous parts. Dispersal of pappose cypselae may be effected by animals and to a lesser extent by wind. However, in the three species observed in the field, almost all cypselae of both pappose and apappose types were shed directly on to the ground around the parent plant.

All species are annuals. In southern Australia, seeds germinate with the onset of winter rains, usually in April or May, and the plants grow slowly during winter. Flowering takes place from (June) August to October (December). In *M. tenuifolia* and *M. myosotidifolia*, the times of flowering for local populations appear to be approximately the same each year, irrespective of variations in the seasons, such as in rainfall which affects vegetative growth appreciably.

In arid Australia, the cycle of germination and development is similar but more erratic and the flowering generally earlier. *M. greevesii* and *M. macrocarpa*, which grow in the regions with irregular or mainly summer rainfall (Burbidge, 1960, Fig. 1), flower consistently between July and October. It appears likely, therefore, that these species have arisen from temperate ancestors and have retained a life cycle with winter growth.

Germination

The results from germination experiments in incubators are: No seeds germinated at temperatures above 21° C.; ± all viable seeds germinated at temperatures below 18·6° C. The 12·5-18·6° C. range produced the highest germination percentages and fastest germination which was from 6-14 days in all species; no significant differences were noted between the species in their responses. This temperature range corresponds in general to the day temperatures in the southern districts of South Australia between April and June. Germination percentages averaged from 70-100 p.c. for *M. tenuifolia* and *M. myosotidifolia*, and from 40-50 p.c. for *M. macrocarpa*, and varied considerably between local populations of each species.

Germination will occur only in a moist situation. On wetting, the cypsela papillae in all species dissolve and form a colourless glutinous jacket over the cypselae. The probable function of this jacket is to fasten the cypselae to surrounding soil particles during germination.

In all species grown, the radicle emerges from a slit on the side of the cypsela, usually near the base. In associated genera, the radicle usually penetrates through the base in *Toxanthes* (*T. muelleri* (Sond.) Benth.) or from a slit on the side near the apex of the cypsela in *Quinetia* (*Q. urvillei* Cass.). The cotyledons of *Toxanthes* are more sharply recurved at the apices than those of *Millotia*, and those of *Quinetia urvillei* are fleshy and almost straight.

Tricotyly was observed in one specimen of *Millotia tenuifolia* germinated from seed collected by P. G. Wilson (894) from Kangaroo Island.

Taxonomic Relationships

Cassini (1829) referred *Millotia* to the subtribe Gnaphaliinae, tribe Inuleae, a position which has been corroborated by later authors such as De Candolle (1838) and Hoffman (1890), and also Lessing (1832), Bentham (1873), and Lemée (1943) who subdivided the Gnaphaliinae further and placed the genus in their group Helichryseae. The characters of the genus confirming this latter position are its woolly indumentum, scarious-margined bracts, homogamous-discoid flower heads, and tailed anthers; its closest allies are also members of the Helichryseae.

Characters of *Millotia* anomalous in the Gnaphaliinae-Inuleae are the ± uniseriate involucre, homogamous-discoid flower heads, conical stigmatic appendages, and beak cypselae, even though other members of the Helichryseae possess one or more of these features. Similarities have been noted between *Millotia* and other genera outside the Inuleae, for example with *Erechtites* Rafin. (De Candolle, 1838) in the involucre, and with *Eurybiopsis* DC. (Hooker, 1856) and *Conyza* Less. in the habit. Bentham (1873a) even noted that *Millotia* connected "in some measure" the Helichryseae with the Senecioneae, because of its "almost uniseriate involucre". This possibly explains why he described *M. myosotidifolia* first as a *Senecio*. Cassini (1829) and De Candolle (1838) saw in the beaked cypselae affinities also with *Chevreulia* Cass. (of Bentham's Eugnaphalieae group), a South American genus which is quite distinct on account of its perennial habit, several seriate involucre, and heterogamous flower heads. The similarities are, however, in isolated characters only and of little consequence.

Within the Helichryseae, the affinities of *Millotia* have been discussed by several authors. Bentham (1867), then Bailey (1900) stated that *Millotia* differed from *Leptorhynchos* Less., and *Waitzia* Wendl. in its non-radiate involucre, and from other Gnaphaliinae in its cypsela beak. Mueller and Tate (1896), and Black (1919, 1927, 1957) noted that *Millotia greevesii* subsp. *kempei* resembled *Toxanthes* Turcz., though their observations were based on the general absence of pappus, a character which is strikingly variable in *Millotia*.

It is well known that the limits of many genera of the Compositae are difficult to define; *Millotia* is no exception. It seems that *Millotia* is allied to *Ixiolaena* Benth., and possibly *Waitzia* (and thence other genera with radiate involucres) through *M. myosotidifolia* on the one hand, and to *Scyphocoronis* A. Gray through *M. greevesii* and to *Toxanthes* through *M. tenuifolia* on the other.

The affinities between *Millotia* and *Ixiolaena*, which lie in the woolly often glandular indumentum, the pedunculate and homogamous-discoid flower heads the morphology of the involucral bracts and deflexed corollas, are not great. Significant differences in *Ixiolaena* are its larger size, perennial habit, multiseriate involucre, truncate style branches, and smooth unbeaked cypselae.

The relationship between *Millotia*, *Scyphocoronis*, and *Toxanthes*, all of which are confined to Australia, is far more complex. Outstanding is the striking variation in pappus in the three genera. Features common to each are the small annual habit, ± uniseriate involucre, homogamous-discoid flower head and ± deflexed corolla; the distinguishing characters are given in the following conspectus:

1. **Millotia** Cass. *Habit* ± open. *Stems* conspicuously and densely woolly, rarely sparsely woolly. *Primary stems* unbranched, or with several lateral branches usually near the base. *Leaves* alternate. *Flower heads* conspicuously pedunculate. *Involucral bracts* ca. 6-14, free at the base, with conspicuous scarious margins. *Corollas* tubular to funnel-form, the *limb* remaining cream to yellow after anthesis; the *tube* erect, or straight and sharply bent below the throat to deflex the corolla. *Style branches* with broadly acute to expanded conical tips. *Cypselae* muricate or with ± strigulose papillae; *cypsela beak* present and straight, rarely slightly curved at the apex. *Pappus* of bristles, scales, or absent.

2. **Scyphocoronis** A. Gray (1852). *Habit* ± dense. *Stems* and leaves without wool, or sparsely and not conspicuously woolly. *Primary stems* with numerous lateral branches (ca. 5-10) in lush specimens, the laterals most frequent near and above middle of primaries. *Leaves* opposite, sub-opposite, or alternate. *Flower heads* subsessile and surrounded by cauline leaves, or conspicuously pedunculate. *Involucral bracts* 3-8 (10), connate or free at the base, with or without inconspicuous scarious margins. *Corollas* tubular and funnel-form; the *limb* becoming pink-red or remaining yellow after anthesis; the *tube* curved through its whole length or bent below the throat. *Style branches* subulate or with expanded conical tips. *Cypselae* with glandular papillae; *cypsela beak* absent. *Pappus* absent: conspicuous cup crowning cypsela.

3. **Toxanthes** Turcz. (1851). *Habit* ± dense. *Stems* and leaves without wool or sparsely woolly. *Primary stems* with numerous lateral branches in lush specimens, as in *Scyphocoronis*. *Leaves* usually opposite, rarely sub-opposite or alternate. *Flower heads* subsessile and surrounded by cauline leaves. *Involucral bracts* ca. 3-5, connate at base, with or without narrow scarious margins. *Corollas* tubular; the *limb* becoming pink-red after anthesis; the *tube* curved through its entire length. *Style branches* subulate. *Cypselae* with glandular papillae; *cypsela beak* present, ± curved through its length. *Pappus* (apparently) of ± dense wool, or the corolla base glabrous or almost so.

Despite the separation of these genera in the conspectus, *Scyphocoronis major* (Turcz.) Druce seems to be morphologically identical with *Toxanthes muelleri* except for the cup crowning the cypsela. There is also an undescribed species from the arid regions north of the Nullarbor Plain (N. Forde 409: AD, CANB: and Elder Exploring Expedition: AD95732062), the characters of which have been incorporated under *Scyphocoronis* in the conspectus, and which has the habit, indumentum, and involucre form of *Toxanthes*, the apical cypsela cup of *Scyphocoronis*, and the alternate leaves, peduncles, free bracts, and floret form found in two species of *Millotia*, particularly *M. greevesii*.

Notwithstanding the intricacy of these relationships, *Millotia*, *Toxanthes* and *Scyphocoronis* are not united under one genus here because (1) together they would form a taxonomically unwieldy grouping with an unusually wide range in infra-generic variation, (2) the species of *Millotia* still form a most discrete alliance on their own, and (3) the delimitation of *Millotia* in its customary sense is in accord with the generic limits recognised by Bentham (1873 bis) and Hoffman (1890) in this group of the Compositae.

KEY TO THE SPECIES AND INFRA-SPECIFIC TAXA

1a Corolla limb of 5 (exceptionally 4) acute, almost attenuate lobes which are ½-⅓ mm long. Anther thecae oblong, ⅔-1½ mm long. Connective apices exserted prominently beyond the limb at anthesis.

2a Cypselae ± strigulose, i.e. with oblong-clavate appressed papillae which are minutely bifid at the apex. Leaves ± oblanceolate to narrow oblanceolate. Pappus of finely toothed setae ca. as long as corolla. Midrib of involucral bracts carinate, as broad as or narrower than scarious margin. Corollas creamy white, rarely creamy yellow. 1. *M. myosotidifolia*

2b Cypselae papillate, i.e. with short rounded or conical papillae. Leaves narrow-linear to ± filiform. Pappus of plumose setae ± ½ as long as corolla, of minute scales, or absent. Midrib of involucral bracts navicular, ± twice as broad as scarious margin. Corollas bright yellow. 2. *M. greevesii*

3a Pappus of 10-20 plumose setae ± $\frac{1}{3}$ as long as corolla. Beaks of inner cypselae usually protruding more than 1 mm above top of involucre.
(*M. greevesii* subsp. *greevesii*)

4a Involucral bracts appearing connate with a dense lanuginose indumentum, without glandular hairs.
M. greevesii subsp. *greevesii* var. *greevesii*

4b Involucral bracts distinctly free, with a glandular and ± woolly indumentum.
M. greevesii subsp. *greevesii* var. *glandulosa*

3b Pappus of minute scales or absent. Beaks of inner cypselae rarely protruding to 1 mm above the top of involucre.
(*M. greevesii* subsp. *kempei*)

5a Involucral bracts with dense lanuginose indumentum only.
M. greevesii subsp. *kempei* var. *kempei*

5b Involucral bracts with a glandular and ± woolly indumentum.
M. greevesii subsp. *kempei* var. *helmsii*

1b Corolla limb of 3-4 (exceptionally 5) ± obtuse or hardly acute lobes which are ($\frac{1}{5}$) $\frac{1}{4}$-$\frac{1}{3}$ ($\frac{2}{5}$) mm long. Anther thecae elliptic, ($\frac{1}{5}$) $\frac{1}{4}$-$\frac{2}{5}$ ($\frac{1}{2}$) mm long. Connective apices enclosed, or only slightly protruding from the limb at anthesis.

6a Indumentum of dense woolly hairs only. Cypselae narrow-linear, (7) ± 10 (12) mm long, the beaks protruding (1) 2-3 (4) mm above top of involucre at maturity. Corolla narrow cyathiform, the limb 3- to 4-lobed, spreading at anthesis. Pappus of semi-plumose setae. 3. *M. macrocarpa*

6b Indumentum of woolly and straight hairs. Cypselae linear-clavate, (3) 4-6 ($7\frac{1}{2}$) mm long, the beak apices ± level with top of involucre at maturity. Corolla ± tubular, the limb 4-lobed (exceptionally 3- or 5-lobed), and ± erect. Pappus never semi-plumose. 4. *M. tenuifolia*

7a Pappus of ca. 20-30 fine setae, ± as long as corolla. Corollas ± erect.
M. tenuifolia var. *tenuifolia*

7b Pappus reduced, varying from a ring of 20-30 (40) setae of unequal length and up to ± $\frac{2}{3}$ as long as corolla, to ± 5 unequal setae in number, or a ring of minute scales in size. Corollas ± deflexed.
M. tenuifolia var. *nudescens*

1. **Millotia myosotidifolia** (Benth.) Steetz in Lehm., Pl. Preiss. 1(1845)457; Walp. Rep. 6(1846-7)234; Sonder, Linnaea 25(1853)502-3; Hannaford, Notes Fl. & Faun. Vict. (1856)61.

Senecio myosotidifolius Benth. in Endl., Enum. Pl. Hügel. 1(1837)66; D.C., Prodr. 6(1838)371.

Millotia glabra Steetz in Lehm., Pl. Preiss. 1(1845)458; Walp. Rep. 6(1846-7) 234.

Millotia robusta Steetz in Lehm., Pl. Preiss. 1(1845)458; Walp. Rep. 6(1846-7) 234.

Millotia myosotidifolia var. *robusta* (Steetz) Sonder, Linnaea 25(1853)503.

Millotia myosotidifolia var. *glabrescens* Sonder, Linnaea 25(1853)503.

Millotia tenuifolia (non Cass.) Hook.f., Fl. Tasm. 1(1856) 209 p.p.; Benth., Fl. Austral. 3 (1867) 596 p.p.; Johnston, Memorand. Tasm. Botanists (1874) 24 ? p.p.; Spicer, Handb. Pl. Tasm. (1878) 27, 117 p.p.; F. v. Muell., Trans. Roy. Soc. Tasm., Rep. for 1878 (1879) 17 p.p.; Tate, Trans. Roy. Soc. S. Austral. 3 (1880) 72 p.p.; F.v. Muell., Syst. Cens. Austral. Pl (1882) 82 p.p.; Moore, Cens. Pl. N.S. Wales (1884) 37 p.p.; F.v. Muell., Key Syst. Vict. Pl. 2 (1885) 34 p.p.; F.v. Muell., *ibid.* 1 (1887-8) 337 p.p.; F.v. Muell., 2nd Syst. Cens. Austral. Pl. (1889) 138 p.p.; Tate, Handb. Fl. Extratrop. S. Austral. (1890) 119, 239 p.p.; Moore & Betche, Handb. Fl. N.S. Wales (1893) 286 p.p.; Rodway, Tasm. Fl. (1903) 84 ?p.p.; Diels & Pritzel, Fragm.

Phytograph. Austral. occ. (1905) 616 ? p.p.; Dixon, Pl. N.S. Wales 1 (1906) 197 p.p.; Sulman, Guide Wildfl. N.S. Wales 2 (1914) 83 ?p.p.; Maid. & Betche, Cens. N.S. Wales Pl. (1916) 201 p.p.; F.N. Club Vict. Cens. Pl. Vict. (1923) 67 p.p.; Cleland & Black, Trans. Roy. Soc. S. Austral. 51 (1927) 59 p.p.; Black, Fl. S. Austral. (1929) 638, f.291 p.p.; Ewart, Fl. Vict. (1931) 1139 p.p.; Gardner, Enum. Pl. Austral. Occ. (1931) 134 ?p.p.; Black, Fl. S. Austral. ed. 2, (1957) 917, f.1215 p.p.

Millotia depauperata Stapf, Kew Bull. 1910(1910)22. "*Millottia depauperata*."

TYPE: C. L. Hügel : K : Swan River; W s.n. : Fremantle.

The Kew specimens, which were seen from a photograph in CANB (Neg. No. Kew 1636, 10.12.1953) are to be treated as the holotype because their label bears the name "Swan River", the only locality cited by Bentham in his original description. The specimens in both herbaria are identical in appearance and stage of development, and probably constitute a single collection. The collection in W is therefore considered an isotype.

Grey, rarely virescent *herb*, (1)4-16(± 30) cm tall, (1)2-12(± 30) cm broad. *Indumentum* white lanuginose only, of variable density, very woolly or floccose in some specimens to ± absent in others, always densest at the apices of the peduncles enhancing their expanded appearance. *Stems* 1-10(25), ascending or sometimes erect with a central leader, more robust than in any other species and usually thickened at the base. *Cotyledons* (3)4-6(7) mm long, the tips slightly recurved. *Leaves* narrow to broad oblanceolate or occasionally spathulate, exceptionally oblong or linear (except the first leaves above cotyledons and the uppermost leaves at base of peduncles), (½)2-4(6) cm long, (1) 2-5 (8) mm broad (at the widest part), ± mucronulate, conspicuously amplexicaul, relatively sparse and often appearing basal due to the long prominent peduncles. *Flower heads* (1)5-30(200). *Peduncles* (¼)2-8(11) cm long raising the involucre (0)1½-6(9) cm above the tops of cauline leaves, becoming relatively stout at maturity, appearing slightly expanded below the involucre. *Involucres* (3)5-7(10) mm long, of (3)8-13(20) ± biseriate and basally imbricate narrow to broad oblong *bracts* with carinate midribs usually narrower than the broad, straw-coloured or sometimes red-purple margins; *bract apices* caudate rarely acuminate or acute, ± entire, sometimes recurved, often red-purple. *Flower heads* with ca. (3)15-45(100) florets, honey-scented. *Corollas* funnelform, (2½)3½-5(7) mm long, deflexed over involucre (peripheral corollas most deflexed, innermost corollas usually ± erect), creamy white rarely creamy yellow with the *tube* becoming brownish to reddish brown after anthesis; *corolla limbs* of 5, exceptionally 4, ± spreading acute to almost attenuate lobes ½-⅗ mm long. *Stamens* 5, with tips exserted beyond corolla limb; *anthers* with oblong *thecae* (7/10)⅘-1⅕(1½) mm long, the *connective tip* extending (⅕)3/10-⅖(½) mm beyond theca; *pollen grain* diameter ca. 20-25 μ. *Style branches* (1)1⅕-1⅗(2½) mm long, with acute broadly dilated conical appendages at the *apices*. *Cypselae* ± strigulose, linear rarely oblong, (3)4-8(10) mm long and protruding up to ± 2 mm above top of involucre at maturity, entirely pale brown to brownish black; *cypsela papillae* ± relatively sparse, oblong-clavate, ⅕-3/10 mm long, appressed, shortly and acutely bifid at apex, transparent or white translucent but sometimes reddish-brown at base; *cypsela beaks* (¾) 1½-3(5½) mm long, compressed to rarely broadly compressed, distinctly demarcated, with papillae ± restricted to margins. *Pappus* of (15)18-25(30) – exceptionally fewer and rudimentary – erect barbate *setae* which are ± as long as corolla though often slightly shorter, and with the teeth usually longer and denser at setae tips (Fig. 1).

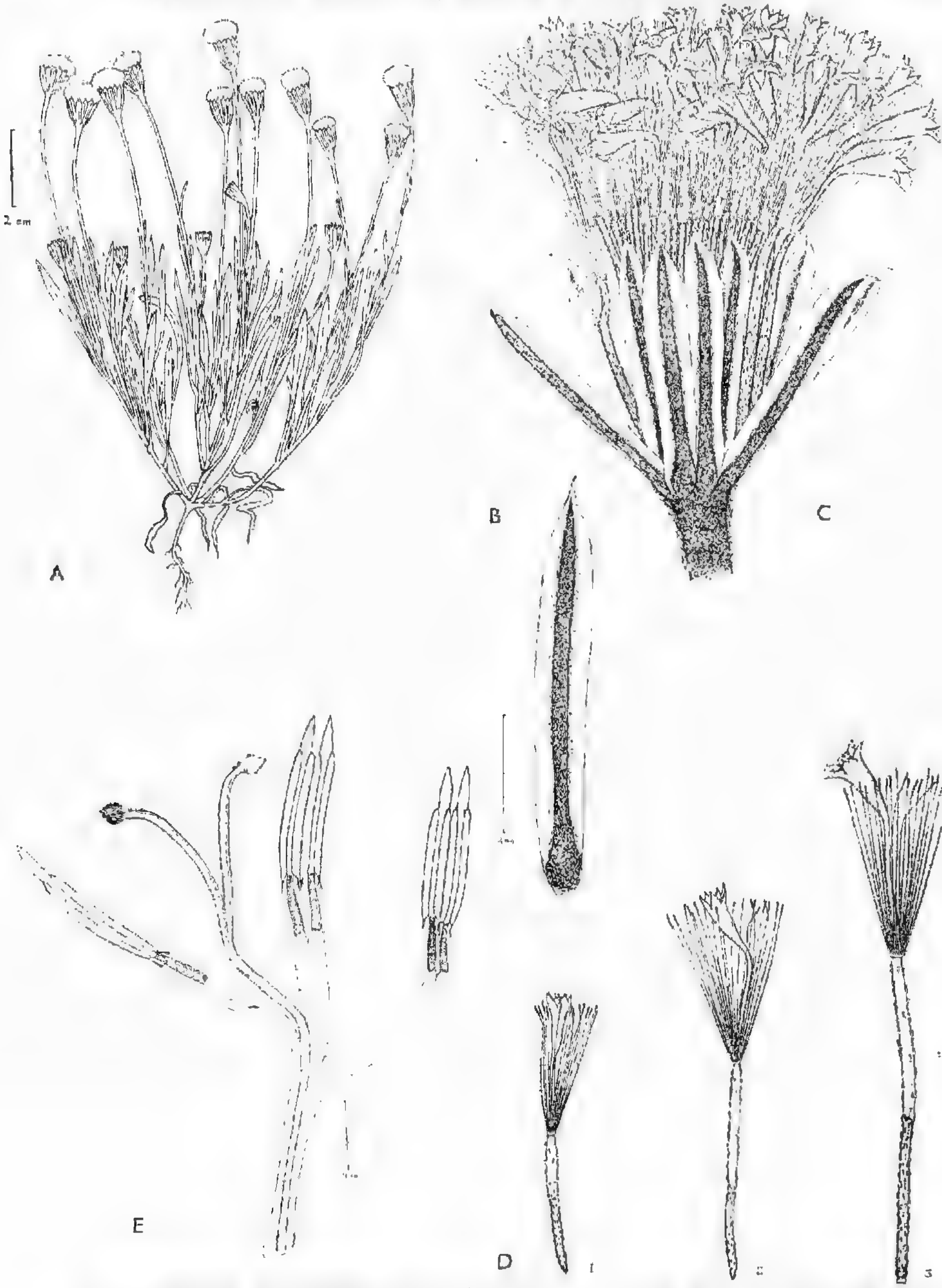

Fig. 1. *Millotia myosotidifolia* (Benth.) Steetz. A, whole plant (Schodde 956); B, involucral bract (type—Hügel: W); C, flower head (Schodde 956); D, florets with maturing cypselae (1,2 = Schodde 1010, and 3 — Whibley 401); E, whole style and androecium just after anthesis (Schodde 956).

SPECIMENS EXAMINED

WESTERN AUSTRALIA: — *Anonym 11*: AD95724011: Rottnest. — *W. E. Blackall 2631*: PERTH 5532/41. Dongarra. 16.IX.1932. — Carey: MEL: Geograph(e) Bay. — *J. B. Cleland*: NSW41778: Cunderdin. IX.1908. — *Dempster*, MEL (2 sheets). Between Esperance Bay and Fraser's Range. 1876. — *J. Drummond 365* (probably 5th collection): MEL, W s.n.: W.A. (MEL), Nov. Holl. Aust. occ. (W): Rea. 1844. — *W. V. Fitzgerald*: NSW41785: Boulder. IX.1898. p.p. — *C. A. Gardner 560, B569*: PERTH s.n.: Near Wiluna. VIII.1931. p.p. — *B. T. Goadby 208*; NSW41790; Mt. Barker. X.1900. — *Heal*: MEL: E. sources of Swan Riv(er). 1889. p.p. — *R. Helms*: ME, N.S.W.41873: Pinjarra, Murray R. 23.IX.1927. — *per R. Helms*: PERTH s.n.: Karridale. X.1898. — *Hügel*: W s.n.: Fremantle. (*type* of *Senecio myosotidifolius* Benth.). — *J. H. Maiden s.n.*: AD95727060: Busselton. X.1909. — *A. Morrison*: LY: Kelmscott, Canning River. 10.IX.1898. p.p. — *F. Mueller*: MEL: Hamelin-Harbour, Shark Bay. X.1877. — *F. Mueller*: NSW41795: Stirling Range. — *Muir*: MEL: Lake Muir. *Oldfield*: MEL (2 sheets), W Acqu. 1889 No. 36953: Murchison R. — *Oldfield*: MEL: Tone River. — *Preiss 100*: MEL (2 sheets): In valley near lake. Rottnest Island (Swan River Colony). 22.VIII.1839. (*type* of *Millotia glabra* Steetz and *M. myosotidifolia* var. *glabrescens* Sonder). — *Preiss 66*: HBG, KIEL252/7, MEL (2 sheets), P, W (2 sheets: Acqu. 1889 No. 130458, and s.n.): In fields about Perth (Swan River Colony). 27.IX.1839. (cited by Steetz, 1845). — *Preiss 67*: MEL (2 sheets): Interior District Plantagenet (Swan River Colony). X.1840. (*type* of *Millotia robusta* Steetz). — *E. Pritzel 545*: NSW41791, W Acqu. 1902 No. 7032: Sharks Bay. VIII.1901. — *R. D. Royce 1207*: PERTH L1600/44: 6 miles east of Ballidu. 9.IX.1946. p.p. — *F. E. Stoward s.n.*: PERTH s.n.: Busselton. 1916.

SOUTH AUSTRALIA: — *H.W.A.* (= *H. W. Andrew*): AD95731018: Blackheath, nr. Harrogate. 24.X.1918. — *Anonym.* (*Herb. R. Tate*): AD95724016: Mt. Parry Rocks. — *Anonym.* (? *Behr*): MEL: K.I. (= Kangaroo Island) (Fiedler's section). XI. — *Anonym.*: MEL: Coffins Bay. — *E. Ashby 1010*: NSW41792: Middle River, N.W. Kangaroo Is. X.1905. — *L. F. Boehm s.n.*: ADW6791: Sutherlands. IX.1931. — *J. B. Cleland s.n.*: AD95730057 Mt. Wedge, 20 miles north of Elliston. 22.VIII.1925. — *Hj. Eichler 12678*: AD95710015. Gammon Ranges. Near mouth of gorge of Arcoona creek south of Arcoona Bluff Range. 17.IX.1956. — *Hj. Eichler 14000*: AD95751038: Between Corny Point and Cape Spencer. Ca. 17½ km south of Corny Point. 26.IX.1957. — *Hj. Eichler 14221*: AD95808039: Scrub between Stansbury and Minlaton, ca. 6 km north-west of Stansbury. 2.X.1957. — *F. M. Hilton 865*: ADW10188: S.W. Bookaloo, Yudnapinna Stn. 15.VII.1954. — *J. L. Hussey*: MEL: Port Elliot. 1893. — *E. H. Ising 651*: AD95817028: Moolooloo Stn. X.1918. — *E. H. Ising s.n.*: AD95833159: Tarcoola. 21.IX.1920. — *E. H. Ising s.n.*: AD95833155: Hackham. 10.X.1928. — *E. H. Ising s.n.*: AD95817017, AD96008001: Waterfall Gully. 12.XI.1932. — *E. H. Ising s.n.*: AD95817034: Waddikee Rock. 2.IX.1935. — *E. H. Ising s.n.*: AD95833158: Wudinna, E.P. 21.IX.1939. — *E. N. S. Jackson s.n.*: AD95915100: Telowie Gorge, Lower Flinders Range. 27.IX.1958. — *C. W. Johns 1*: AD95731010: Wudinna. p.p. — *D. Kraehenbuehl 18*: AD95909049: On rocky hillslopes of the old Blinman Copper Mine, north end of Blinman. 4.X.1958. — *W. H. Litchfield*: ADW8892: Hd. Stirling, Upper Sth.-east. X.1950. — *F. Mueller*: MEL: Guichen Bay. 1848. — *T.B.P.* (= *T. B. Paltridge*): AD95724008: Bumbumbie Springs, Koonamore. 23.VIII.1930. — *R. Schodde 508*: AD95807104: Golden Grove, ca. 16 km north-east of Adelaide. 5.X.1957. — *R. Schodde 958*: AD95908081: The Pinery, Adelaide Plains. 3.X.1958. — *R. Schodde 1006*: AD95909029: South side of Chauncey's Line, ca. 4 km south-east of Hartley. 22.X.1958. — *J. G. O. Tepper 275*: AD95903122, MEL: Clarendon, Coromandel Valley. 9.XI.1881. — *D. J. E. Whibley 101*: AD95909053: Gawler Range. Hill behind Yardea Station. 17.X.1958. — *L. D. Williams 2*: AD95919001: Meningie. 7.X.1958. — *P. G. Wilson 290*: AD95909064: Boston Island, nr. Port Lincoln. 8.X.1958. — *P. G. Wilson 1020*: AD95909031: Julia Range, ca. 100 km north of Adelaide. 11.XII.1958.

NEW SOUTH WALES: — *L. Abrahams 201*: NSW41769: Cobar. IX.1911. — *Andrews s.n.*: NSW41770: Broken Hill. IX.1918. — *Anonym.*: NSW41772: Wilcannia. VIII.1887. — *W. Bäuerlen 104*: MEL: Tarella. VIII.1887. — *J. L. Boorman*: NSW41771: Condobolin. IX.1906. — *G. Day s.n.*: MEL: Upper Darling River. 1878. — *Holding*: MEL: Junction of Murray and Darling Rivers. 1889. — *A. Morris (382)*: ADW11147, NSW41774: Lake's Grave. 4.IX.1920. — *G. V. Scammell*: SYD: Griffith. 28.VIII.1927.

VICTORIA: — *Anonym.*: MEL: Epping. 19.IX.1902. — *Anonym.*: MEL, W Acqu. 1889 No. 75248: Mount Korong. (14.X). — *W. R. Baker*: MEL: Jeparit. 9.X.1912. — *H. Bird 19*: MEL: Lake Boga, near Kerang. X.1903. — *St. E. D'Alton 5*: MEL: Black Range, Stawell. 1878. — *J. P. Eckert 114*: MEL: Wimmera. 1890. — *D. Kraehenbuehl 29*: AD95909054:

Field Naturalists' Reserve, Dimboola. 11.X.1958. — *F. Mueller*: MEL: Grassland on the Glenelg (River). X.1851. — *W. W. Watts 1242*: NSW41799: Wedderburn Distr. X.1918. — *H. B. Williamson*: BRI004776: Grampians. XI.1903. p.p. — *H. Worsely*: MEL: near Lake Hindmarsh. 1889.

TASMANIA: — *Stuart*: MEL: Tasmania. p.p.

SCOTLAND: — *J. Fraser*: K (photograph, drawings, and description of Kew specimen also preserved in AD under AD95728001, AD95834001): Calafoot, Galashiels. 19.VIII.1908. (*type of Millotia depauperata* Stapf).

Distribution and Ecology

Occurs from the Shark Bay district of Western Australia south and east through that State, over the entire southern region of South Australia and north through the Flinders Range and Olary Spur, through central and western Victoria and south-western and central New South Wales. There are also two collections from Tasmania (Fig. 10-1).

The species grows primarily in sandy situations, but has been frequently recorded in loamy and even hard rocky sandy soils; its habitat tolerance is apparently the widest of any species of *Millotia*. Flowering: September to November along the southern part of its range, and July to September (October) in the north.

Morphological Variation

M. myosotidifolia is a rather polymorphic species, with greatest variability in south-west Australia. Variation is most marked in the habit and indumentum, with specimens ranging between ± glabrous erect plants with a central stem leader and densely woolly or floccose ascending plants branched from the base. Moreover, erect plants tend to be larger in all parts: compare the specimens of *Anonym. 11*: AD95724011: Rottnest, and *Oldfield*: W Acqn. 1889 No. 36953: Murchison River. Eastern Australian plants are far more uniform, having in general an ascending habit and fairly dense woolly indumentum as exemplified by the specimens of *D. Kraehenbuehl 29*: AD95909054: Dimboola. *Tepper* (275): AD95903122, MEL: from Clarendon is a peculiarly depauperate form with ± sessile flower heads.

The type specimens of *M. glabra* Steetz and *M. robusta* Steetz were collected in south-west Australia; the former are typical of the glabrous, central stemmed forms of *M. myosotidifolia*, while the latter are large specimens of the woolly, basally branched forms. The type specimens of *M. myosotidifolia* actually fall between these extremes. Although Sonder (1853) treated *M. glabra* and *M. robusta* as varieties of *M. myosotidifolia*, variation between them is so continuous that they cannot be distinguished.

M. depauperata Stapf is clearly a depauperate specimen of *M. myosotidifolia* Fig. 9, D. In a footnote to the type description, Stapf says that the "species" was "no doubt accidentally introduced from Australia". It is most likely that seeds of *M. myosotidifolia* were introduced at Galashiels, which is a milling centre for wool, from an Australian wool clip. G. L. Davis (1952) has also recorded the introduction of *Calotis squamigera* C. T. White at Galashiels which doubtless occurred through similar circumstances.

2 **Millotia greevesii** F. v. Muell., Fragm. 3(1862)18. t.18; Benth., Fl. Austral. 3(1867)596; Tate, Trans. Roy. Soc. S. Austral. 3(1880)72 ?p.p.; F. v. Muell., Syst. Cens. Austral. Pl. (1882)82; Moore, Cens. Pl. N.S. Wales (1884)37. F. v. Muell., Sec. Syst. Cens. Austral. Pl. (1889)139; Tate, Trans. Roy. Soc.

S. Austral. 12(1889)100 ?p.p.; Bailey, Cat. Pl. Queensl. (1890)25; Tate, Handb. Fl. Extratrop. S. Austral. (1890) 119, 239 ?p.p.; Moore & Betche, Handb. Fl. N.S. Wales (1893)286; Bailey, Queensl. Fl. 3(1900)843; Dixon, Pl. N.S. Wales (1906)197; Bail., Compreh. Cat. Queensl. Pl. (1913)267; Sulman, Guide Wildfl. N.S. Wales 2(1914)83; Maid. & Betche, Cens. N.S. Wales Pl. (1916)201; Black, Fl. S. Austral. (1929)638 p.p.; Black, Fl. S. Austral. ed. 2, (1957)917 p.p.

TYPE: H. Beckler : K : Barrier Ranges.

The Kew specimen, possibly the only one extant and therefore the holotype, was seen from a photograph in CANB (Neg. No. Kew 1637, 10.12.1953).

Grey *herb*, sometimes virescent when young, (2)3-15(20) cm tall, (2)3-20(30) cm broad. *Indumentum* dense white lanuginose, with golden glandular pilose hairs intermingled on upper stems, upper leaves, peduncles and involucres in some forms. *Stems* (2)4-15(50), ascending or decumbent, slender. *Cotyledons* (4)5-6(7) mm long. *Leaves* narrow linear to ± filiform, (⅓)¾-2 (2½) cm long, hardly amplexicaul, becoming progressively shorter up the stem from the base. *Flower heads* (1)5-100(300). *Peduncles* less than 1 cm long and indistinct to 1-8 cm long and distinct. *Involucres* 4-6 mm long, of 7-18 uniseriate rarely ± biseriate slightly imbricate linear *bracts* with navicular midribs 1-3 x as broad as the straw-coloured margins and acute ± fimbriate *apices*. *Flower heads* with ca. 10-100 florets. *Corollas* funnel form, 2-3(3½) mm long, deflexed over involucre (peripheral corollas most deflexed), bright yellow, with the tube sometimes becoming reddish after anthesis; *corolla limbs* of 5 fully spreading acute lobes ½-⅘ mm long. *Stamens* 5, with tips prominently exserted beyond corolla limb; *anthers* with oblong *thecae* (½)⅗-⅘(1) mm long, the *connective tip* extending ⅕-⅖ mm beyond the theca; *pollen grain* diameter (15)18-20 (22) μ. *Style branches* 1-1⅒ mm long, with acute broadly dilated conical appendages at the *apices*. *Cypselae* papillate, linear to filiform, 3½-8 mm long, with central cypselae of head protruding to 3 mm above top of involucre and peripheral cypselae rarely longer than involucre, brownish to reddish black, the beak usually paler; *cypsela papillae* rather dense, obtuse, often larger on beak, brownish slightly transparent; *cypsela beaks* ½-4½ mm long, slightly compressed and distinctly demarcated. *Pappus* various, of ca (5)10-20 plumose *setae* ± ⅓ length of corolla, or of predominantly minute scales with rare solitary setae, or absent.

DISTRIBUTION AND ECOLOGY

Occurs through the south-central arid region of Australia, confined to sandy habitats which are so widespread through its area of occurrence that its distribution is ± continuous (Fig. 10-2).

subsp. **greevesii**

Habit decumbent to ascending. *Involucres* 5-5½(6) mm long. *Cypselae* (4)5-7(8) mm long; *beaks* (1)2-4(5) mm long; *central cypselae* of head protruding (½)1-2½(3) mm above top of involucre, with surrounding cypselae becoming progressively shorter to the *peripheral cypselae* which protrude up to 1 mm above top of involucre or not at all. *Pappus* of ca. (5)10-20 plumose setae, ¾-1½ mm long.

DISTRIBUTION

Confined to the region east of the Finke River (Central Australia) and Flinders Range (South Australia) to the arid plains of south-west Queensland and central New South Wales.

Fig. 2. *Millotia greevesii* F. v. Muell. var. *greevesii*. A, whole plant (Cleland; AD 95730073); B, involucral bract (Cleland: AD95730073); C, flower head just after anthesis (Cleland: AD95730073); D1, mature outer floret of flower head, D2, mature inner floret of flower head, D3, floret showing slight reduction of pappus (Cleland: AD95730073); E, mature cypselae showing stages of reduction of pappus (Menzel 45); F, whole style and androecium (Cleland: AD95730073).

var. greevesii

Habit ± decumbent, but often ascending, (2)4-7(10) cm tall, (2)5-20 (32) cm broad. *Peduncles* indistinct, rarely + 1 cm long, with cauline leaves (of decreasing length) right up to flower head. *Involucres* grey-white, the (7) 8-9(12) bracts covered with a dense white lanuginous indumentum which binds them into a seemingly connate involucre. *Heads* with (10)15-25(35) florets. *Central cypselae* of head (5½)6-7(8) mm long, beaks (2¼)2¾-3½(4) mm long; *peripheral cypselae* (4)4¾-5½(6) mm long, beaks (1)1¾-2¼(2½) mm long. *Pappus* of ca. (5)10-15(20) plumose *setae* which are sometimes conspicuously unequal in length (due to reduction) (Fig. 2).

Specimens Examined

South Australia. – *Anonym.* (*Herb. J. M. Black*): AD95911087: Yadlakeena (= Yadlakina Well). – *J. B. Cleland*: AD95730073: William Creek, 18.VIII.1930, 10.IX.1930. *Herb. O. E. Menzel 45*: AD95724020: Hergott Springs (= Marree). 1895. – *T. G. B. Osborn*: AD95724032: Curnamona. 24.VIII.1923.

Queensland: – *Wheeler*: MEL: Between Stokes Range and Coopers Creek.

New South Wales: – *Anonym. 38* (*Herb. J. G. O. Tepper 2046*): AD95833148: Culpaulin. VII.1893. – *Anonym.*: W Acqn. 1889 No. 71441: Barrier Ranges. (part of *type*?). – *Anonym. 44*: MEL: Momba. Mount Murchison. – *W. Bäuerlen 221*: MEL: Kooningbirry (= Kooruingbirry), IX.1887. – *N. C. Beadle*: SYD: Near Pooncarie. VII.1942.

Distribution and Ecology

Lake Eyre Basin and north and eastern margins of Flinders Range east and south to the Paroo and Darling Rivers (Fig. 10-2). Flowering: July-September (December).

var. **glandulosa** Schodde, var. nov.

Affinis var. *greevesii*, sed habitu altiore erectioreque (etsi semper a basi ramoso), pedunculis distinctis (1)2-5(8) cm longis sine foliis caulinis, numero maiore (7)10-15(18) bractearum involucralium, numero maiore (30)50-60 (80) florum per capitulum, et praecipue pilis glandulosis super bracteae involucrales, pedunculi, folia superaque, differt.

Typus: W. MacGillivray 1002: ADW s.n., BRI004770 (*holotypus*): Near Adavale. 28.VIII.1923.

Habit ascending, more upright than var. *greevesii* (3)9-15(17) cm tall. *Peduncles* distinct, (1)2-5(8) cm long, densely white woolly or predominantly golden glandular hairy under the flower heads, without cauline leaves but often with several virescent, glandular hairy *peduncle leaves* c. 2-5 mm long. *Involucres* virescent, the (7)10-15(18) bracts free with midribs golden glandular hairy and dense to sparse (rarely absent) white woolly hairs on margins of midribs. *Heads* with (30)50-60(80) florets. *Central cypselae* of head (5½) 6-7¾(8) mm long, beaks (3)3¾-4½(5) mm long; *peripheral cypselae* (3)4½-5½(6) mm long, beaks (1)2-3(3½) mm long. *Pappus* of (10)13-17(20) plumose setae of ± equal length (Fig. 3).

The golden glandular haired involucre is the principal character distinguishing this variety. The only previous reference to it has been made by Mueller and Tate (1896) when describing *Millotia kempei* var. *helmsii*.

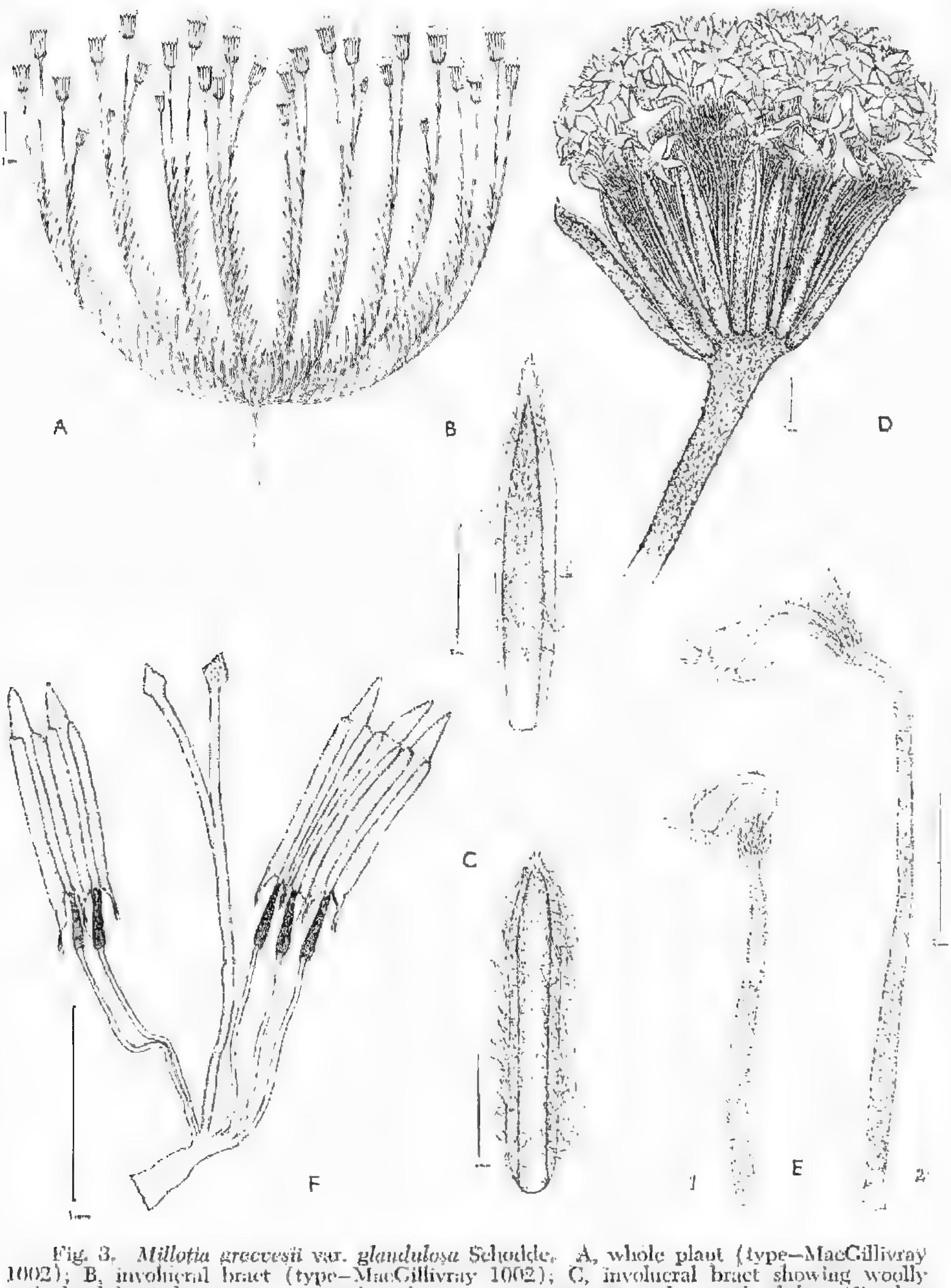

Fig. 3. *Millotia greevesii* var. *glandulosa* Schodde. A, whole plant (type–MacGillivray 1002); B, involucral bract (type–MacGillivray 1002); C, involucral bract showing woolly and glandular indumentum intermediate between var. *greevesii* and var. *glandulosa* (Betche: AD95727059); D, flower head with florets maturing after anthesis (type–MacGillivray 1002); E1, mature outer floret of flower head, E2, mature inner floret of flower head (type–MacGillivray 1002); F, whole style and androecium (type–MacGillivray 1002).

SPECIMENS EXAMINED

QUEENSLAND: — *Bucknell*: NSW41763: Hungerford. IX.1910. — *S. L. Everist 1643*: BRI004768: Gilruth Plains, near Cunnamulla. 17.IX.1938. — *W. MacGillivray 1002*: ADW s.n., BRI004770: Near Adavale. 28.VIII.1923. (*type*). — *J. Wend 698*: BRI004769: St. George. X.1894.

NEW SOUTH WALES — *E. Betche*: AD95727059 ex NSW41764A: Paroo River District. IX.1900. — *J. T. Waterhouse*: AD95922010: Invernay (near Collarenebri). 24.IX.1951. — *W. Campbell*: NSW41764B: Bourke. III.1893.

DISTRIBUTION AND ECOLOGY

East and north of the Paroo River (New South Wales) to St. George and Adavale (Queensland) (Fig. 10-2). Flowering: August to October, with one record in March.

subsp. **kempei** (F. v. Muell.) Schodde, comb. et stat. nov.

Millotia kempei F. v. Muell., South Sci. Rec. 2(1882)2; F. v. Muell., Syst. Cens. Austral. Pl. (1882)82; Tate, Trans. Roy. Soc. S. Austral. 5(1882)87; F. v. Muell., Sec. Syst. Cens. Austral. P. (1889)138; Tate, Trans. Roy. Soc. S. Austral. 12(1889)100; Tate, Handb. Fl. Extratrop. S. Austral. (1890)119, 239; Tate, Rep. Horn Exped. 3(1896)166; Gardner, Enum. Pl. Austral. Occ. (1931)134.

TYPE: H. Kempe (238); MEL (*lectotype*), NSW41759: (Prope) Finke River. IX.1880.

Habit ascending, very rarely decumbent or erect. *Involucres* (3¾)4-5(6) mm long. *Cypselae* (3½)3¾-5(6½) mm long, beaks (½)¾-1½(2¾) mm long; *central cypselae* of head ± equal in length to involucre, the beaks rarely protruding up to 1 mm above it, *peripheral cypselae* little shorter than central cypselae and exceptionally longer than involucre. Pappus absent, or of predominantly minute scales with rare plumose setae ca. ½-1 mm long.

DISTRIBUTION

Confined to the region west of the Finke River and northern Flinders Range to the Nullarbor Plain and Victoria Desert (Western Australia).

var. **kempei**

Habit ascending, rarely ± decumbent. *Peduncles* ± indistinct, rarely up to 2 cm long, often with cauline leaves (of decreasing length) right up to flower head. *Involucres* grey-white, 4½-6 mm long, the (7)9-12(15) bracts covered with a white lanuginose indumentum which may bind them into a seemingly connate involucre. *Heads* with ca. 20-30 florets. *Cypselae* 4-6½ mm long, beaks ca. ¾-2¾ mm long. *Pappus* of minute scales and rare plumose setae, more rarely entirely absent (Fig. 4).

SPECIMENS EXAMINED

CENTRAL AUSTRALIA: — *H. Kempe (238)*: MEL, NSW41759: (Prope) Finke River. IX.1880. (*type* of *Millotia kempei* F. v. Muell.).

SOUTH AUSTRALIA: — *Anonym. 14*: MEL: Peake. — *Herb. O. E. Menzel 45*: AD95724020: Hergott Springs (= Marree). 1895.

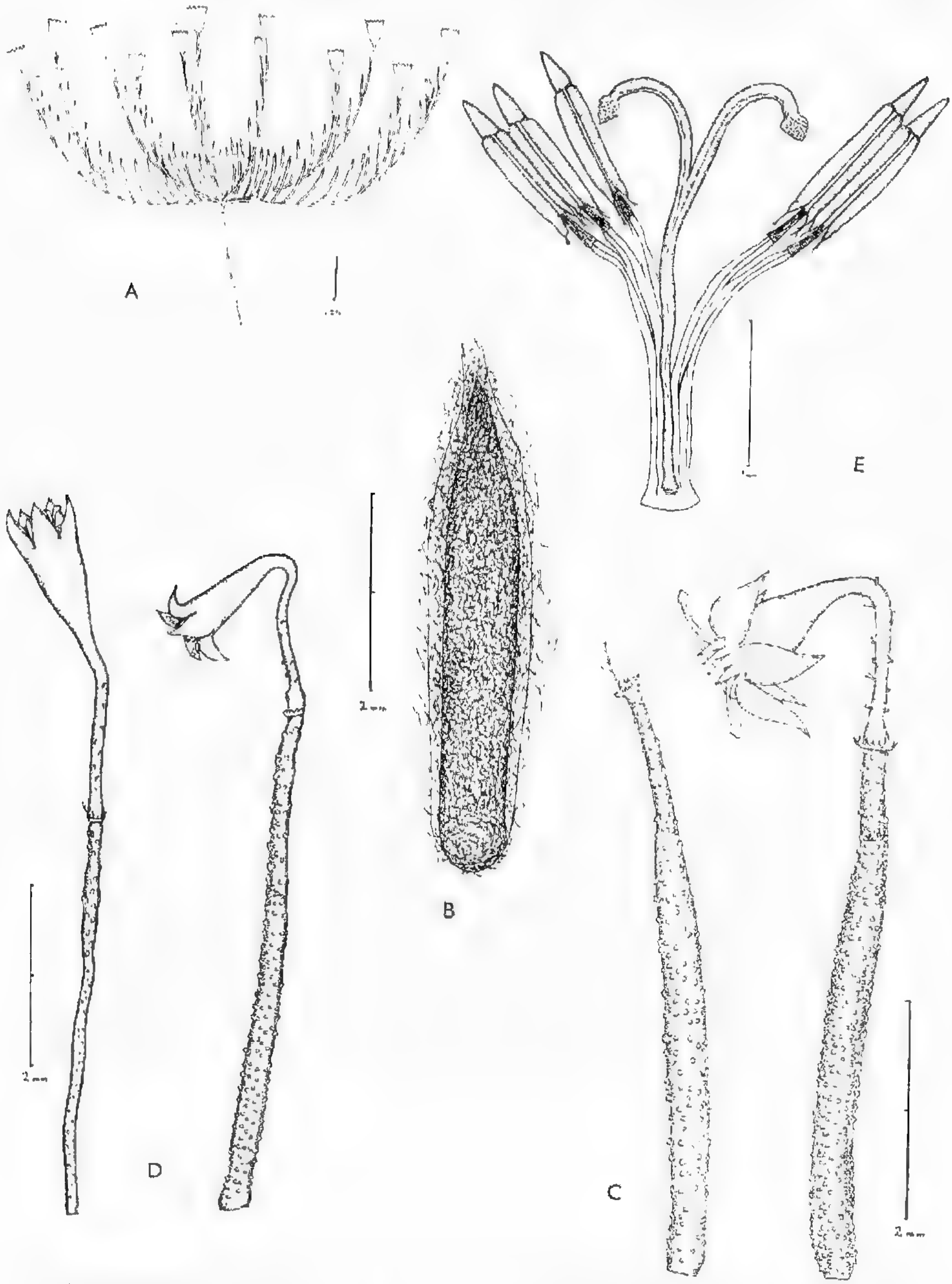

Fig. 4. *Millotia greevesii* var. *kempei* (F. v. Muell.) Schodde. A, whole plant (Menzel 45); B, involucral bract (type—Kempe: NSW41759); C, mature floret and cypselae showing rudimentary pappus (type—Kempe: NSW41759); D, florets showing extreme stages of pappus reduction (Menzel 45); E, whole style and androecium (type—Kempe: NSW41759).

Distribution and Ecology

Found along the western margins of the Lake Eyre Basin, between the Finke River and north-west Flinders Range (Fig. 10.2). Flowering: September.

Rare in herbaria, the above cited collections comprising the only specimens seen.

var. **helmsii** (F. v. Muell. & Tate) Schodde, comb. nov.

Millotia kempei var. *helmsii* F. v. Muell. & Tate, Trans. Roy. Soc. S. Austral. 16(1896)368; Black, Trans. Roy. Soc. S. Austral. 43(1919)43; Black, Fl. S. Austral. (1929)638, pl. 51(1-2); Black, Fl. S. Austral. ed. 2, (1957)917, f. 1197(1-2).

Toxanthes whitei Black, Trans. Roy. Soc. S. Austral. 39(1915)840, pl. 69. "Toxanthus whitei".

Type: R. Helms: AD95731002, AD95732063, MEL (*lectotype* and *isolectotype*), NSW41761: Between Birksgate and Blyth Ranges (Camp 22, Elder Exploring Expedition). 16.VII.1891.

Habit ascending, exceptionally erect. *Peduncles* ± distinct, ½-5 cm long, golden glandular and white woolly hairy, usually with several glandular hairy *peduncle leaves* which grade in increasing length into the cauline leaves below. *Involucres virescent*, ca. 4-5 mm long, the (10)12-16(18) bracts free with midribs golden glandular hairy and dense to absent white woolly hairs on margins of midribs. *Heads* with (20)30-70(100) florets. *Cypselae* 3-5½ mm, beaks ca. ½-1½ mm long. *Pappus* absent, exceptionally with rare scales or plumose setae present (Fig. 5).

Specimens Examined

Western Australia: — *R. Helms*: AD95731003: Victoria Desert (Camp 54, Elder Exploring Expedition). 17.IX.1891.

Central Australia: — *H. Basedow*: BRI004771, NSW41762, PERTH s.n.: Finke River District (S. Australian Medical Relief Expedition). 1919. — *R. Schodde 390*: AD95807233: Central west base of Ayers Rock. 30.VIII.1957.

South Australia: — *Anonym.* (*Herb. R. Tate*): AD95910047: Idyaka sandhills. 2.IX.1883. — *J. B. Cleland*: AD95730071: Ooldea Soak. 20.VIII.1939. — *R. Helms*: AD95731002, AD95732063, MEL (2 sheets), NSW41761: Between Birksgate and Blyth Ranges (Camp 22, Elder Exploring Expedition). 16.VII.1891 (*type* of *Millotia kempei* var. *helmsii* F. v. Muell. & Tate). — *T. R. N. Lothian L/768a/54*: AD95918015: Rock hole, De Rose Hill Station. 6.VIII.1954. — *D. J. E. Whibley 680*: AD96051015: Maralinga—Sandhills Rifle Range — ca. 55 km north of Watson. 18.IX.1960. — *S. A. White 107* (*Herb. J. M. Black*): AD95731004: Claypan between Flat Rock Hole and Morrilyanna (= Moorilyanna) Native Well. 26.VII.1914 (*holotype* of *Toxanthes whitei* Black). — *S. A. White, 1, 3 4*: AD95833147, MEL, NSW41760: Everard Range. 8.VIII.1914 (*paratype* of *Toxanthes whitei* Black). — *P. G. Wilson 1840*: AD96139106: ca. 22 km east of Ooldea. 24.IX.1960.

Distribution and Ecology

From the Finke River and northern Flinders Range south and west to the Nullarbor Plain and Victoria Desert (Fig. 10-2). Flowering: July to September.

Aboriginal name: "Tjuderura" (Ooldea, fide J. B. Cleland).

Black published *Toxanthus whitei* in ignorance of *Millotia kempei* var. *helmsii* F. v. Muell. & Tate, an oversight he himself later realized and corrected (1919).

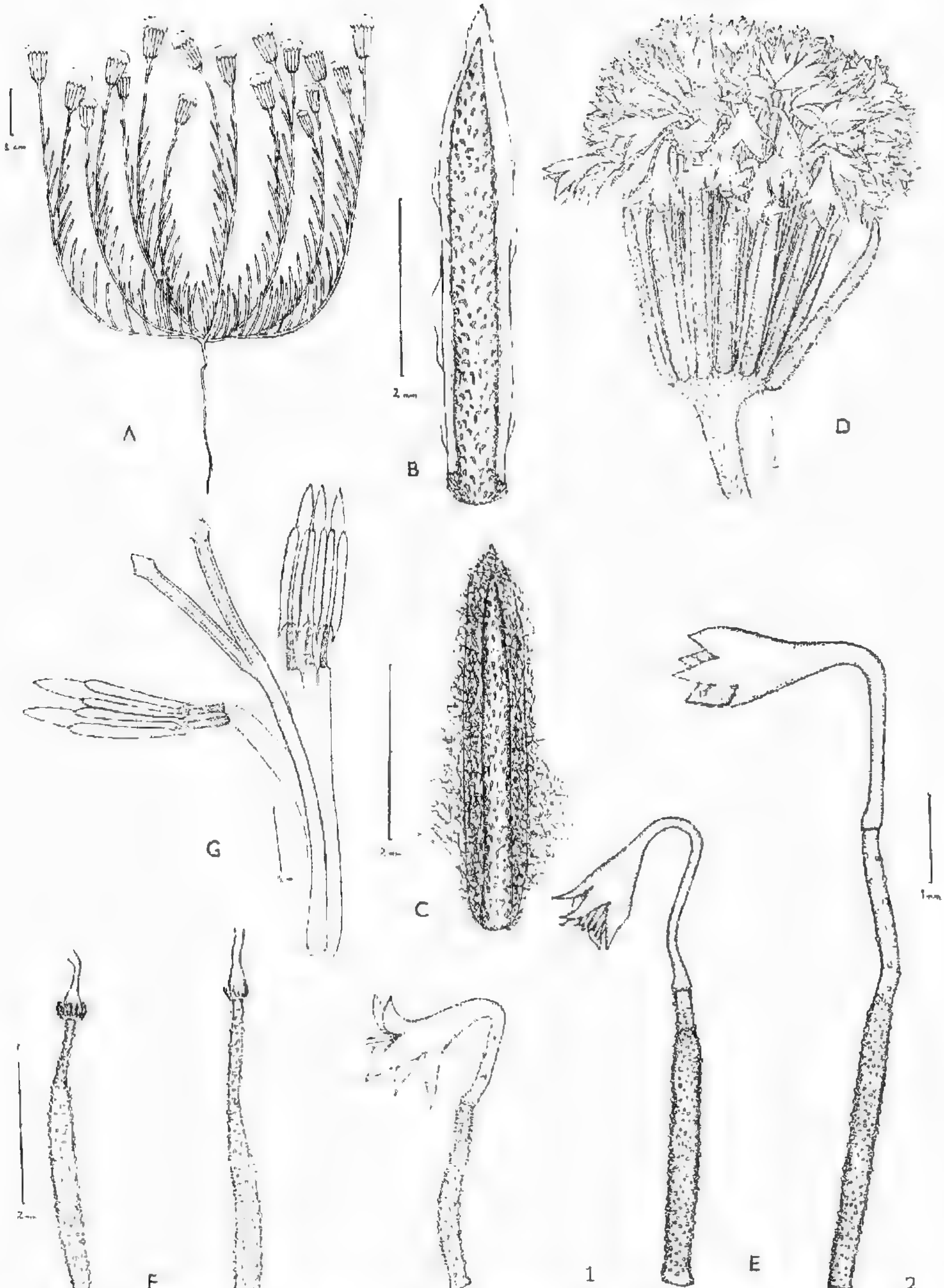

Fig. 5. *Millotia greevesii* var. *helmsii* (F. v. Muell and Tate) Schodde. A, whole plant (Wilson 1810); B, involucral bract (Wilson 1840); C, involucral bract showing a woolly and glandular indumentum intermediate between var. *helmsii* and var. *kempei* (Lothian L/768a/54); D, flower head soon after anthesis (Wilson 1840); E1, mature outer floret of flower head, E2, mature inner floret of flower head (Wilson 1810); F, mature cypselae showing presence of rudimentary pappus in varying degrees (Lothian L/768a/54); G, whole style and androecium just after anthesis (Wilson 1818).

MORPHOLOGICAL VARIATION IN *Millotia greevesii*

Variation in the pappus, a character normally so stable in the species of Compositae, is undoubtedly a most striking feature of this species and has led Mueller (1882) and later authors to distinguish the apappose forms as a distinct species, *M. kempei*. Other characters showing change are the habit, involucral indumentum, and the length of the cypselae beaks.

All variations are clinal, giving rise to the following patterns,

(1) in the pappus: Along the western margins of the Lake Eyre basin there is a relatively sudden transition from the fully pappose forms of the east to the apappose forms of the west. Specimens in the collection of *O. E. Menzel* 45 from Hergott Springs (AD95724020) show various stages in the reduction of pappus, and type material of *M. kempei*, from farther north, possesses a rudimentary pappus of scales and occasional solitary setae, contrary to Mueller's original description. All traces of pappus are absent in specimens of the glandular-haired var. *helmsii* except in two easterly collections — *S. A. White* 4: MEL; Everard Range and *T. R. N. Lothian L/768a/54*: AD95918015: De Rose Hill Station — in which the pappus is of scales;

(2) in the cypselae beaks: From east and north-east to west and south-west, there is a gradual reduction in the length of the cypselae beaks. Significantly, it becomes most marked along the western margins of the Lake Eyre basin, and together with the change in pappus provides the basis for separating the two sub-species, *greevesii* and *kempei*;

(3) in the involucral indumentum: Forms in the east and north-east, and in the west and south-west areas have glandular-haired involucres; those in the central area, which have woolly-haired involucres, grade on either side into the glandular-haired forms. Examples of intermediates are from the Paroo River District (*E. Betche*: AD95727059) on the east, and Everard Range (*S. A. White 1, 3, 4*: AD95833147, MEL, NSW41760), De Rose Hill Station (*T. R. N. Lothian L/768a/54*: AD95948015), and Ayers Rock (*R. Schodde 390*: AD95807233) on the west. Forms with woolly involucres possess fewer florets per head. The two glandular-haired groups are distinguished as distinct varieties:

(4) in the habit: There is a gradual north to south change from an ascending to a ± decumbent habit in those centrally located forms of *M. greevesii* with woolly involucres. Both glandular-haired varieties possess a consistently ascending habit.

3. **Millotia macrocarpa** Schodde, sp. nov.

Millotia greevesii (non F. v. Muell.) Tate, Trans. Roy. Soc. S. Austral. 3(1880)72 ?p.p.; Tate, Trans. Roy. Soc. S. Austral. 12(1889)100 ?p.p.; Tate, Handb. Fl. Extratrop. S. Austral. (1890)119, 239 ?p.p.; Black, Fl. S. Austral. (1929)638 p.p.; Black, Fl. S. Austral. ed. 2, (1957)917 p.p.

Annua incana, 2-8 cm alta. *Indumentum* conferte lanuginosum, sine pilis glandulosis. *Caules* ascendentes diffusi, vel interdum erecti neque a basi ramosi. *Cotyledones* 5-7 mm longae. *Folia* anguste linearia, ½-2 cm longa, vix amplexicaulia. Bracteae involucrales 6-9, lineares, 6½-8½ mm longae, sine cacuminibus rubidis; costae mediae bractearum naviculares, conferte laneae, ± 2 x margines scariosae abdite latitudine. *Flores* 15-25 raro plures per capitulum. *Corollae* anguste cyathiformes, 2-2½ mm longae, ± deflexae, tribus vel interdum quattuor lobis paene obtusis, ± leviter expanditis sed interdum erectis, ± ³⁄₁₀ mm longis.

Antherae thecae ellipticae, ± 0·4 mm longae. *Styli rami* ± ⅜ mm longi, apice acuti et leviter dilatati. *Cypselae* muricatae filiformes, omnino rubidae, (7)± 10(12) mm longae, et (1)2-3(4) mm supra involucro extensae; *rostra cypselarum* 3½-7½ mm longa, leviter compressa. *Pappisetae* semi-plumosae, erectae vel leviter expanditae, ⅝-¾ x corollae longitudine.

Affinis *M. tenuifoliae*, sed habitu, indumento eglanduloso, corolla deflexa valde trilobata, longitudine cypselarum, et pappi setis semi-plumosis erectioribusque praesertim differt.

TYPUS: P. G. Wilson 596: AD95903126 (*holotypus*): North Gawler Range, south-west of Lake Gairdner. 13 km south of Moonaree Head Station, near the main road between Moonaree H.S. and the Nonning-Yardea road. Growing in reddish sand. 18.X.1958.

Grey *herb*, 2-8 cm tall. *Indumentum* dense white lanuginose only. Stems 1-10, usually ascending, rarely simple or erect, slender. Cotyledons 5-7 mm long. Leaves narrow linear, ½-2 cm long, hardly amplexicaul, becoming progressively shorter up the stem from the base. *Flower heads* (1)2-15(30), on short *peduncles* up to 1½ cm long. *Involucres* 6½-8½ mm long, of 6-9 uniseriate linear *bracts* with lanate navicular midribs ± 2 x as broad as the concealed straw-coloured margins and acute finely fimbriate *apices*. *Flower heads* with ca. 15-25 florets, slightly honey-scented. *Corollas* narrow cyathiform, 2-2½ mm long, slightly deflexed over involucre (especially the peripheral corollas), cream, with the *tube* often becoming dark reddish-purple after anthesis; *corolla limbs* of 3, sometimes 4, ± obtuse slightly expanded lobes ca. ³⁄₁₀ mm long. *Stamens* 3-4, sometimes 4 in a 3-lobed corolla, almost entirely enclosed; *anthers* with elliptic *thecae* ± ⅖ mm long, the *connective tip* extending ⅕ mm beyond the theca; pollen grain diameter (17)22-25(28) μ. *Style branches* ⅜ mm long, with narrow obtuse, slightly dilated *apices*. *Cypselae* muricate, filiform, (7)±10(12) mm long, prtruding (1)2-3(4) mm above top of involucre, entirely reddish-black, rather densely and evenly covered with slightly transparent *papillae* which are identical in shape with those of *M. tenuifolia* and larger on the beak; *cypsela beaks* 3½-7½ mm long, slightly compressed and distinctly demarcated. Pappus of ca. (12)15-20(25) erect or slightly spreading semi-plumose *setae* ⅝-⅘ length of corolla (Fig. 6).

SPECIMENS EXAMINED

SOUTH AUSTRALIA: — *Anonym.* (*Herb. R. Tate*): AD95724022: Blanchetown. VIII.1881. — *Anonym.* (*Herb. R. Tate*): AD95724029. MEL: Yadlacena (= Yadlakina) Soakage. Lake Torrens Plain. 18.VIII.1883. — *T.G.B.O.* (= *T. G. B. Osborn*): AD95731022: Koonamore. 27.VIII.1923. — *P. G. Wilson 536*: AD95903128: Gawler Range. 2 km west of Peterby Tanks. 16.X.1958. — *P. G. Wilson 596*: AD95903126: North Gawler Range, south-west of Lake Gairdner. 13 km south of Moonaree Head Station. 18.X.1958 (*type*).

VICTORIA: — *A. C. Beauglehole 1098*: Herb. Beauglehole: Kulkyne National Forest X.1948.

DISTRIBUTION AND ECOLOGY

Although it is rarely represented in herbarium collections, *M. macrocarpa* apparently occurs through the semi-arid parts of South Australia from the Gawler Range, around the margins of the Flinders Range to the northern Murray Mallee, and extending into north-west Victoria. Geographically, it overlaps the distribution of all other species of *Millotia* (Fig. 11-3).

Grows in open red sandy situations. Flowering: August to October (not later).

Fig. 6. *Millotia macrocarpa* Schodde. A, whole plant (type—Wilson 596); B, involucral bract from mature involucre (type—Wilson 596); C, flower head at anthesis (Tate: AD95724029); D, mature florets (type—Wilson 596); E, whole style and androecium (type—Wilson 596).

MORPHOLOGICAL VARIATION

Even though the series examined is too small to permit generalisations on variability, specimens in extant collections, which are from widely separated localities, are notably uniform in all parts.

4. **Millotia tenuifolia** Cass., Ann. Sci. Nat. 17(1829)31, 417; Cass., Dict. Sci. Nat. 60(1830)592; DC., Prodr. 6(1838)161; Steetz in Lehm., Pl. Preiss. 1(1845) 456; Walp. Rep. 6(1846-7)234; Sonder, Linnaea 25(1853)502; Hannaford, Notes Fl. & Faun. Vict. (1856)61; Hook. f., Fl. Tasm. 1(1856)209 p.p., Benth., Fl. Austral. 3(1867)596 p.p.; Johnston, Memorand. Tasm. Botanists (1874)24 ?p.p.; Spicer, Handb. Pl. Tasm. (1878)27, 117 p.p.; F. v. Muell., Trans. Roy. Soc. Tasm., Rep. for 1878(1879)17 p.p.; Tate, Trans. Roy. Soc. S. Austral. 3(1880)72 p.p.; F. v. Muell., Syst. Cens. Austral. Pl. (1882)82 p.p.; Moore, Cens. Pl. N.S. Wales (1884)37 p.p.; F. v. Muell., Key Syst. Vict. Pl. 2(1885)34 p.p.; F. v. Muell., *ibid.* (1887-8)337 p.p.; F. v. Muell., Sec. Syst. Cens. Austral. Pl. 1(1889)138 p.p.; Tate, Handb. Fl. Extratrop. S. Austral. (1890)119, 239 p.p.; Moore & Betche, Handb. Fl. N.S. Wales (1893)286 p.p.; Rodway, Tasm. Fl. (1903)84 ?p.p.; Diels & Pritzel, Fragm. Phytograph. Austral. occ. (1905)616 ?p.p.; Dixon, Pl. N.S. Wales (1906)197 p.p.; Sulman, Guide Wildfl. N.S. Wales 2(1914)83 ?p.p.; Maid. & Betche, Cens. N.S. Wales Pl. (1916)201 p.p., F.N. Club Vict. Cens. Pl. Vict. (1923) 67 p.p.; Cleland & Black, Trans. Roy. Soc. S. Austral. 51(1927)59 p.p.; Black, Fl. S. Austral. (1929)638, f.291 p.p.; Ewart, Fl. Vict. (1931)1139 p.p.; Gardner, Enum. Pl. Austral. Occ. (1931)134 ?p.p.; Black, Fl. S. Austral. ed. 2, (1957)917, f.1215 p.p.

Millotia hispidula Gandoger, Bull. Soc. Bot. France 65(1918)45; Gardner, Enum. Pl. Austral. Occ. (1931)134.

TYPE: D'Urville; P (*lectotype*): Port du Roi George (= King George Sound).

Virescent *herb*, becoming greyish only ± after seed maturation, (½)2-10 (14) cm tall. Vegetative parts with aromatic odour. *Indumentum* of white woolly and pale golden glandular-pilose hairs, the latter most prominent on young parts and longer than those of *M. greevesii*. *Stems* 1-5(20), erect and branched from near the base, rarely ascending or simple, slender. *Cotyledons* 2-5 (6) mm long, often strongly recurved. *Leaves* narrow linear to linear, exceptionally becoming oblanceolate, (½)¾-2(2½) cm long, 1-3(5) mm broad (at the widest part), hardly amplexicaul, relatively dense. *Flower heads* 1-15 (± 100). *Peduncles* (¼)1-4(8) cm long raising the involucre (0)¾-3(6) cm above the tops of cauline leaves, ± slender. *Involucres* (3)4½-7(8) mm long, of (5)8-14(20) ± uniseriate hardly imbricate linear to oblong *bracts* with navicular midribs ± 1-3 x as broad as the straw-coloured rarely red-tinted margins; *bract apices* acute to attenuate, fimbriate, sometimes red-purple. *Flower heads* with ca. (5)10-40(65) florets. *Corollas* tubular, (1¾)2¼-3(4) mm long, ± erect, rarely deflexed, lemon yellow (?white in Tasmania), with the tube becoming deep purplish-red after anthesis; *corolla limbs* of 4 (exceptionally 3 or 5) ± erect narrow obtuse lobes (⅕)¼-3/10(⅖) mm long. *Stamens* 4 (exceptionally 3 or 5), ± entirely enclosed; *anthers* with elliptic *thecae* (⅕)3/10-⅖(½) mm long, the *connective tip* extending (1/10)⅕-¼(3/10) mm beyond the theca; *pollen grain* diameter 20-25 μ. *Style branches* (½)⅔-¾(1) mm long, with narrow obtuse hardly dilated *apices*. *Cypselae* muricate, linear-clavate, (3)4-6(7½) mm long, the apices ± level with top of involucre, reddish-brown to reddish-black, the beak often conspicuously paler; *cypsela papillae* ± dense, evenly dis-

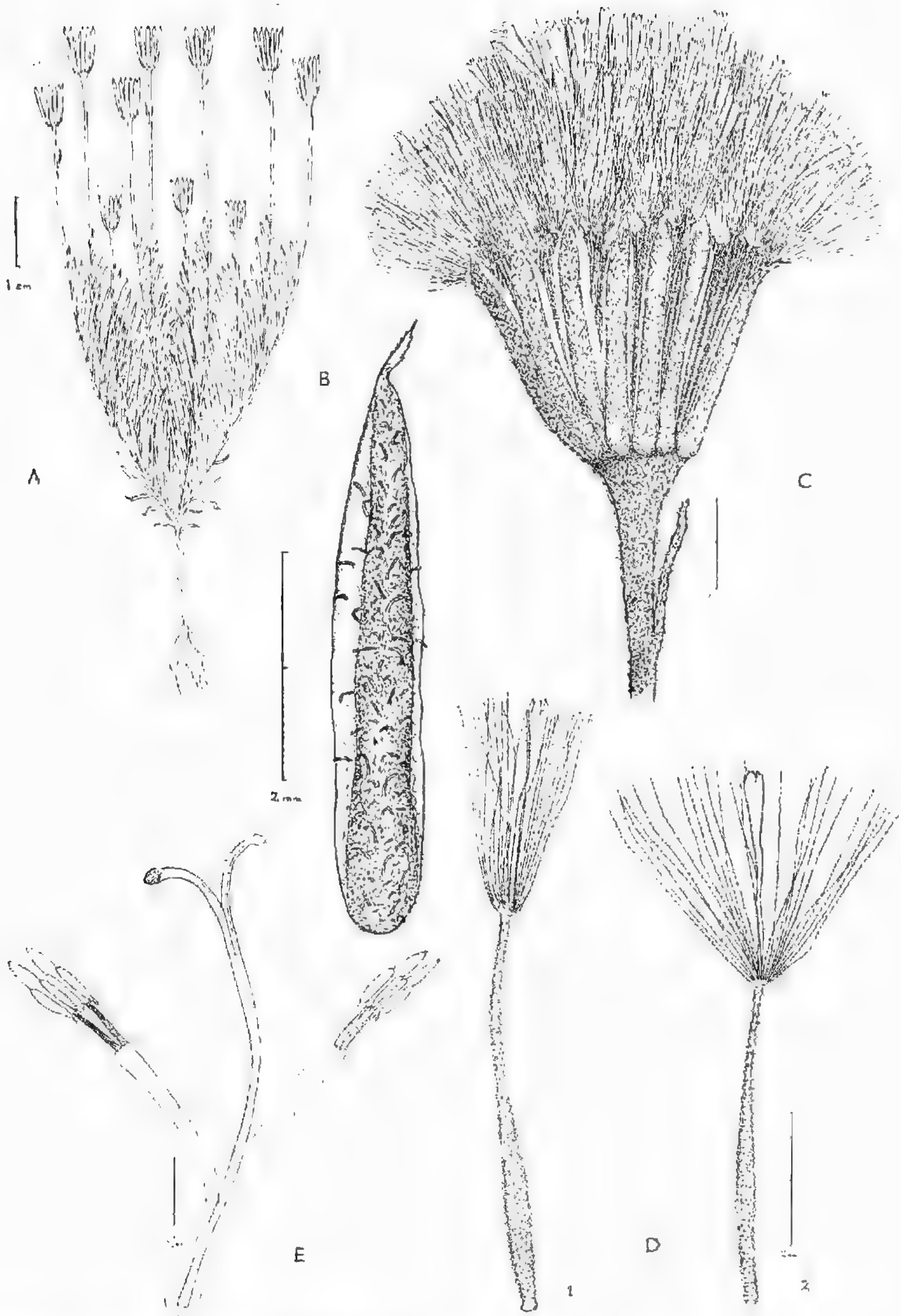

Fig. 7. *Millotia tenuifolia* Cass. var. *tenuifolia*. A, whole plant (Schodde 932); B, involucral bract (type—D'Urville: P); C, flower head with maturing cypselae (Schodde 932); D, florets with maturing cypselae (1 = Schodde 1015, and 2 = Schodde 932); E, whole style and androecium (Schodde 932).

tributed over cypsela, ± acute conical, ± larger on beak, transparent to whitish translucent; *cypsela beaks* (⅔)1½-2½(3½) mm long, not compressed, merging gradually into ovular region. *Pappus* of (19)20-30(35) + ascending spreading fine barbate setae which are ± slightly longer than corolla and evenly and relatively sparingly toothed to the apices, and rarely shorter or reduced to scales.

Distribution and Ecology

Occurs in the south-west of Western Australia east to Esperance, and in south-eastern Australia from Eyre Peninsula and the Flinders Range south and east through the southern Murray Mallee, across central and southern Victoria to the Australian Alps and west Gippsland. Fairly widespread in Tasmania. Gardner's collection from Wiluna is anomalous (Fig. 11-4).

Grows in a moister habitat than any other species of *Millotia*, on infertile grey rarely reddish sands — although occasionally recorded on clayey or stony leached soils — and is generally associated with a heathy or sclerophyllous vegetation. Flowering: September to December.

var. tenuifolia

Herb (½)3-10(14) cm tall with 1-15 (± 100) flower *heads*, ± erect *corollas* and *pappus setae* ± as long as or slightly longer than corolla (Fig. 7).

Specimens Examined

Western Australia: — *Anonym.*: P: Port du Roi Georges (= King George Sound). — *Brooke*: MEL: Near Israelite Bay. XII.1884. — *N. T. Burbidge 2373*: BRI004773, CANB 14452: Badjarning Hill, west of Wagin. 10.IX.1947 — *Dempster*: MEL: Between Esperance Bay & Fraser's Range. 1876. — *D'Urville*: P: Port du Roi George (= King George Sound) (*type* of *M. tenuifolia* Cass.). — *A. Eaton*: MEL (2 sheets): E. (= east) of York. 1889. p.p. — *Hj. Eichler 16138*: AD96009028: Ca. 10½ km south-east of Donnybrook near Nowlands. 3.IX.1959. — *W. V. Fitzgerald*: NSW41785: Boulder. IX.1898. p.p. — *C. A. Gardner B 559, 560*: PERTH s.n.: ?Near Wiluna. VIII.1931. p.p. — *Heal*: MEL: E. (= east) sources of Swan Riv(er). 1889. p.p. — *Merrall*: MEL: Yilgarn. 1892. — *A. Morrison*: LY: Kelmscott, Canning River. 10.IX.1898. p.p. (*type* of *M. hispidula* Gdgr.). — *Preiss 68*; HBG, MEL (2 sheets), P, W. Acqu. 1889 No. 130457, W s.n.: Melville Hill, Plantagenet. (Swan River Colony). 3.X.1840. — *R. D. Royce 1207*: PERTH I. 1600/44: 6 miles east of Ballidu. 9.IX.1946. p.p.

South Australia: — *H.W.A.* (= *H. W. Andrew*): AD95731026; Ashbourne. 6.IX.1919. — *Anonym.* (*Herb. J. M. Black*): AD95731020: Beetaloo. XII.1908. p.p. — *Anonym.* (*Herb. J. M. Black*): AD95731023: Karoonda. 5.X.1915. p.p. — *Anonym.* (*Herb. R. Tate*): AD95724014: Wirrabara. X.1882. — *A. Barton*: AD95807068: 2 miles north-east of Victor Harbour. 13.X.1957. — *Hj. Eichler 12766*: AD95717001: Gammon Ranges. North Tusk. 19.IX.1956. — *Hj. Eichler 13941*: AD95750023: Southern Yorke Peninsula. Ca. 8 km south of Corny Point. 25.IX.1957. — *E. H. Ising 1090*: AD95817015: Moolooloo Station. X.1916. — *E. H. Ising s.n.*; AD95817020: Warren Reservoir. 10.X.1923. — *E. H. Ising s.n.*: AD 95817012; Craters. 14.X.1930. — *E. H. Ising s.n.*: AD95817009: Arno Bay. 27.VIII.1935. *E. H. Ising s.n.*: AD95833165: Gawler Rge. (= Range). 13.IX.1938. — *E. H. Ising s.n.*: AD95833163: Mt. Wudinna. 29.IX.1939. — *C. W. Johns 4*: AD95731010: Wudinna. p.p. — *F. Mueller*: MEL: Bugle Range. Lofty Ranges. X.1848. p.p. — *R. Schodde 503*: AD 95807169: Ca. 11 km north-west of Gawler. 29.IX.1957. — *R. Schodde 509*: AD95807098: Golden Grove, ca. 16 km north-east of Adelaide. 5.X.1957. — *R. Schodde 914*: AD95908093: East side of Chauncey's Line-Monarto South road, ca. 3·1 km north of the junction of Chauncey's Line and the Chauncey's Line-Monarto South road. 4.X.1958. — *R. Schodde 932*: AD95908082: Ca. 2 km north of the junction of Chauncey's Line and the Monarto South to Chauncey's Line road. 4.X.1958. p.p. — *R. L. Specht*: AD: Dark Island Heath, 10 miles NNE (of) Keith. IX.1952. — *D. J. E. Whibley 328*: AD95909046: Marble Range. 7 miles along Warrow-Edillilie road. 10.X.1958. — *L. D. Williams 3*: AD95909050: Meningie. 7.X.1958. — *P. G. Wilson 91*: AD95909095: Whyalla-Cowell road, c. 47 km south of Whyalla. 1.X.1958. — *P. G. Wilson 187*: AD95909096: Whyalla-Kimba road, c. 74 km west of

Whyalla. 3.X.1958. — *P. G. Wilson 333b*: AD95915022: Stamford Hill, c. 8 km south-east of Port Lincoln. 8.X.1958. — *P. G. Wilson 506*: AD95909097: Gawler Ranges; Yandinga Falls, c. 32 km north of Minnipa. 16.X.1958. — *P. G. Wilson 894*: AD95908171: Kangaroo Island. Near Birchmore Lagoon, 21 km south-west of Kingscote. 13.XI.1958. — *P. G. Wilson 2126*: AD96201145: Ca. 97 km north of Bordertown on Pinnaroo-Bordertown road. 30.VIII.1961. p.p.

New South Wales: — *Anonym.*: MEL: Near base of Mt. Kosciusko. X.1887. — *E. J. McBarron 1996 (bis)*: NSW41768: Monument Hill, Albury. 12.IX.1948.

Victoria: — *Anonym.* (?F. Mueller): MEL: Seymour. — *W. R. Baker*: MEL: Jeparit. 9.X.1912. — *A. W. Brotherton*: MEL: Loddon River. 1894. — *C. French*: MEL (2 sheets): N.W. (= north west) of Lake Albacutya. IX.1887. — *C. French jr.*: MEL: Near Dandenong Creek. 1892. — *C. Green 89*: MEL: Ararat Plains. — *D. Sullivan 39*: MEL: Moyston. X.1872. — *C. S. Sutton*: MEL: Bendigo. 1923. — *Tadgell*: MEL: Beaumaris. XI.1909. — *H. B. Williamson s.n.*: BRI004776: Grampians. XI.1903. p.p. — *W. B. Wilson 5*: MEL (2 sheets): Near Geelong. 1885.

Tasmania: — *E. Atkinson 147*: HO H450 5: Huon road. 14.XI.1931. — *J. Bufton 27*: MEL: Port Arthur. 1892. — *A. V. Giblin*: HO H450 3: G. (= Great) Lake. — *R. C. Gunn 164*: HO H450 1, NSW41806, NSW41807: Epping Forest. 17.X.1842, Glen Leith. 23,24.X.1840. 1833. — *J. Milligan 1036*: HO H450 2, MEL (2 sheets), NSW41808: Killi(e)-crankie-Flinders Island. 4.X.1847. — *L. Rodway*: NSW41809: Near St. Helen's Heads. IX.1892. — *E. Rodway*: CANB8636, HO H450 7: Mt. Fa(u)lkener. X.1929. — *A. Simpson*: BRI004775: Near Launceston.

Distribution and Ecology

Distribution and ecology as for the species.

var. **nudescens** Schodde, var. nov.

Affinis varietatis *tenuifoliae*, sed habito ± minore, maturitate praecociore florum cypselarumque, corollis ± deflexis, et pappo reducto differt.

Types: R. Schodde 914a: AD95908093 (*holotypus*): South-west Murray Mallee. East side of the Chauncey's Line-Monarto South road, ca. 3·1 km north of the junction of Chauncey's Line and the Chauncey's Line-Monarto South road, which is ca. 19 km south-west of Murray Bridge. Growing on grey sand. Corollas lemon. 4.X.1958.

Erect virescent to grey *herb*, differing from var. *tenuifolia* in its frequently smaller size, being (¾)1½-6(6½) cm tall with 1-10(± 40) *flower heads*, the relatively earlier maturation (by several days to about a week) of its florets and cypselae, its ± deflexed *corollas*, and its reduced *pappus* which varies from a ring of 20-30(40) dentate setae of unequal length ± ⅔ length of corolla to ± 5 unequal setae in number, or to a ring of minute scales in size (Fig. 8).

The reduced pappus is the principal distinguishing character of this variety.

Specimens Examined

South Australia: — *Anonym.* (*Herb. J. M. Black*): AD95731023: Karoonda. 5.X.1915. p.p. — *E. H. Ising s.n.*: AD95909057: Ca. 2 km west of Murray Bridge. 9.X.1958. — *R. Schodde 493*: AD95807142: Field Naturalists' Society Sanctuary at Chauncey's Line. 14.IX.1957. p.p. — *R. Schodde 859*: AD95908174: Chauncey's Line, ca. 0·6 km east of the junction of Chauncey's Line and the Chauncey's Line-Monarto South road. 6.IX.1958. p.p. — *R. Schodde 914a*: AD95908093: Ca. 3·1 km north of the junction of Chauncey's Line and the Chauncey's Line-Monarto South road. 4.X.1958. (*type*). — *P. G. Wilson 2029*: AD 96202135: Ca. 50 km north of Bordertown, near Bunn's Bore. 27.VIII.1961. p.p. — *P. G. Wilson 2126*: AD96201145: Ca. 97 km north of Bordertown on Pinnaroo-Bordertown road. 30.VIII.1961. p.p.

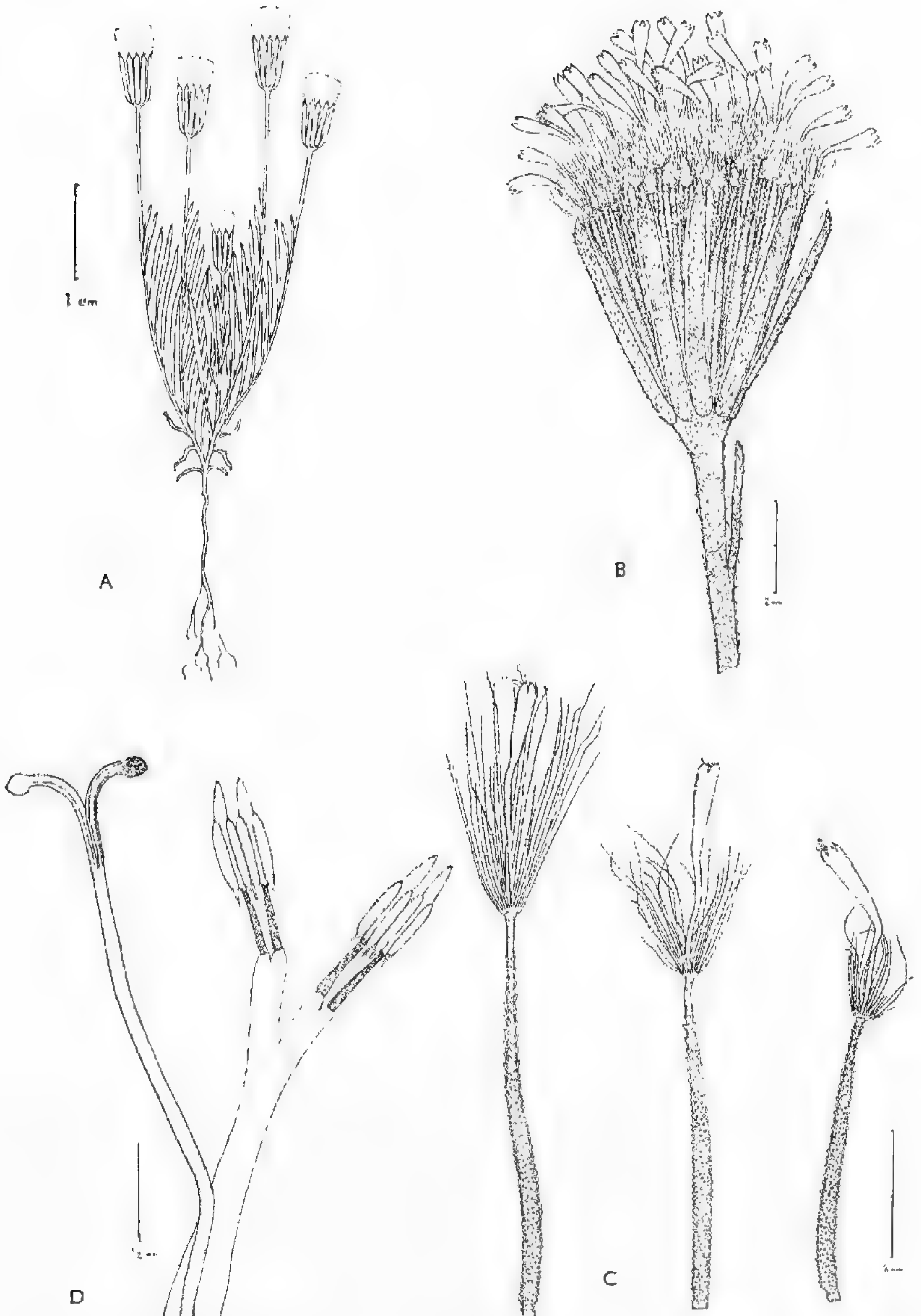

Fig. 8. *Millotia tenuifolia* var. *nudescens* Schodde. A, whole plant (type–Schodde 914a); B, mature flower head (type–Schodde 914a); C, mature florets showing variation in pappus (type–Schodde 914a); D, whole style and androecium (type–Schodde 914a).

Distribution, Ecology and Morphological Variation

South Murray Mallee and upper 90-mile Desert of South Australia, probably extending into the Big Desert of Victoria. Throughout its range, it grows side by side with var. *tenuifolia*.

In the Chauncey's Line area, *M. tenuifolia* in its fully pappose form is found commonly throughout, both on the whitish sand ridges and intervening red sandy flats; the reduced pappus form is restricted to the whitish sand ridges, slightly predominating there in numbers over fully pappose plants. The degree of reduction of pappus is the same for all florets in any one plant. On the sand ridges, plants with fully developed pappus, plants with completely reduced pappus, and plants showing various degrees of pappus reduction grow side by side. The reduced pappus forms tend to flower and mature seed earlier than fully pappose forms and this may have survival advantage because the sand ridges are probably prone to earlier spring dessication than the surrounding low-lying loamy flats.

Morphological Variation in *Millotia tenuifolia*

A strikingly uniform species throughout its range, the only distinct variant being the form with reduced pappus in the lower Murray Mallee of South Australia. Tasmanian plants often have slightly larger flower heads and involucral parts than those on the Australian mainland.

The type collection of *Millotia hispidula* Gdgr. is a mixture of specimens of *M. tenuifolia* and *M. myosotidifolia*. It appears likely that Gandoger did not check the types of these latter names nor Steetz's enumeration (1845), confused *M. myosotidifolia* with *M. tenuifolia*, and hence described the specimens with pilose (or hispid) hairs as a new species. A lectotype has been chosen.

Affinities between the species of *Millotia*

M. myosotidifolia is not closely allied to any other species of *Millotia*. The shape of its leaves, involucral bracts, and cypselae with their elongate appressed papillae, and its pappus of toothed setae which usually tend to subplumose at the apices render it obviously distinct.

In its assemblage of morphological characters, *M. greevesii* is somewhat intermediate between *M. myosotidifolia* on the one hand, and *M. macrocarpa* and *M. tenuifolia* on the other, yet is not closely related to any. It resembles *M. myosotidifolia* in its floral morphology and the other two species in its leaves, indumentum, cypselae, and cypsela papillae.

M. macrocarpa and *M. tenuifolia* are closely allied, the fundamental similarities lying in the floral parts and cypsela papillae. The distribution of the two species overlaps at least in the Cawler Range region of South Australia, though both occur in different ecological sites and *M. macrocarpa* flowers earlier.

That *M. tenuifolia* and *M. myosotidifolia* were not distinguished since 1853, despite their many differences, is due to the fact that the species of *Millotia* have been hitherto recognised by the character of the pappus rather than that of the floret and cypsela. Both species occur close to each other over much of their

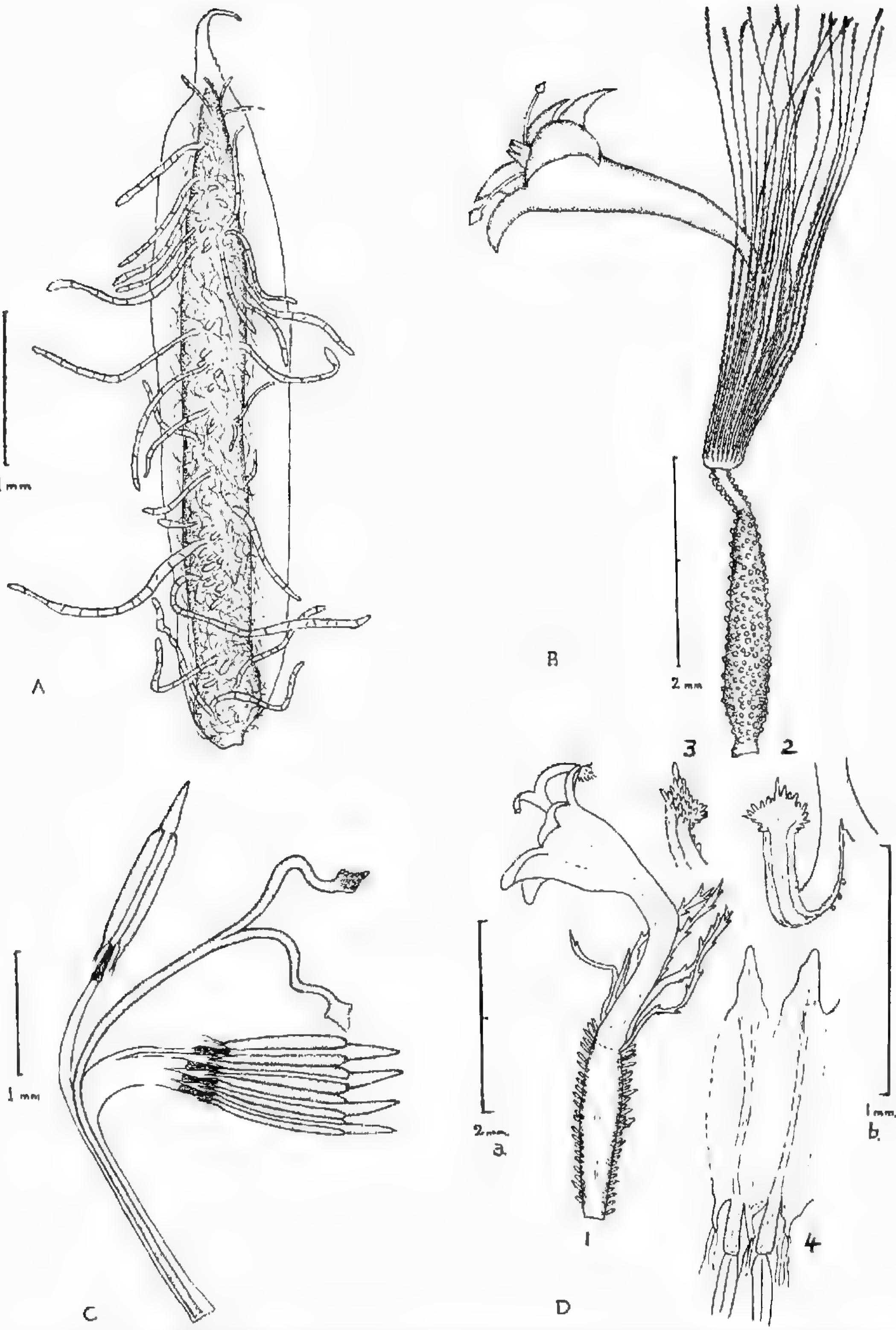

Fig. 9. Intermediate form between *Millotia myosotidifolia* (Benth) Steetz and *M. tenuifolia* Cass., leg. Heal: MEL. A, involucral bract; B, whole floret; C, whole style and androecium.

Type of *Millotia depauperata* Stapf. D, showing floret, style, and androecium, though the form of the cypsela papillae may not be accurate. (By courtesy of R. Melville.)

range. Where this happens, at least in southern South Australia, they are usually separated by their preferences for different soils, *M. myosotidifolia* being found on loamy sands and *M. tenuifolia* on less fertile sands and sandy clays, and different flowering times, that of *M. tenuifolia* being up to several weeks in advance. There is, however, among a mixture of *M. myosotidifolia* and *M. tenuifolia* in MEL collected by Heal at the sources of the Swan River in 1889, a single specimen which combines the character of one or other of these species and perhaps indicates that hybridisation may sometimes occur (Fig. 9, A-C).

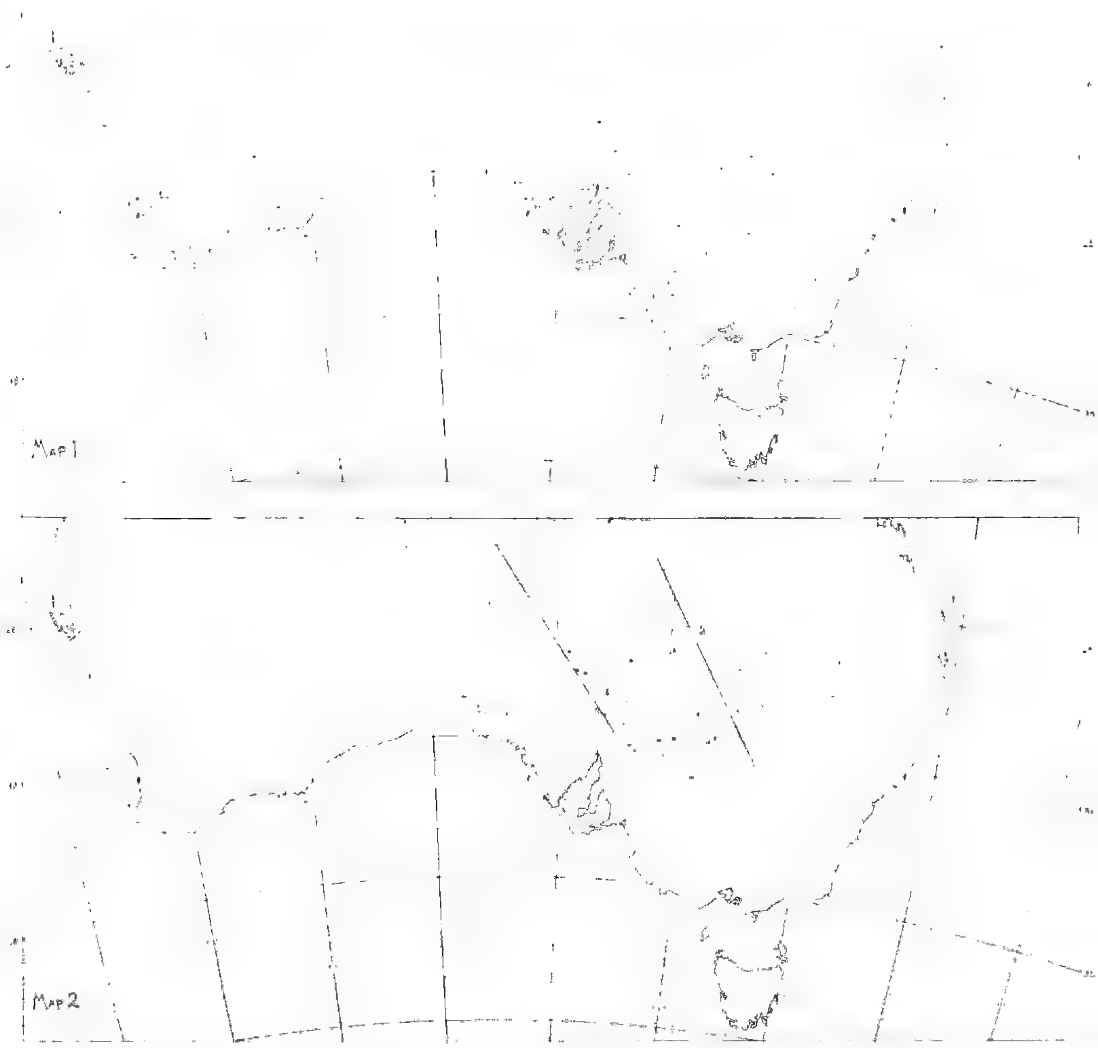

Fig. 10. Map 1—Distribution of *Millotia myosotidifolia* (Benth.) Steetz.

Map 2—Distribution of *Millotia greevesii* F. v. Muell. var. *greevesii* ●; var. *glandulosa* Schodde ×; var. *kempei* (F. v. Muell.) Schodde +; var. *helmsii* (F. v. Muell. and Tate) Schodde ○. Line 1 indicates region of change of pappose to apappose forms and of woolly to glandular-haired involucres in var. *helmsii*. Line 2 indicates region of change of woolly to glandular-haired involucres in var. *glandulosa*.

Fig. 11. Map 3—Distribution of *Millotia macrocarpa* Schodde.

Map 4—Distribution of *Millotia tenuifolia* Cass. var. *tenuifolia* ×; var. *nudescens* Schodde ●.

Acknowledgments

I wish to thank the Curators of all herbaria who made available loans or donations of material, those members of the staff of the Kew herbarium and particularly Dr. R. Melville for submitting details of their collections of *Millotia*, Dr. N. T. Burbidge for photographs of several types, Mr. R. T. M. Pescott for allowing me to examine type specimens held in the National Herbarium of Victoria, Dr. Hj. Eichler and Messrs. E. N. S. Jackson, D. N. Kraehenbuehl, D. J. E. Whibley and P. G. Wilson for their efforts in field collecting, the Adelaide

University Zoology Dept. and Adelaide Botanic Garden for making available facilities for germinating and growing seeds, and Miss C. M. Eardley and Mr. P. G. Wilson for their advice and criticism.

I am especially grateful to Dr. Hj. Eichler for making available the facilities of the State Herbarium of South Australia and his invaluable encouragement, criticism, and assistance in the execution of this study.

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TWO NEW ECHIUROIDS (ECHIUROIDEA) FROM AUSTRALIA

BY S. J. EDMONDS

Summary

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by S. J. Edmonds*

[Read 13 June 1963]

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Listriolobus bulbocaudatus n. sp.

(Plate 1, Fig. 1)

Listriolobus Fischer, 1926, p. 110; Fisher, 1946, p. 233.

Material: Four specimens dredged from 8-10 fathoms, west of Mud Island, Moreton Bay (Queensland): coll. Prof. W. Stephenson (University of Queensland), Aug., 1962.

Description: The specimens are sausage-shaped. The length of the trunk is 48-80 mm. and the maximum width is 14-20 mm. The proboscis (still attached to the body in all specimens) is, in the preserved condition, short, stout and rounded, about 10-16 mm. long and about as wide. The trunk is dark reddish-brown but the proboscis is much lighter in colour. A feature of all the specimens is that the posterior extremity of the trunk is expanded into a fleshy, bulbous structure, light pink in colour like the proboscis. The bulb is slightly pointed posteriorly and bears a number of rings of very large, prominent, wart-like papillae. The trunk is covered with whitish papillae that are easily discernible to the naked eye. They are closely packed posteriorly and anteriorly and largest posteriorly.

In three of the specimens the longitudinal muscles are grouped into seven bundles that are best seen on dissection. The body wall of the other specimen, the smallest, is very thin and the muscle bands are not as well-defined. The oblique musculature between the longitudinal bands is not grouped into fascicles as it is in the genus *Ochetostoma*. There are two relatively long setae connected internally by a well-developed interbasal muscle. There is a well-developed mesentery attached to the anterior part of the oesophagus and the body wall.

The alimentary canal is very long and much coiled and contains sausage-shaped faecal pellets. The walls of the pharynx, oesophagus, gizzard and crop are thicker than those of the intestine. The siphon is not very prominent. There is a caecum near the posterior extremity of the alimentary canal and a ventral, ciliate groove which terminates at the caecum.

The nephridia arise behind the setae. In the two smaller specimens there are two pairs but in the larger specimens there are three nephridia on the left

* Department of Zoology, University of Adelaide.

side and two on the right side (dorsal view). No trace of a third on the right side was discernible. The presence of this extra nephridium is difficult to explain. Fisher (1946, p. 222) reported the presence of three nephridia on one side and two on the other in a species of *Lissomyema* (*Thalassema*) *mellita* Conn. *L. mellita* is regarded as possessing two pairs of nephridia. In the Queensland specimen the region of the nephridia near the body wall is globular in shape, the rest tubular. The nephrostomal lips of all the nephridia are very long and much coiled, much more so than those of *L. hexamyotus* Fisher (1949, plate 29) and *L. pelodes* Fisher (1946, plate 22).

The blood system resembles that of *L. pelodes*. The intestinal vessel makes contact with the crop where it expands into a thin-walled structure of large diameter. There is a ring vessel which gives off two neuro-intestinal vessels that join before they reach the interbasal muscle and then, in two specimens at least, bifurcate to form a loop around the muscle. The ventral vessel runs close to the nerve cord and terminates at the rectal caecum.

The anal vesicles are long, thin and brown in colour. They are not swollen near the rectum. They bear numerous small ciliate funnels with short stalks

Systematic Position: These specimens fall into the genus *Listriolobus* (Fisher, 1949, p. 480). They differ from *L. hexamyotus* Fisher (1949) which has six longitudinal muscles and one pair of nephridia, from *L. bahamensis* (Fischer, 1926) which has 16 longitudinal muscles, from *L. pelodes* (Fisher, 1946) which has eight bands, from *L. riukiuensis* Sato, 1939, which has twelve bands, and from *L. sorbillans* (Lampert, 1883), already reported from Sydney by Augener (1903, p. 349), which has thirteen muscles. A near species is *Thalassema formulosum* Lampert, 1883, which Fisher (1946) placed in the genus *Ochetostoma*. It has 7-8 muscle bands, two pairs of nephridia with spirally-coiled nephrostomal lips and sparsely distributed white papillae. Fisher, however, must have had evidence that the oblique musculature between the muscle bands was grouped into small bundles. Neither Lampert (1883) nor Wharton (1913) mention the posterior swelling of the trunk in their description of *T. formulosum*. *Thalassema exilii* F. Muller has 8-10 muscles and two pairs of nephridia. Its nephrostomal lips are folded and crinkled but not elongated. Fisher (1946, p. 24) thinks that it is probably a *Lissomyema*.

Through the kindness of the authorities of the U.S. National Museum, Washington, I have been able to compare these specimens with a dissected specimen of *L. pelodes*. The latter, U.S.N.M. Cat. No. 20622, was collected at Tomales Bay and identified by Fisher. Most of its internal structures were damaged. The specimen, however, lacks the bulb and posterior rings of papillae that are found on all the Australian animals and its proboscis is long and thin.

Consequently it seems reasonable to regard these specimens from Queensland, although close to *L. pelodes*, *O. formulosum* and *T. exilii*, as new. It is of interest to note that *L. bulbocaudatus* was dredged from a mud bank very much as *L. pelodes* was by Barnard and Hartman (1959) in California.

Diagnosis: Body sausage-shaped and proboscis short and stout. In older specimens the longitudinal musculature is grouped into seven bundles; in younger specimens this is not so apparent. Oblique musculature between the longitudinal muscles not grouped into small bundles. Two pairs of nephridia arise behind the setae. In the two largest specimens there are three nephridia on one side and two on the other. A stout fastening mesentery is connected to the oesophagus. Posterior region of the trunk is swollen into a light-pink, fleshy, bulb-like structure. Body covered with whitish papillae which are warty and arranged in a number of rings on the posterior swelling.

Type Specimen: Australian Museum, Sydney.

Type Locality: Mud Island in Moreton Bay, Queensland.

Ochetostoma myersae n.sp.

(Plate 1, Fig. 2)

Ochetostoma Leuckart and Rüppell, 1828; Fisher, 1946, p. 240.

Specimens: Four (three dissected), Aust. Museum collection W 3757.

Locality: Long Reef, near Sydney, New South Wales. Collected by Miss D. Myers, 20-4-62.

Description: The specimens are sac- or sausage-shaped. The anterior region of the trunk tends to be rounded while the posterior region is more pointed. The animals were described by the collector as being "chlorophyll green" in colour. Preserved in alcohol they are pink. The length of the trunk in 20-35 mm. and the maximum width 9-15 mm. The surface of the trunk is covered with soft, white, wart-like papillae which are largest and most noticeable in the posterior third. The proboscis, which was still attached in three specimens, is about a quarter to half the length of the trunk. It tapers slightly anteriorly and in the fixed specimen is almost tubular in shape.

The longitudinal muscles are grouped into 18-21 bundles that are usually visible externally but which are best counted in dissected specimens. In two specimens two muscles anastomose. The longitudinal muscles lie close together and are most strongly developed over the anterior half or two-thirds of the trunk. The oblique muscles between the longitudinal bands are grouped rather weakly into fascicles and not into such strongly developed bundles as they are in *O. australiense* Edmonds (1960). There are two pairs of nephridia which lie posterior to the setae. The nephrostomes are expanded into two elongate, thread-like lips which are rather weakly coiled. In the largest specimen only one pair of nephridia could be found. The nephridia of this specimen were larger than those of the other two dissected specimens and not as coiled as those shown for *O. edax* Fisher (1946, p. 14). This variation in the number of nephridia is puzzling. There seems no doubt, however, that since all the specimens look alike and were collected at the same time and in the same locality they belong to the same species. There are two prominent setae and a strong interbasal muscle. Three or four strong and prominent muscles connect each seta and the body wall. The alimentary system consists of (1) a comparatively short foregut which extends as far as the ring vessel of the vascular system, (2) a thicker intestine with a ciliate groove and a collateral intestine, and (3) a short rectum which bears a small caecum. The contents of the canal are very coarse and not formed into pellets. The vascular system consists of a dorsal vessel, a ring vessel, two neuro-intestinal vessels and a ventral vessel. The neuro-intestinal vessels join and then split again to enclose the interbasal muscle. The anal vessels are long and thin and do not branch. The ciliate funnels are borne on very short stalks.

Systematic Position: These specimens closely resemble *O. baronii* (Greef, 1879) and *O. edax* Fisher, 1946. *O. baronii* possesses 17-19 longitudinal muscle bands and *O. edax* 16 or 17. Short branching outgrowths are present on the anal vesicles of *O. baronii*. Such structures are not present in the specimens from Long Reef. Fisher (1946) says that the normal number of muscle bands of *O. edax* is probably 16. Through the kindness of the authorities of the U.S. National Museum, Washington, I have been able to compare the Australian specimens with a specimen of *O. edax* from Puerto Refugio (U.S.N.M. Cat. No. 20623). It was identified by Fisher. It is a small specimen with a deciduate proboscis. It possesses fewer longitudinal muscles than the Australian specimens, its body wall is much thinner and the papillae are more prominent, especially in the mid-region of the trunk. Consequently the specimens from Long Reef are considered to be different from *O. edax* and new. *O. myersae* differs from *O. australiense* Edmonds, 1960, in the number of its longitudinal muscles and in the number and position of its nephridia.

Diagnosis: Trunk sac- or sausage-shaped, posterior region somewhat pointed. Trunk bears numerous white, wart-like papillae which are most noticeable on the surface of the posterior third. Proboscis not readily deciduate, about a quarter to half the length of the trunk and tapering slightly anteriorly. 18-21 longitudinal bundles, placed closely together. Oblique muscles between the bundles weakly developed. Two pairs of nephridia which lie posterior to the setae (one specimen has only one pair of nephridia). Nephrostomal lips elongate and weakly coiled. Two prominent setae and a strong interbasal muscle. Rectal caecum. Contents of alimentary canal very coarse and not formed into pellets. Vascular system as in *O. australiense* and *O. edax*. Anal vesicles long, thin and unbranching. Ciliate funnels on very short stalks. When alive chlorophyll green in colour.

Type Specimen: Australian Museum, Sydney.

Type Locality: Long Reef, near Sydney, New South Wales.

KEY TO THE GENERA OF AUSTRALIAN ECHIUROIDS

This key replaces the one given in Edmonds, 1960

1. Proboscis usually conspicuous (although sometimes deciduous if specimen is handled) and often several times the length of the body but never bifid. Anal vesicles long, sac-like, unbranched and covered with minute ciliate funnels—family *Echiuridae* 3, 4
2. Females with elongate, bifid proboscis. Anal vesicles with many branches that end in ciliate cups. Male degenerate, living in or on the female—family *Bonelliidae* 11, 12
3. Longitudinal muscles of body-wall grouped into bundles 5, 6
4. Longitudinal muscles of body-wall not grouped into bundles 7, 8
5. The interval between the bundles is crossed by numerous separate, small bundles of the inner oblique layer. Nephridia with spirally coiled, nephrostomal lips—genus *Ochetostoma*.
6. The interval between the bundles is not crossed by numerous separate, small bundles of inner oblique layer; nephrostomal lips elongate and spirally coiled—genus *Listriolobus*.
7. Nephrostomal lips either coiled or expanded into leaf-like structures 9, 10
8. Nephrostomal lips neither coiled nor expanded into leaf-like structures—genus *Thalassema*.
9. Nephrostomal lips long and spirally coiled—genus *Anelassorhynchus*.

10. Single pair of nephridia with nephrostomal lips produced to form leaf-like structures. Proboscis long, deciduous and slender with a small fan-like extremity — genus *Arhynchite.*

11. Only one nephridium or uterus present. Coelomic aperture of the nephridium is situated near the base of nephridium at the end of a short lateral tube — genus *Bonellia.*

12. More than one nephridium or uterus 13, 14

13. Two nephridia or uteri with nephrostomes placed near their distal ends. Male permanently lodged in a small blind tube which opens between the nephridiopores — genus *Pseudobonellia.*

14. Third nephridium placed between two paired nephridia — genus *Archibonellia.*

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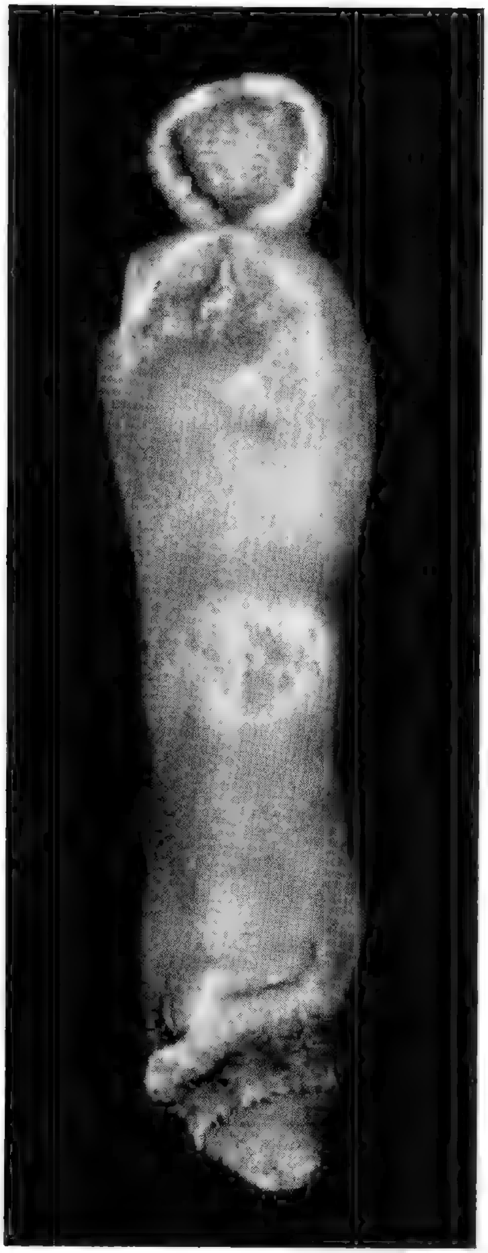

Fig. 1. *Listriolobus bulbocaudatus* (1·5 x natural size).

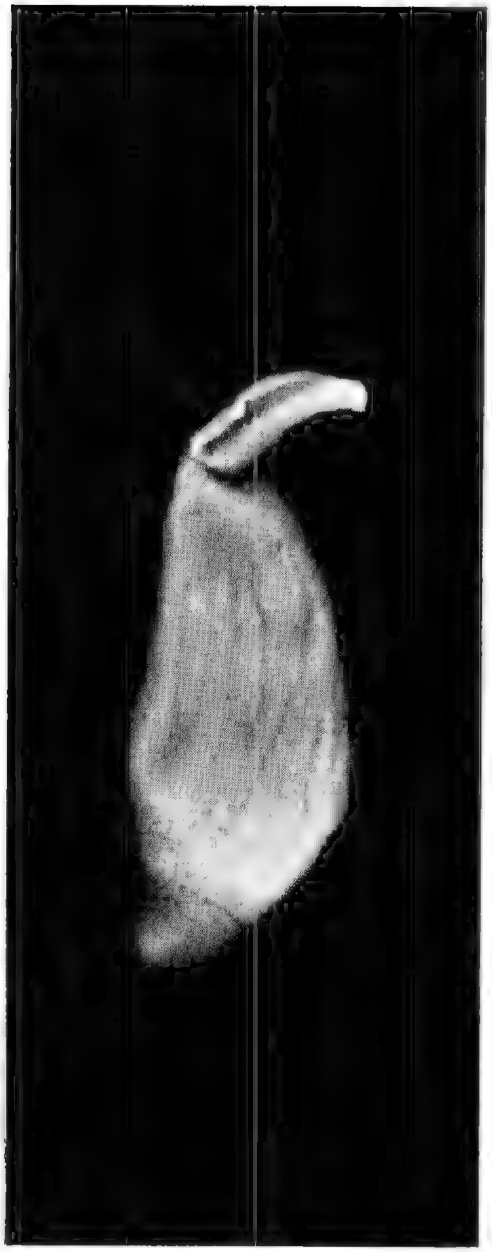

Fig. 2. *Ochetostoma myersae* (2 x natural size).

OBITUARIES: HERBERT WOMERSLEY

Summary

HERBERT WOMERSLEY,
A.L.S. (HON. CAUSA), F.R.E.S.

1889-1962

Herbert Womersley died in Adelaide on the 14th October, 1962. Although he was aged 73 years, and was subject to increasing ill-health, he had worked on the classification of the Acarina until within a fortnight of his death. Although without formal University training, he was a world authority upon the Acarina, and, at an earlier period, the Apterygota. He was able to accomplish a great deal in descriptive taxonomy, in which in fact he had few equals, owing to his intellectual discipline and methodical habits of work. His contribution to the subject of acarology will be considered in another memoir, and separate treatment will also be given to his career as an entomologist, both in the economic and taxonomic spheres.

Womersley was born at Warrington, Lancashire, England, on 10th April, 1889. He trained as an industrial chemist, and it was not until 1930 that he was able to transfer into the professional ranks of entomology. His interest in biology was life-long, and commenced with a youthful interest in entomology, no doubt fostered by his father, who was an enthusiastic amateur lepidopterist. Womersley's early interests in entomology were the Lepidoptera and the Diptera. While still a youth he was attracted by microscopy and microscopical technique, and had the good fortune to be instructed by Abraham Flatters in Manchester. Out of this came his first publication, on the use of terpineol as a clearing agent (1912). He served in the Imperial army in 1914-1917, firstly in the Royal Army Medical Corps, through his St. John Ambulance Brigade training, and then in the Chemical Corps of the Royal Engineers, serving on the Western Front. In 1917 the demand for trained chemists was intense. He was recalled to England and discharged to explosives manufacture, both there and in Scotland, until the war was over. In 1920 he left Warrington for Bristol, and while employed there he was able to resume his entomological studies.

In addition to these efforts, he took a prominent part in natural history societies in the west of England. He served a term as President, Bristol Naturalists' Society, and was also one of the promoters of the South-Western Union of Naturalists, acting as Secretary from its inception until he left England. He worked to such purpose that within a few years he was the leading British authority on the Apterygota, particularly the Collembola and Protura. Foreign collections were referred to him for working up as well as material from the British Isles. In 1930 he was appointed Entomologist, Section of Pasture and Field Pests, Division of Economic Entomology, C.S. & I.R. (now C.S.I.R.O.). His work had attracted the attention of R. J. Tillyard, the author of the well-known text book, "Insects of Australia and New Zealand", and who later became the Chief of the Division.

After induction and training periods at the British Museum and in South Africa, Womersley took up his duties in Western Australia. Here he was given the difficult assignment of developing or improving methods of control of the two major pasture pests, the "lucerne flea", *Sminthurus viridis* (L.), and the Red-legged Earth Mite, *Halotydeus destructor* (Tucker). In this field his new contribution was the study of possible control of *Sminthurus* by predatory bdellid mites. The results achieved were considered promising, though hampered by the financial stringency then ruling in Australia, and reluctantly he resigned his position to take up the appointment of Entomologist, South Australian Museum, in 1933. The study of the effects of these predators was continued by other workers in the Division, with Womersley acting as a consultant in the taxonomy of the Collembola and the Acarina. A more detailed story of this work will be told in another study.

At the South Australian Museum Womersley was able to devote much of his time to continuing his studies on the taxonomy of the Apterygota. He was able to produce a large amount of work, including publishing a large paper on this group in the Transactions of the Royal Society of South Australia in 1933, as well as two short papers on the Acarina in the same year. These two major taxonomic fields were pursued with great vigour. His studies on the Australian Apterygota culminated in 1939 in the "Primitive Insects of South Australia", which in actual fact monographed the whole of the Australian fauna then known. Possibly attracted more by the larger unworked area of the Acarina, he devoted increasing attention to this group. The material from the Berlese funnels was now examined mainly for Acarina, and simultaneously collections of free-living and parasitic mites were studied. Increasingly requests for identifications came to Womersley, and he finally was prepared to identify mites in nearly every category submitted. This was no small order, since ultimately the Acarina may begin to rival the insects in the number of species and higher categories. Again, a separate memoir will be necessary to give in any detail the extent of Womersley's studies in this group. His major work was his monograph of the trombiculid mites of the Oriental and Australasian regions, published in 1952. In this the immense collections that had been referred to him from field workers, particularly teams studying the epidemiology of scrub typhus over the "Austro-Asian area", were brought into systematic order. This work remains the most complete account of the trombiculid mite fauna of this region, even though, in the ten years since it has been published, many of the taxonomic categories have since been changed, with the intense continuing studies of these mites. Among workers responsible may be mentioned R. Domrow of Queensland, who received initial training from Womersley in Adelaide.

In 1954 Womersley retired as Entomologist, South Australian Museum, but was immediately re-appointed Acarologist, a salaried position created specially for him. He retired from this in 1959, at the age of 70, but immediately again became Honorary Acarologist, and continued his systematic habits of work. Following the production of his 1952 monograph, he was able to produce a large number of shorter papers on the Trombiculidae and many other families. Increasingly he devoted his efforts to the Mesostigmata, which had been comparatively neglected.

Immediately on coming to South Australia in 1933 he took the interests of the Royal Society of South Australia to heart, serving in succession in every office on the Council over a number of years. These were no sinecures, as they included the task of Editor for the six years 1937-1943, and Treasurer for four years (1950-1, 1956-9). He served as President in 1943-4, and from 1945 onwards he was the Society's representative on the Flora and Fauna Protection Committee which was advisory to the Minister of Fisheries and Game. Commencing with his period as President, he was later (1945) appointed a Commissioner of The National Park in his own name (later the Commissioners of The National Park and Wild Life Reserves with their expanded scope). He identified himself closely with wildlife preservation in the State, and his duties as a Commissioner gave him a great deal of pleasure. At one meeting, which the writer had the honour to attend, it was announced that Womersley had attended 68 meetings without any absence. This was a remarkable record, particularly in view of the ill-health which he suffered. He continued to attend until the record stood at 91 meetings over eight years. It was fitting that at his funeral the Rangers of the National Parks in their grey-green uniforms formed a guard of honour.

In 1943 he was awarded the Verco Medal of our Society. In 1962 another honour was bestowed, in his being elected Honorary Fellow, a fitting tribute to his scientific achievements and his long service to the Society. Another honour which he greatly valued was his election as Associate of the Linnean Society (*Honoris causa*), in 1929. He was also a member of the Linnean Society of New South Wales (1934), and a Fellow of the Royal Entomological Society (1926). On leaving Bristol for Australia in 1930, the Bristol Naturalists' Society also bestowed upon him the title of Honorary Member, as a mark of appreciation.

Most of his time, over the last 30 years of his life, was spent in South Australia, and as the years progressed his own collecting fell to quite small proportions, except on special trips. Thus he travelled to New Guinea in 1954, and also (1952) made a trip to New Zealand. His major travelling in his final decades was a visit to North America and Europe to study acarology, under a grant for this purpose (the study of the vector mites of scrub typhus and scrub-itch, the Trombiculidae) from the United States Public Health Department. He was gratified to be able to meet personally his colleagues in these somewhat restricted groups, as well as a number of the more general students of the Acarina, particularly the continental students of the *acari diversi*.

Womersley was twice married. By his first wife he had two sons, J. S. Womersley and H. B. S. Womersley, both botanists, and both members of this Society.

He has left behind him the legacies of a vast amount of publication in descriptive taxonomy, more particularly so in the Acarina, and the reference collection of the Acarina in the South Australian Museum is one of the great collections of these arthropods for the world.

The reference list of Womersley's publications will be given elsewhere, and more detailed accounts of his taxonomic work. His colleagues had a warm appreciation of his gifts and industry. His name is commemorated in a number of taxa in the Arthropoda, and these are given below.

Genera named for Womersley

ACARINA

Womersia Wharton, 1947. J. Parasitol. 33 (4): 381. Type species *W. strandtmani* (sic for *strandtmanni*), Wharton, *loc. cit.* (Trombiculidae).

Womersleyessia Feider, 1955. Fauna R. P. Rom., 5 (1): 186. Type species not designated (Trombidiidae).

Womersleyia Radford, 1946. Parasitol., 37 (1-2): 48. Type species *W. minuta* Radford, 1946, *loc. cit.*, p. 51.

Womersleyna Vercammen-Grandjean, 1960. Acarologia, 2 (4): unpaged table between pages 470 and 471. Type species *Tragardhula geckobia* Womersley, 1952 (Trombiculidae).

COLLEMBOLA

Womersleya Denis, 1948. Notes Ent. chin., Shanghai, 12: 198. Type species *Protanura tricina* Denis.

Womersleyella Salmon, 1944. Rec. Dominion Mus. N.Z., 1: 142. Type species *Womersleyella niveata* Salmon, *loc. cit.* (Isotomidae).

Womersleymeria Stach, 1949. Acta monogr. Cracow, p. 64. Anuridae. Type species *Ceratrimeria bicornis*, Womersley, 1940.

Species named for Womersley

CRUSTACEA

Quasimodia womersleyi Sheard, 1936. Rec. S. Aust. Mus., **5** (4): 464 (Amphipoda, Philiantidae).

ACARINA

Agaue parva womersleyi Viet, 1950. Further zool. Results Swed. Antarc. Exped., 1901-1903. **4**, 3: 44 (Halacaridae).

Austrombicula womersleyi Lawrence, 1949. Ann. Nat. Mus., **11** (3): 419, for *Leeuwenhoekia womersleyi* Lawrence, 1948, Parasitol., **39** (1-2): 41 (Trombiculidae).

Callidosoma womersleyi Southcott, 1946. Proc. Linn. Soc. N.S. Wales, **71** (1-2): 43 (Erythraeidae).

Ceratocelaenopsis womersleyi Trägårdh, 1950, Ark. f. Zool., (2) **1** (25): 384 (Celaenopsidae).

Cunaxa womersleyi Baker and Hoffman, 1948. Anales, Escuela Nac. Ci. Biol. Mexico, **5** (3-4): 234 (Cunaxidae).

Erythraeus womersleyi Southcott, 1946. Proc. Linn. Soc. N.S. Wales, **71** (1-2): 40 (Erythraeidae).

Fainiella womersleyi Vercammen-Grandjean, 1953. Rev. Zool. Bot. afr., **48** (1-2): 19 (Trombiculidae).

Holcothrombidium [sic, for *Holcotrombidium*] *womersleyi* André, 1948. Bull. Mus. Nat. Hist. Nat., (2) **20** (2): 159 (Trombidiidae).

Hypoaspis womersleyi Domrow, 1957. Proc. Linn. Soc. N.S. Wales, **81** (3): 205 (Phytoseiidae).

Leeuwenhoekia womersleyi Lawrence, 1948. Parasitology, **39** (1-2): 41 (subsequently type species of *Austrombicula* Lawrence, 1949; q.v.).

Marquesania womersleyi Lawrence, 1951. Ann. Natal Mus., **12** (1): 117 (Listrophoridae).

Paralimnochares womersleyi Lundblad, 1952. Entom. Tidsk., **73** (1-2): 23 (Hydracarina).

Neoschöngastia womersleyi Gunther, 1940. Proc. Linn. Soc. N.S. Wales, **65** (3-4): 254 (Trombiculidae).

Speleognathus womersleyi Fain, 1955. Ann. Soc. Belg. Med. Trop., **35** (6): 695 (in key only); also Rev. Zool. Bot. afric., **50** (1-2): 21 (formal description).

Sphaerotarsus womersleyi Southcott, 1946. Proc. Linn. Soc. N.S. Wales, **70** (3-4): 177 (Smarididae).

Tenuipalpus womersleyi Pritchard and Baker, 1958. Univ. Calif. Publ. Entom., **14** (3): 238 (Phytoptipalpidae).

Trichonyssus womersleyi Domrow, 1958. Proc. Linn. Soc. N.S. Wales, **83** (3): 231 (Laelapidae).

Tydeus womersleyi Thor, 1932. Zool. Anz., **100** (3-4): 108 (Tydeidae).

Whartonia womersleyi Brennan and Dalmat, 1960. Ann. Ent. Soc. America, **53** (2): 185 (Trombiculidae).

PROTURA

Eosentomon womersleyi Bonet, 1942. Ciencia, Mexico, **3** (1): 16.

DIPLURA

Anisocampa womersleyi Silvestri, 1932. Bull. Lab. Zool. Portici, **26**: 75.

Japyx (Metajapyx) womersleyi Pagés, 1952. Rec. Canterbury Mus., **6**: 161.

COLLEMBOLA

Entomobrya womersleyi Bagnall, 1939. Ent. Mon. Mag., **75**: 101 (Entomobryidae).

Protullbergia womersleyi Bagnall, 1947. Ann. Mag. Nat. Hist., (11) **14** (114): 442 (Tullbergiidae).

Sminthurus womersleyi Denis, 1948. Notes Ent. chin., Shanghai, **12**: 295.

A full bibliography of Womersley's scientific publications will be given in the obituary notice to be published in the Records of the South Australian Museum, where his career in entomology and his early life will be described. A further notice, dealing with his contribution to acarology, has been published in "*Acarologia*" in Paris. Other short notices have also been submitted to societies to which he belonged, or appropriate journals. The archival material from which basic information has been obtained is in the correspondence files of the South Australian Museum, and other material entrusted to the author by Womersley will be deposited in the South Australian Archives.

R. V. SOUTHCOTT.

OBITUARIES: CHARLES MERVYN DELAND, M.B., B.S., D.P.H., D.T.M.

Summary

CHARLES MERVYN DELAND,

M.B., B.S., D.P.H., D.T.M.

1902-1962

Charles Mervyn Deland died in Adelaide on 11th July, 1962, at the comparatively early age of 60 years. He was an authority on tropical diseases and public health, and combined these attainments with a love of natural history. A regular attendant at meetings of the Royal Society of South Australia, he was seldom absent from meetings over the last decade. He served on the Council of the Society from 1952-1960.

Deland was born in Gawler on 9th March, 1902, and was educated at Prince Alfred College, Adelaide, where he won many scholastic prizes. From there he proceeded to the University of Adelaide, graduating M.B., B.S. in 1924.

In 1926 Dr. Deland began his tropical work which was to continue with few intermissions to 1950. His first appointment was as medical and quarantine officer by the Vanikoro Timber Company in the British Solomon Islands after which he joined the medical services of the Papua-New Guinea Territories where he remained for nearly 20 years. Dr. Deland's pre-war service was at Kieta, Wewak and Manus with a visit to New Caledonia.

With the Japanese aggression of 1941, he enlisted in the Australian Army and until 1943 was stationed in South Australia where his knowledge of tropical diseases was useful in treating Japanese internees in Loveday camp. In May, 1943, he returned to New Guinea, serving with ANGAU, and being promoted to Temporary Major, as DADMS, ANGAU, Southern Region, Papua. On discharge in 1945, he continued in New Guinea at Madang (1946-7), until completion of his period of civilian service there, and returned to Adelaide. After short locums in South Australia and a brief period of service in the Commonwealth Health Department, in Darwin, he joined (1950) the State Public Health Department, South Australia, being finally appointed Industrial Medical Officer. During this period in South Australia he was Lecturer in Public Health to the South Australian Nurses Board, and was Visiting Specialist in Tropical Medicine, Repatriation Department.

Dr. Deland was a stimulating conversationalist and could discourse authoritatively over a wide range of subjects, from public health, anthropology, virology, geography and even vulcanology and the chemistry of the newer organic poisons. His actions were responsible in preserving the ochre quarry used by the now extinct aborigines of the Noarlunga district from destruction. His extensive library on geography and anthropology was left to the South Australian Museum.

Apart from purely medical articles, Deland's most important contribution lay in a series of papers in which he was able to combine his interests in natural history and medicine. These were published in "Good Health", the quarterly bulletin of the Department of Public Health, South Australia. These are:

iv. 1953 Troublesome worms. No. 86, pp. 22-24.
v. 1956 Mosquito threat: possible aftermath of Murray floods. No. 100, p. 64.
i. 1958 Flies. No. 105, pp. 36-8.
iv. 1958 Venomous land animals. No. 106, pp. 26-30.
iv. 1959 Poisonous and venomous fish. No. 110, pp. 18-22.
iv. 1960 Vectors of disease in South Australia. No. 114, pp. 31-32. (A general article, dealing mainly with the role of insects in public health, but refers also to shellfish and mammals.)
x. 1960 Water absorbing plants. No. 116, pp. 24-27. (Refers to species of *Eucalyptus*, *Melaleuca* and *Casuarina*.)

R. V. SOUTHCOTT.

OBITUARIES: HERBERT MATHEW HALE, O.B.E. 1895-1963

Summary

HERBERT MATHEW HALE, O.B.E.
1895-1963

Born in North Adelaide on the 3rd June, 1895, Herbert Hale spent his life promoting biological science on two fronts – public education and research.

As Director of the South Australian Museum (1928-1960), Chairman of the Flora and Fauna Advisory Committee (1937-1960), permanent Vice-President of the Royal Zoological Society (since 1928), and as a member of the Commissioners of the National Park and Wildlife Reserves (1936-1960), of which he was Deputy Chairman between 1955-1960, he proved a most able administrator and a respected advisor, and did a great deal to heighten public interest in and improve their appreciation of our irreplaceable heritage of native fauna and flora.

His conscientious service to the Society led to the award of Honorary Fellowship in 1962 following 31 years of continuous service on the Council, during which he occupied several senior offices, including President (1936-37), Vice-President (1934-36 and 1937-38) and Treasurer (1938-50 and 1953-56).

His unselfish services to the community were recognised by his inclusion in the New Year Honours List for 1954.

Although he possessed the wide knowledge of biology essential to his position as Director of the South Australian Museum, his deeper interests always appear to have had an aquatic bias. His earliest writings concern freshwater life, outstanding among which were his studies on aquatic Hemiptera, while his subsequent research was mainly in marine biology. He will be remembered best for his work on southern Australian Crustaceans. His British Science Guild Handbook, "The Crustaceans of South Australia", published in 1927 (Part I) and 1929 (Part II) is now a widely recognised text, while his revisionary studies on the Australian Cumacean fauna provided a new foundation for the taxonomy of this order. His work has been used extensively by subsequent systematists.

After retiring on the 30th September, 1960, he maintained an active interest in his investigation of the whale fauna of the Southern Ocean, and added three papers to his already impressive contribution to research in this field. The manuscript of a further paper was completed just prior to his death, and is now being prepared for publication.

In addition to the 94 papers which he published under his own name, some of his work was undertaken in collaboration with other authors, outstanding of which were his work with Edgar R. Waite on Lophobranchiate fishes, and his joint papers with Norman B. Tindale on Australian ethnology and anthropology.

For his outstanding contributions to "research in science" he was awarded the Verco Medal of this Society at its General Meeting in June, 1947.

F.J.M.

LIST OF LECTURES GIVEN AT MEETINGS DURING THE YEAR 1962-63

Summary

LIST OF LECTURES GIVEN AT MEETINGS DURING THE YEAR 1962-63.

July, 1962.	Dr. N. H. Ludbrook: "Correlation of the Tertiary Rocks of South Australia".
Aug., 1962.	Dr. R. L. Hodge: "Studies on the Peripheral Circulation of Man".
Sept., 1962.	Mr. K. J. Hutchinson: "Factors Affecting Wool Production in S.A."
Oct., 1962.	Dr. C. R. Twidale: "Geomorpholgy of the Adelaide District".
Nov., 1962.	Mr. H. C. Brideson: "Libraries in the Scientific Age".
April, 1963.	Dr. C. R. Jenkin: "The Host-Parasite Relationship".
May, 1963.	Dr. H. B. S. Womersley: "Plant Food from the Sea".
June, 1963.	Mr. E. S. O'Driscoll: "The Earth as a Transformed Ellipsoid".

Exhibits

During the year the following members exhibited material at Ordinary Meetings:

Dr. B. Daily—Lower Cambrian Fossils from Metamorphosed Rocks at Delamere, Fleurieu Peninsula, S.A.

Mr. F. J. Mitchell—An example of parallel evolution between two different genera of gecko lizards.

Mr. M. J. Tyler—Unusual secondary sexual characteristics exhibited by *Hyla nannotis*, a Queensland tree frog.

Mr. M. J. Tyler—An unusual defensive mechanism in a Leptodactylid frog.

BALANCE SHEET

Summary

ROYAL SOCIETY OF SOUTH AUSTRALIA (INCORPORATED)

REVENUE ACCOUNT

Receipts and Payments for Year ended 30th June, 1963.

				£	s.	d.
To Balance 1/7/62				289	19	6
,, Subscriptions				370	2	8
,, Government Grant				1,750	0	0
,, Sale of Publications, etc.				1,189	1	0
,, Rent of Rooms				47	0	0
,, Interest						
Endowment Fund	£454	7	4			
Bank of Adelaide	31	4	9			
				485	12	1
				£4,131	15	3

	£	s.
By Printing and Publishing Volume 86, Reprints, etc.	2,035	13
,, Binding and Book Ends	539	4
,, Shelving	133	10
,, Amount Transferred to Library Account	313	5
,, Journals, etc.	80	5
,, Library Assistants	164	1
,, Clerical Assistance	180	1
,, Printing and Stationery	82	5
,, Postages and Duty Stamps	143	4
,, Cleaning and Polishing	98	0
,, Telephone	23	10
,, Insurance	72	8
,, Packing and Freight	13	11
,, Lighting	7	13
,, Addressing Machine	46	15
,, Hire of Key Discs	13	10
,, Wreath	3	1
,, Balance at Bank of Adelaide	181	13
	£4,131	15

LIBRARY ACCOUNT

	£	s.	d.
To Balance	£313	5	0
Balance at Bank of Adelaide	£313	5	[illegible]

Audited and found correct.

(Sgd.) F. M. ANGEL
N. S. ANGEL, A.U.A. (Com.) } Hon. Auditors

F. J. MITCHELL,
Hon. Treasurer.

Adelaide, 1st July, 1963.

ENDOWMENT FUND

Transactions for the Year ended 30th June, 1963.

				£	s.	d.
To Balance				9,670	0	0
,, Investment Interest—						
Com'wealth Inscribed Stock	£434	6	3			
S.A. Inscribed Stock	4	10	0			
S.A. Gas Co. Bonds	15	11	1			
				454	7	4
				£10,124	7	4

				£	s.	d.
By Revenue Transfer				454	7	[illegible]
,, Balance—						
Inscribed Stock—						
Com'wealth	£9,220	0	0			
South Aust.	150	0	0			
S.A. Gas Co. Bonds	300	0	0			
				9,670	0	[illegible]
				£10,124	7	[illegible]

Audited and found correct. The Commonwealth Stock has been verified by certificate, and the S.A. Stock [illegible] and the Gas Co. Bonds have been inspected in the hands of the Treasurer.

(Sgd.) F. M. ANGEL
N. S. ANGEL, A.U.A. (Com.) } Hon. Auditors

F. J. MITCHELL,
Hon. Treasurer.

Adelaide, 1st July, 1963.

AMENDED LIST OF FELLOWS

Summary

AWARDS OF THE SIR JOSEPH VERCO MEDAL

1929 Prof. Walter Howchin, F.G.S.
1930 John McC. Black, A.L.S.
1931 Prof. Sir Douglas Mawson, O.B.E., D.Sc., B.E., F.R.S.
1933 Prof. J. Burton Cleland, M.D.
1935 Prof. T. Harvey Johnston, M.A., D.Sc.
1938 Prof. J. A. Prescott, D.Sc., F.A.C.I.
1943 Herbert Womersley, A.L.S., F.R.E.S.
1944 Prof. J. G. Wood, D.Sc., Ph.D.
1945 Cecil T. Madigan, M.A., B.E., D.Sc., F.G.S.
1946 Herbert M. Hale, O.B.E.
1955 L. Keith Ward, I.S.O., B.A., B.E., D.Sc.
1956 N. B. Tindale, B.Sc.
1957 C. S. Piper, D.Sc.
1959 C. G. Stephens, D.Sc.
1960 H. H. Finlayson.
1961 R. L. Specht, Ph.D.
1962 H. G. Andrewartha, M.Ag.Sc., D.Sc., F.A.A.
1963 For outstanding palaeontological research and contributions to geological chronology in Australia.
N. H. Ludbrook, M.A., Ph.D., D.I.C., F.G.S.

LIST OF FELLOWS

AS AT 30th JUNE, 1963

Those marked with an asterisk (*) have contributed papers published in the Society's Transactions. Those marked with a dagger (†) are Life Members.

Any change in address or any other changes should be notified to the Secretary.

Note.—The publications of the Society are not sent to those members whose subscriptions are in arrears.

Date of Election	Date of Honorary Election	Honorary Fellows
1895	1949	*Cleland, Prof. J. B., M.D., Dashwood Road, Beaumont, S.A.—*Verco Medal*, 1933; *Council*, 1921-26, 1932-37; *President*, 1927-28, 1940-41; *Vice-President*, 1926-27, 1941-42.
1913	1955	*Osborn, Prof. T. G. B., D.Sc., 103 Ward Street, North Adelaide—*Council* 1915-20, 1922-24; *Vice-President*, 1924-25, 1926-27; *President*, 1925-26.
1912	1955	*Ward, L. K., I.S.O., B.A., B.E., D.Sc., 22 Northumberland Street, Heathpool, Marryatville, S.A.—*Verco Medal*, 1955; *Council*, 1924-27, 1933-35; *Vice-President*, 1927-28; *President*, 1928-30.
1922	1962	*Hale, H. M., O.B.E., 12 Bellevue Place, Unley Park, S.A.—*Verco Medal*, 1946; *Council*, 1931-34, 1950-53, 1956-62; *Vice-President*, 1934-36, 1937-38; *President*, 1936-37; *Treasurer*, 1938-50, 1953-56; *Council*, 1957-62.

Date of Election	Fellows
1946.	*Abbie, Prof. A. A., M.D., D.Sc., Ph.D., Department of Anatomy, University of Adelaide, North Terrace, Adelaide, S.A.
1961.	Abele, C., B.Sc., 42 Kildonan Road, Warradale Park, S.A.
1959.	Aitken, P., B.Sc., South Australian Museum, North Terrace, Adelaide, S.A.
1927.	*Alderman, Prof. A. R., Ph.D., D.Sc., F.G.S., Department of Geology, University of Adelaide, North Terrace, Adelaide, S.A.—*Council*, 1937-42, 1954-57; *Vice-President*, 1962-63.
1961.	Anders, D. J., B.Sc., Dip.Ed., B.Ed., M.A.C.E., c/o. Adelaide Teachers' College, Kintore Avenue, Adelaide, S.A.
1951.	*Anderson, Mrs. S. H., B.Sc., 31 Lakeman Street, North Adelaide, S.A.
1935.	*Andrewartha, H. G., M.Ag.Sc., D.Sc., F.A.A., Zoology Dept., University of Adelaide, North Terrace, Adelaide, S.A.—*Verco Medal*, 1962; *Council*, 1949-50; *Vice-President*, 1950-51, 1952-53; *President*, 1951-52.

Date of Election

1935. *Andrewartha, Mrs. H. G., B.Agr.Sc., M.Sc. (nee H. V. Steele), 29 Claremont Avenue, Netherby, S.A.
1929. *Angel, F. M., 34 Fullarton Road, Parkside, S.A.
1939. *Angel, Miss L. M., M.Sc., Zoology Dept., University of Adelaide, North Terrace, Adelaide, S.A.
1960. Archbold, R. T., South Australian Museum, North Terrace, Adelaide, S.A.
1962. Auvaart, Mrs. R. I., c/o. South Australian Museum, North Terrace, Adelaide, S.A.
1962. Bagot, P. H., 62 Hawkers Road, Medindie, S.A.
1963. Baldock, R. N., B.Sc., 62 Robsart Street, Parkside, S.A.
1958. Bauer, F. H., Department of Geography, University College of Townsville, Townsville, Queensland.
1950. Beck, R. G., B.Ag.Sc., R.D.A., Lynewood Park, Mil-Lel, via Mount Gambier, S.A.
1932. Begg, P. R., D.D.Sc., L.D.S., Shell House, 170 North Terrace, Adelaide, S.A.
1928. Best, R. J., D.Sc., F.A.C.I., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1956. Black, A. B., A.S.A.S.M., M.I.M.M., 36 Woodcroft Avenue, St. Georges, S.A.
1934. Black, E. C., M.B., B.S., Magill Road, Tranmere, S.A.
1962. Blesing, Mrs. N. M., c/o. South Australian Museum, North Terrace, Adelaide, S.A.
1950. Bonnin, N. J., M.B., B.S., F.R.C.S. (Eng.), F.R.A.C.S., 19 Marlborough St., College Park, S.A.
1945. †*Bonython, C. W., B.Sc., F.R.A.C.I., Romalo House, Romalo Avenue, Magill, S.A.: *Council*, 1961-.
1945. *Boomsma, C. D., M.Sc., B.Sc.For., 6 Celtic Avenue, South Road Park, S.A.
1947. *Bowes, D. R., Ph.D. (Lond.), D.I.C., F.G.S., Department of Geology, University, Glasgow, Scotland.
1957. *Brookes, Miss H. M., Dept. of Entomology, Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1962. Brown, R. G., B.Sc., 3 Jenkins Avenue, Myrtle Bank, S.A.
1961. *Brownell, P. F., Ph.D., c/o. Department of Botany, University of Adelaide, Adelaide, S.A.
1957. Buick, W. G., B.A., c/o Public Library, North Terrace, Adelaide, S.A.
1944. *Burbidge, Miss N. T., M.Sc., C.S.I.R.O., Div. Plant Industry, P.O. Box 109, Canberra, A.C.T.
1958. Buring, I., 51 Richmond Road, Westbourne Park, S.A.
1922. *Campbell, Prof. T. D., D.D.Sc., D.Sc., 24 Lynington Street, Tusmore, S.A.—*Council*, 1928-32, 1935, 1942-45; *Vice-President*, 1932-34; *President*, 1934-35.
1960. Candler, C., 8 First Avenue, Glenelg, S.A.
1959. Carrodus, B. B., R.D.Oen., 26 Dequetteville Terrace, Kent Town, S.A.
1953. Carter, A. N., B.Sc., 8 Scott St., Maroubra Bay, N.S.W.
1960. Catley, D. E., 8 Cudmore Terrace, Whyalla, S.A.
1957. *Chippendale, G. M., B.Sc., Lindsay Avenue, Alice Springs, N.T.
1955. Clothier, E. A., Hydroelectric Commission, Hobart, Tas.
1949. Colliver, F. S., Geology Department, University of Queensland, St. Lucia, Brisbane, Q.
1962. Cobbett, D. W. P., Ph.D., F.G.S., c/o South Australian Museum, North Terrace, Adelaide, S.A.
1929. *Cotton, B. C., F.R.Z.S., J.P., 166 Wellington Road, Payneham, S.A.—*Council*, 1943-46, 1948-49; *Vice-President*, 1949-50, 1951-52; *President*, 1950-51; *Programme Secretary*, 1959-62.
1956. Crawford, A. R., B.Sc., Mines Department, 169 Rundle St., Adelaide, S.A.
1963. Crowcroft, W. P., M.Sc., D.Phil., South Australian Museum, North Terrace, Adelaide, S.A.
1956. Daily, B., Ph.D., Department of Geology, University of Adelaide, North Terrace, Adelaide, S.A.—*Programme Secretary*, 1957-59; *Council*, 1960-.
1962. Dalgarno, C. R., M.Sc., 2 Warrego Crescent, Linden Park, Adelaide, S.A.
1951. Davidson, A. L. C., Ph.D., B.Sc., c/o Messrs. Simpson & Brookman, 35 Grenfell St., Adelaide, S.A.
1930. Dix, E. V., Box 12, Aldgate, S.A.
1957. Doull, K. M., M.Ag.Sc., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1963. Drayton, R. D., B.Sc. (Hons.), 309 Oaklands Road, Marion, S.A.
1959. Dunlop, P. R. G., B.Sc., 13 Walton Ave., Clearview, S.A.
1944. Dunstone, S. M. L., M.B., B.S., 170 Payneham Road, St. Peters, S.A.
1931. Dwyer, J. M., M.B., B.S., 157 East Terrace, Adelaide, S.A.
1933. *Eardley, Miss C. M., M.Sc., F.L.S., Department of Botany, University of Adelaide, North Terrace, Adelaide, S.A.—*Council*, 1943-46.
1963. Eddy, N. G., 110 Mitchell Street, Darwin, N.T.

Date of Election

1945. *EDMONDS, S. J., B.A., Ph.D., Zoology Department, University of Adelaide, North Terrace, Adelaide, S.A.—*Council*, 1954-55; *Programme Secretary*, 1955-56, *Secretary*, 1956-57.
1902. *EDQUIST, A. G., 19 Farrell Street, Glenelg, S.A.—Council, 1949-53.
1962. *EDWARDS, R., Marion Road, Marion, S.A.
1956. *EICHLER, H., Dr.rer.nat., State Herbarium, Botanic Garden, North Terrace, Adelaide, S.A.
1960. FANDER, H. W., 15 Auburn Ave., Myrtle Bank, S.A.
1959. FIELDER, D. R., B.Sc., Dept. of Zoology, University College of Townsville, Townsville, Queensland.
1927. *FINLAYSON, H. H., 305 Ward St., North Adelaide, S.A. *Verco Medal*, 1960; *Council*, 1937-40.
1963. FIRMAN, J. B., B.Sc. (Hons.), 11 Wilkins Street, East Glenelg, S.A.
1951. FISHER, R. H., 21 Seaview Road, Lynton, S.A.
1958. *FORBES, B. G., Ph.D., F.G.S., 9 Flinders Road, Hillcrest, S.A.
1959. FORDE, N., Dip.For., C.S.I.R.O., Canberra, A.C.T.
1962. FOSTER, R. J., B.E., c/o P.E.D., B.S.P., Seria, State of Brunei, Borneo.
1962. FREYTAG, I. B., B.Sc., 2 Selway Street, Oaklands Park, S.A.
1954. GIBSON, A. A., A.W.A.S.M., Mines Department, 169 Rundle St., Adelaide, S.A.
1953. *GLAESSNER, M. F., D.Sc., F.A.A., Geology Department, University of Adelaide, North Terrace, Adelaide, S.A.—*Council*, 1953-54; *Vice-President*, 1958-59.
1935. †GOLDSACK, H., Coromandel Valley, S.A.
1963. GRAETZ, R. D., B.Sc. (Hons.), c/o. Botany Department, University of Adelaide, North Terrace, Adelaide, S.A.
1961. GREER, W. J., B.Sc., Delhi Australian Petroleum Ltd., 32 Grenfell St., Adelaide, S.A.
1962. GREGORY, G. C., M.B., B.S., Medical Practitioner, Leigh Creek, S.A.
1959. GREEN, Miss L. M. A., B.A., M.Sc., Dept. of Anatomy and Histology, University of Adelaide, North Terrace, Adelaide, S.A.
1948. GROSS, G. F., M.Sc., South Australian Museum, Adelaide, S.A.—*Secretary*, 1950-53.
1944. GUPPY, D. J., B.Sc., c/o W.A. Petroleum Co., 251 Adelaide Terrace, Perth, W.A.
1949. HALL, D. R., Tea Tree Gully, S.A.
1962. HAMILTON-SMITH, E., A.U.A., 17 Helwig Avenue, Montmorency, Vic.
1930. †HANCOCK, N. L., 3 Bewdley, 66 Beresford Road, Rose Bay, N.S.W.
1962. HARDING, J. H., B.Sc. (W.A.), 92 East Avenue, Clarence Park, S.A.
1946. *HARDY, MRS. J. E. (nee A. C. Beckwith), M.Sc., Stewart Ave., Salisbury, S.A.
1944. HARRIS, J. R., B.Sc., c/o Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1963. HARRIS, W. K., B.Sc., 49 George Street, Torrens Park, S.A.
1960. HARRISON, J., 7 McQuillan Ave., Renown Park, S.A.
1963. HAWKE, V. L., M.B., B.S., 43 Semaphore Road, Semaphore, S.A.
1958. HAYBALL, J. F., B.Sc., 68 Pleasant Avenue, Clandore, S.A.
1960. HAYMAN, D. L., Ph.D., Genetics Department, University of Adelaide, North Terrace, Adelaide, S.A.
1962. *HEATH, G. R., B.Sc. (Hons.), Department of Mines, 169 Rundle St., Adelaide, S.A.
1941. HERRIOT, R. I., B.Agr.Sc., 49 Halsbury Avenue, Kingswood, S.A.
1951. HOCKING, L. J., 46 Kauri Parade, Seacliff, S.A.
1963. HODGE, R. L., M.B., B.S., M.R.A.C.P., Department of Physiology, University of Adelaide, North Terrace, Adelaide, S.A.
1959. HORWITZ, R. G. H., D.Sc., Glenside Road, Woodbury Hill, Stirling West, S.A.
1924. *HOSSFELD, P. S., Ph.D., 132 Fisher Street, Fullarton, S.A.
1944. HUMBLE, D. S. W., M.P.S., J.P., 238 Payneham Road, Payneham, S.A.
1947. *HUTTON, J. T., B.Sc., A.S.A.S.M., 10 Bellevue Place, Unley Park, S.A.—*Council*, 1957-61; *Vice-President*, 1961-62; *President*, 1962-63.
1928. IFOULD, P., 14 Wyatt Road, Burnside, S.A.
1960. INGHAM, L. J., 34 Lexington Road, Henley South, S.A.
1945. *JESSUP, R. W., M.Sc., 6 North Penno Parade, Belair, S.A.—*Council*, 1961-.
1950. *JOHNS, R. K., B.Sc., Department of Mines, 169 Rundle St., Adelaide, S.A.
1957. JOHNSON, B., B.Sc.Agr., Ph.D., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1958. *JOHNSON, W., B.Sc. (Hons.), 33 Ryan Avenue, Woodville West, S.A.
1963. JONES, J. B., Ph.D., Geology Department, University of Adelaide, North Terrace, Adelaide, S.A.
1954. KEATS, A. L., B.E., 44 LeFevre Terrace, North Adelaide, S.A.
1962. KENNY, MRS. M., c/o South Australian Museum, Adelaide, S.A.
1939. †KHAKHAR, H. M., Ph.D., M.B., F.R.G.S., Khakhar Buildings, C.P. Tank Road, Bombay, India.

Date of Election

1962. KING, MISS M. J. E., Mus.Bac., A.U.A., "Mirrabooka", Wilpena St., Eden Hills, S.A.
1919. *KING, D., M.Sc., c/o Utah Development Co., Room 37A, T. & G. Bldg., Brisbane, Q.
1933. *KLEEMAN, A. W., Ph.D., Dept. of Geology, University of Adelaide, North Terrace, Adelaide, S.A. *Secretary*, 1945-48; *Vice-President*, 1948-49, 1950-51; *President*, 1949-50.
1960. KUCHEL, R. H., Roseworthy Agricultural College, Roseworthy, S.A.
1941. *LANGFORD-SMITH, T., B.A., M.Sc., Ph.D., Dept. of Geography, University of Sydney, Sydney, N.S.W.
1962. LAWS, D. F., M.A., B.D., Ph.D., Zoology Dept., University of Adelaide, Adelaide, S.A.
1922. LENDON, G. A., M.D., B.S., F.R.C.P., c/o. Elder's Trustee and Executor Co. Ltd., 37 Currie Street, Adelaide, S.A.
1958. LINDSAY, H. A., 110 Cross Road, Highgate, S.A.
1948. LOTHIAN, T. R. N., N.D.H. (N.Z.), Director, Botanic Garden, Adelaide, S.A.—*Treasurer*, 1952-53; *Council*, 1953-57; *Vice-President*, 1957-58, 1960-61; *President*, 1958-60.
1931 *LUDBROOK, MRS. N. H., M.A., Ph.D., D.I.C., F.G.S., Department of Mines, 169 Rundle St., Adelaide, S.A.—*Council*, 1958-60; *Vice-President*, 1960-61; *President*, 1961-62; *Vice-President*, 1962-63.
1953. MAELZER, D. A., Ph.D., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1963. MARCUS, J., c/o, South Australian Museum, North Terrace, Adelaide, S.A.
1939. MARSHALL, T. J., M.Agr.Sc., Ph.D., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.—*Council*, 1948-52.
1959. *MARTIN, MISS H. A., c/o Department of Botany and Biology, University of British Columbia, Vancouver 8, Canada.
1950. MAYO, G. M. E., B.Ag.Sc., Ph.D., 29 Angas Rd., Lower Mitcham, S.A.
1920. MAYO, SIR HERBERT, LL.B., Q.C., 90 Northgate St., Unley Park, S.A.
1963. McBRIAR, E. M., M.Sc., University of Adelaide, North Terrace, Adelaide, S.A.
1948. McCULLOCH, R. N., M.B.E., B.Sc., B.Agr.Sc., c/o. Board of Tick Control, Box 54, Lismore, N.S.W.
1945. †*MILES, K. R., D.Sc., F.G.S., 11 Church Road, Mitcham, S.A.
1962. MILLS, K. J., B.Sc., 17 Denis Street, St. Marys, S.A.
1952. MILNE, K. L., F.C.A., 14 Burlington Street, Walkerville, S.A.
1939. MINCHAM, V. H., 30 Wainhouse Street, Torrensville, S.A.
1958. *MIRAMS, R. C., B.Sc., 5 Myrtle Rd., Seacliff, S.A.
1951. *MITCHELL, F. J., South Australian Museum, North Terrace, Adelaide, S.A.—*Treasurer*, 1959-.
1959. MITCHELL, MRS. F. J., M.Sc., Francis Street, Belair, S.A.
1933. MITCHELL, PROF. SIR M. L., M.Sc., c/o Elder's Trustee and Executor Co. Ltd., 37 Currie Street, Adelaide.
1936 *MOUNTFORD, C. P., 25 First Avenue, St. Peters, Adelaide, S.A.
1957. *MUMME, IVAN A., B.Sc. (Hons.), c/o Australian Atomic Energy Commission, P.O., Coogee, N.S.W.
1962. NEWSOME, A., B.Sc., Animal Industry Branch, N.T. Administration, Box 280, Alice Springs, N.T.
1944. NINNES, A. R., B.A., R.D.A., 62 Sheffield Street, Malvern, S.A.
1962. NIXON, L. G. B., B.Sc., 3 Sweetwater St., Seacombe Gardens, S.A.
1945. *NORTHCOTE, K. H., B.Agr.Sc., A.I.A.S., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.
1930. OCKENDEN, G. P., B.A., 68 Holbrooks Rd., Flinders Park, S.A.
1956. O'DRISCOLL, E. S., B.Sc., 9 Vinall Street, Dover Gardens, S.A.
1963. *OFFLER, R., B.Sc. (Hons.), Geology Department, University of Adelaide, North Terrace, Adelaide, S.A.
1963. OLIVER, R. L., Ph.D., Geology Department, University of Adelaide, North Terrace, Adelaide, S.A.
1937. *PARKIN, L. W., M.Sc., A.S.T.C., Department of Mines, 169 Rundle St., Adelaide, S.A.—*Secretary*, 1953-56; *Vice-President*, 1956-57, 1958-59; *President*, 1957-58.
1949. PARKINSON, K. J., B.Sc., 91 Sturt St., Hillcrest, S.A.
1929. PAULL, A. G., M.A., B.Sc., 10 Milton Avenue, Fullarton Estate, S.A.
1926. *PIPER, C. S., D.Sc., C.S.I.R.O., 3 Fowlers Rd., Glenunga, S.A.—*Verco Medal*, 1957; *Council*, 1941-43; *Vice-President*, 1943-45, 1946-47; *President*, 1945-46.
1963. PITMAN, M. G., M.A., Ph.D., 12 Francis Avenue, Fullarton, S.A.
1948. POWRIE, J. K., B.Sc., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1925. *PRESCOTT, PROF. J. A., C.B.E., D.Sc., F.R.A.C.I., F.R.S., F.A.A., 82 Cross Road, Myrtle Bank, S.A.—*Verco Medal*, 1938; *Council*, 1927-30, 1935-39; *Vice-President*, 1930-32; *President*, 1932-33; *Editor*, 1955-62; *Council*, 1962-63.

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1961. PRETTY, G. L., B.A., c/o South Australian Museum, Adelaide, S.A.
1957. *PRINGLE, MISS L. A. B., Box 876G, G.P.O., Adelaide, S.A.
1945. *PRYOR, L. D., M.Sc., Dip.For., 32 La Perouse Street, Griffith, Canberra, A.C.T
1950. *RATTIGAN, J. H., M.Sc., Newcastle University College, Tigh's Hill, 2N, N.S.W.
1944. RICEMAN, D. S., D.Sc., B.Agr.Sc., C.S.I.R.O., Division of Biochemistry, Adelaide, S.A.
1947. RIEDEL, W. R., B.Sc., c/o Scripps Institution of Oceanography, Dept. of Palaeontology, University of California, La Jolla, California, U.S.A.
1963. ROBERTSON, PROF. R. N., F.R.S., F.A.A., D.Sc., Ph.D. (Camb.), Department of Botany, University of Adelaide, North Terrace, Adelaide, S.A.
1953. ROGERS, PROF. W. P., D.Sc., Ph.D., F.A.A., M.I.Biol., Zoology Dept., University of Adelaide, North Terrace, Adelaide, S.A.
1951. ROWE, S. A., 22 Shelley Street, Firle, S.A.
1950. RUDD, PROF. E. A., B.Sc., A.M., University of Adelaide, North Terrace, Adelaide, S.A.
1951. RUSSELL, L. D., c/o Adelaide Boys' High School, West Terrace, Adelaide, S.A.
1963. RUSSELL, R. E., M.B., B.S., M.R.A.C.P., 267 Portrush Road, Glenunga, S.A.
1945. RYMILL, J. R., Old Penola Estate, Penola, S.A.
1933. SCHNEIDER, M., M.B., B.S., 175 North Terrace, Adelaide, S.A.
1959. SCHODDE, R., Division of Land Research and Divisional Survey, C.S.I.R.O., Canberra, A.C.T.
1951. *SCOTT, T. D., M.Sc., Western Teachers' College, Taylors Rd., Thebarton, S.A.—*Programme Secretary*, 1953-54, 1956-57; *Secretary*, 1957-.
1925. *SHEARD, H., Port Elliot, S.A.
1930. *SHEARD, K., D.Sc., 19 Webster St., Nedlands, W.A.
1954. SHEPHERD, R. C., B.Sc., c/o Department of Mines, 169 Rundle St., Adelaide, S.A
1961. SHEPHERD, S. A., B.A., LL.B., 5 Rosevear St., Hawthorn, S.A.
1934. SHINKFIELD, R. C., 57 Canterbury Avenue, Trinity Gardens, S.A.
1962. SMALE, D., M.Sc., c/o Department of Mines, Rundle St., Adelaide, S.A.
1925. ‡SMITH, SIR TOM BARR, Kt., B.A., 25 Currie Street, Adelaide, S.A.
1941. *SOUTHCOTT, R. V., M.D., B.S., D.T.M. & H., 13 Jasper Street, Hyde Park, S.A.—*Council*, 1949-51, 1952-53, 1957-60; *Treasurer*, 1951-52; *Vice-President*, 1953-54, 1955-56, 1961-62; *President*, 1954-55, 1960-61.
1947. *SPECHT, R. L., Ph.D., Botany Department, University of Melbourne—*Verco Medal*, 1961; *Council*, 1951-52, 1958-60; *Programme Secretary*, 1952-53; *Vice-President*, 1961.
1936. ‡*SPRIGG, R. C., M.Sc., 5 Baker Street, Somerton Park, S.A.
1949. *SPRY, A. H., M.Sc., Geology Department, University of Tasmania, Hobart, Tas.
1951. STEADMAN, REV. W. R., 8 Blairgowrie Road, St. Georges, S.A.
1938. *STEPHENS, C. G., D.Sc., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.—*Verco Medal*, 1959; *Council*, 1952-54; *Vice-President*, 1954-55, 1956-57; *President*, 1955-56.
1955. SWAINE, C. D., M.B., B.S., 220 Esplanade, Largs North, S.A.
1962. SWINBOURNE, R. F. G., Box 210, P.O., Alice Springs, N.T.
1951. SWIRSKI, P., M.Ag.Sc., 13 Derwent Ave., Rostrevor, S.A.
1962. *SYMON, D. E., B.Ag.Sc., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1960. SYMONS, E. F., Uranium Treatment Plant, Port Pirie, S.A.
1934. SYMONS, I. G., 35 Murray Street, Lower Mitcham, S.A.—*Editor*, 1947-55; *Council*, 1955-58
1963. *TALBOT, J. L., M.A., Ph.D., University of Adelaide, North Terrace, Adelaide, S.A.
1958. TAYLOR, D. J., Dept. of Entomology, Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1959. TAYLOR, D. J., 23 Westbourne St., Prahran East, Vic.
1929. *TAYLOR, J. K., B.A., M.Sc., B.Sc.Agr., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.—*Council*, 1940-43, 1947-50; *Librarian*, 1951-52; *Vice-President*, 1952-53, 1954-55; *President*, 1953-54; *Editor*, 1962-.
1961. TEAGUE, F. A., c/o Post Office, Hawker, S.A.
1962. TEUSNER, R. E., LL.B., c/o. Post Office, Tanunda, S.A.
1948. *THOMAS, I. M., M.Sc. (Wales), M.I.Biol., Department of Zoology, University of Adelaide, S.A.—*Secretary*, 1948-50; *Council*, 1950-53; *Vice-President*, 1955-56, 1957-58; *President*, 1956-57; *Assistant Editor*, 1958-.
1938. *THOMAS, MRS. I. M. (nee P. M. Mawson), M.Sc., Department of Zoology, University of Adelaide, North Terrace, Adelaide, S.A.
1957. THOMAS, J., B.Sc., Woodleigh Road, Blackwood, S.A.
1959. THOMSON, B. P., M.Sc., 33 Oaklands Road, Parkholme, S.A.
1940. *THOMSON, CAPT. J. M., 135 Military Road, Semaphore South, S.A.

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1923. *TINDALE, N. B., B.Sc., South Australian Museum, North Terrace, Adelaide, S.A.—*Verco Medal*, 1956; *Secretary*, 1935-36; *Council*, 1946-47; *Vice-President*, 1947-48, 1949-50; *President*, 1948-49; *Librarian*, 1952-.

1955. *TUCKER, B. M., B.A., B.Sc., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.

1959. TWIDALE, C. R., Ph.D., M.Sc., Dept. of Geography, University of Adelaide, North Terrace, Adelaide, S.A.

1959. *TYLER, M. J., Dept. of Physiology, University of Adelaide, North Terrace, Adelaide, S.A.—*Programme Secretary*, 1962-.

1960. TYNAN, A. E., c/o Australian Mineral Development Laboratories, Flemington St., Parkside, S.A.

1950. VEITCH, J. T., Box 92, Port Lincoln, S.A.

1953. WATERMAN, R. A., B.A., M.A., Ph.D., Wayne State University, Detroit, Michigan, U.S.A.

1954. *WEBB, B. P., M.Sc., Department of Mines, 169 Rundle St., Adelaide, S.A.

1954. WELLS, C. B., M.Ag.Sc., Broadlees, Waverley Ridge, Crafers, S.A.

1959. WHELAN, PROF. R. F., M.D., Ph.D., D.Sc., Department of Physiology, University of Adelaide, North Terrace, Adelaide, S.A.

1962. WHITTEN, G. F., B.Sc., c/o Department of Mines, Rundle Street, Adelaide, S.A.

1946. *WHITTLE, A. W. G., M.Sc., Department of Economic Geology, University of Adelaide, North Terrace, Adelaide, S.A.

1950. WILLIAMS, L. D., "Dumosa," Meningie, S.A.

1946. *WILSON, PROF. A. F., D.Sc., Dept. of Geology, University of Queensland, St. Lucia, Brisbane, Qld.

1961. *WILSON, P. G., B.Sc., c/o Botanic Garden, North Terrace, Adelaide, S.A.

1954. *WOMERSLEY, H. B. S., D.Sc., Botany Department, University of Adelaide, North Ter-Adelaide, S.A.—*Council*, 1960-.

1944. WOMERSLEY, J. S., B.Sc., Dept. of Forests, Lae, New Guinea.

1957. WOODS, R. V., B.Sc., Mt. Crawford, S.A.

1960. *WOPFNER, H., Ph.D., 16 Reece Ave., Klemzig, S.A.

1949. YEATES, J. N., A.M.I.E., A.M.I.M.E., Highways and Local Government Dept., Adelaide, S.A.

1944. ZIMMER, W. J., Dip.For., F.L.S. (Lond.), 7 Rupert St., Footscray West, W.12, Vic.

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