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UPPER MESOZOIC MICROFLORAS FROM SOUTH-EASTERN AUSTRALIA

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Abstract

Dispersed spores from Upper Mesozoic sediments of SE. Australia are described in detail and an account is given of their stratigraphical and geographical distribution. The samples examined are broadly representative of the partly marine Upper Mesozoic sequence developed in the South Australian portion of the Great Artesian Basin and the non-marine successions of the Otway Basin and E. Victoria. This paper includes systematic descriptions of 110 dispersed-spore species embracing 60 genera. 25 new species and 5 new genera are proposed, and the diagnoses of 7 genera have been amended. Serial sections of 28 species, including azonate, zonate, and saccate forms, are discussed, and it is shown that sections aid the elucidation of wall features. Consideration is given to relevant problems in dispersed-spore nomenclature and taxonomy, and the system initiated by Potonié and Kremp for the classification of forms referable to the Anteturma Sporites H. Potonié is revised. Botanical relationships are indicated for certain of the spore taxa. 3, distinct, successive, microfloral assemblages are distinguishable in sediments examined from the Great Artesian Basin and from elsewhere in SE. Australia. The presence in each of the microfloras of species recorded previously from both within and without Australia permits inter-Australian and world-wide correlation. Evidence is adduced as to the ages of the microfloras and it is concluded that they are of probable lowermost Cretaceous (Valanginian or older), Valanginian-Aptian, and Aptian-Albian ages respectively.

Introduction

The present account incorporates the results of a detailed investigation of dispersed spores from SE. Australian Upper Mesozoic strata. The object of this study was twofold: firstly, to describe systematically the spores, and secondly, to utilize the spores in the inter-Australian and world-wide correlation of SE. Australian Upper Mesozoic sediments.

Results of preliminary palynological (spore) analyses of Mesozoic deposits from E. Australia were presented by Cookson (1953, 1954), Cookson and Dettmann (1958a, b; 1959a, b), and Dettmann (1959). These authors demonstrated that regional correlations of E. Australian Mesozoic strata are possible by means of the microfloras contained therein. The material upon which their investigations were based include marine and non-marine samples from scattered outcrops and bore sequences in the Great Artesian Basin, Victoria, Queensland, and Papua. The majority of the samples yielded diverse and well-preserved microfloras which suggested a Lower Cretaceous age. Further evidence for such an age is provided by numerous other samples, recorded herein, from well-documented reference sequences in the Great Artesian and Otway Basins.

Many of the SE. Australian spore types are referable to spore species previously described from other parts of the world. The spore species are based on morphological criteria and are assigned to similarly based generic categories (form genera). These form categories are classified into an artificial system since the botanical affinities of the larger majority of pre-Quaternary dispersed spore forms are unknown. Nomenclature of the taxa of generic and lower rank is determined by the rules of priority and typification as laid down in the International Code of Botanical Nomenclature (1961, Montreal). Unlike nomenclature, classification of the spore entities is not subject to any international control, and various classification systems have been formulated since palynology was founded during the last century.

The most comprehensive classification scheme presented to date is the one first proposed by Potonié and Kremp (1954) and subsequently amplified by these authors (1955, 1956) and Potonié (1956, 1958, 1960). This system, however, is not entirely satisfactory in that many of the suprageneric categories are arbitrarily based, and hence the framework of the system lacks complete uniformity. Certain of the anomalies in Potonié and Kremp's system are considered subsequently, and the scheme presented by these authors for the classification of Sporites H. Potonié is revised.

Within the systematic section certain important European Mesozoic spore species instituted by Delcourt and Sprumont (1955) and Couper (1958) are redescribed. The descriptions are based on type specimens from the collections of M. Delcourt, Ath, Belgium, and of the Sedgwick Museum, Cambridge. In addition, a Lower Tertiary species that was originally described by Cookson (1947) from Kerguelen is redefined on the basis of the holotype and of additional specimens obtained from a sample lodged in the British Museum of Natural History.

Acknowledgements

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Fig. 1—Map of SE. Australia showing principal outcrops of Upper Mesozoic strata (in heavy black), approximate boundaries of sedimentary basins, and location of samples investigated.

Outline of Stratigraphy

Upper Mesozoic sediments of SE. Australia are most extensively exposed in the S. portion of the Great Artesian Basin, the Otway Basin, and in E. Victoria. They have also been encountered in water bores and oil exploratory wells in the Murray Basin. Bore and outcrop samples collected from these areas constitute the basis of the present study; the sampling localities are indicated on Fig. 1, and a summary of the data relevant to the samples is presented in Appendix II. The collections are far from comprehensive but are broadly representative of the partly marine Upper Mesozoic sequence of the South Australian portion of the Great Artesian Basin and the non-marine sequences developed in the Otway Basin and E. Victoria. A brief summary of the Mesozoic stratigraphy in each of these areas is presented below. Age deductions quoted are largely those based on faunal, microplankton, and megafloral evidence; a reappraisal of the ages of the megafloras recorded from the strata under consideration and a brief account of previous palynological investigations on Australian Upper Mesozoic strata is incorporated in subsequent sections of this paper.

GREAT ARTESIAN BASIN (SOUTH AUSTRALIAN PORTION)

This area, as defined by Sprigg (in Glaessner and Parkin 1958), occupies the NE. part of South Australia, E. from longitude 134°E and N. from latitude 31½°S (see Fig. 1). Within this area Upper Mesozoic sediments are extensively exposed about the Stuart Ranges and near the Queensland and Northern Territory borders where they attain a thickness of over 5,000 ft. Along the SW. margin of the basin Upper Mesozoic rocks rest unconformably on Permian shales and intercalated coals, and around, and northwards from, Lake Eyre and Lake Frome they are overlain by Tertiary sandstones.

As outlined by Sprigg (in Glaessner and Parkin 1958), equivalents of the Upper Mesozoic Blythesdale and Rolling Downs Groups, which are typically developed in Queensland, are represented in the South Australian portion of the Great Artesian Basin. The formational nomenclature used by these authors is adopted here, although it is now understood that new formational names are to be proposed for use in South Australia (fide N. H. Ludbrook). Samples from two bores (Oodnadatta Bore No. 1 and Cootabarlow Bore No. 2) sunk in the South Australian portion of the Great Artesian Basin form an important basis for the present study; the bore successions and the intervals that have been examined palynologically are depicted on Fig. 2 (see also Appendix II).

BLYTHESDALE GROUP

Sediments of this group consist of sandstones, grits, and subordinate shales. Exposures on the eastern slopes of the Flinders Ranges contain non-marine molluscs, thought to be Lower Cretaceous (Neocomian) in age (Ludbrook 1961a), and megaplants (Glaessner and Rao 1955, see also Woodard 1955). Horizons in the 1,052-61 ft interval in the Oodnadatta bore have been determined as Aptian or older on the basis of microplankton (Cookson and Eisenack 1960b; Eisenack and Cookson 1960). Sprigg (in Glaessner and Parkin 1958, p. 91, 94) states that the Blythesdale Group as developed in South Australia 'may include pre-Cretaceous deposits, such as equivalents of the Jurassic Walloon Formation of Queensland, and even Triassic'.

ROLLING DOWNS GROUP

Exposures of this group occur over wide areas in South Australia. Its accepted subdivisions, the Roma Formation (marine Aptian), Tambo Formation (marine

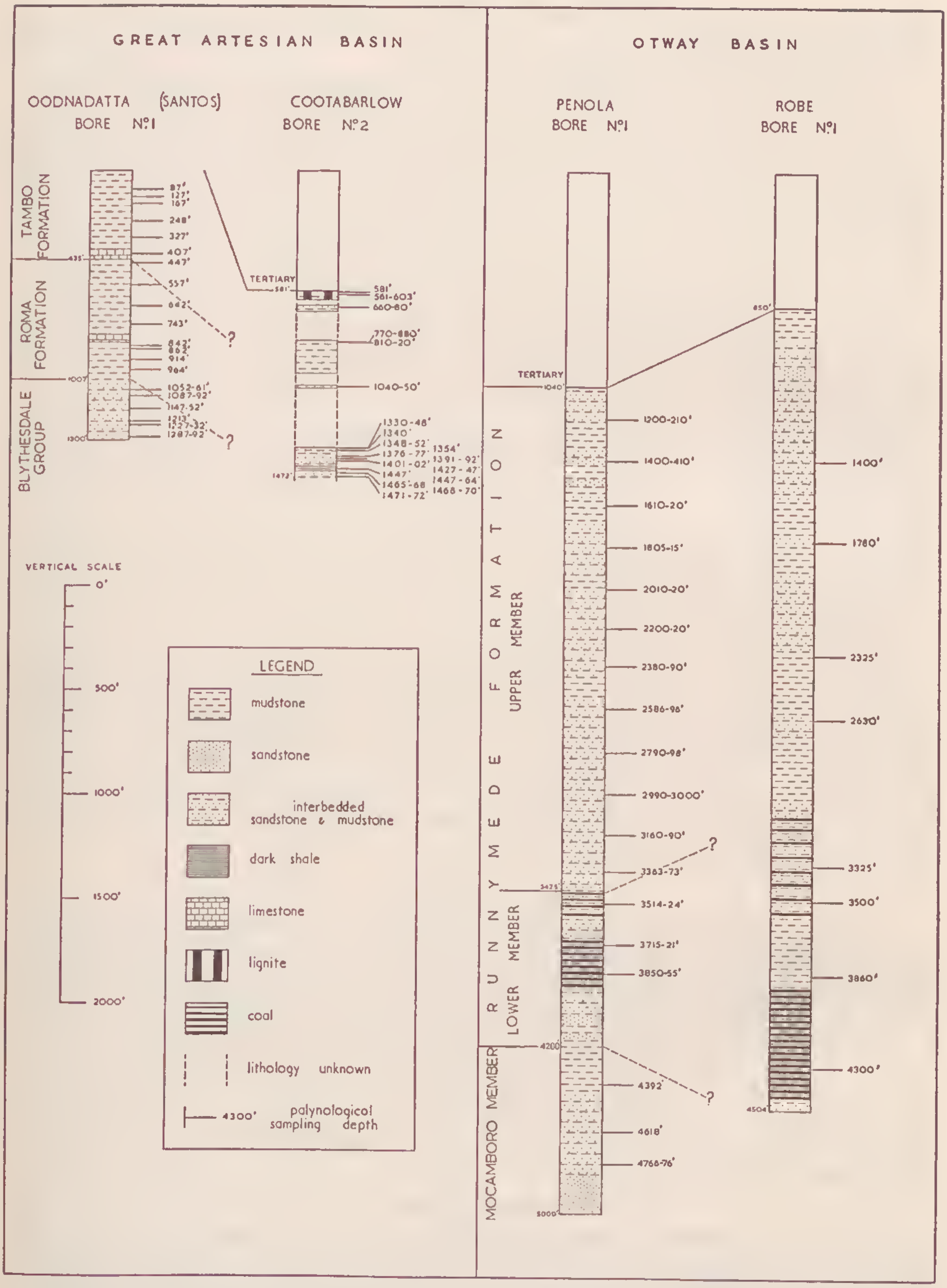

FIG. 2—Stratigraphical columns of the Upper Mesozoic sequences intersected in Oodnadatta (Santos) Bore No. 1 and Cootabarlow Bore No. 2 in the Great Artesian Basin and Penola Bore No. 1 and Robe Bore No. 1 in the Otway Basin. The columns have been compiled from data given by Sprigg in Glaessner and Parkin (1958), Whittle and Chebotarev (1952), O'Driscoll (1960), and Ludbrook (1963a, b).

Albian), and the Winton Formation (lagoonal to lacustrine Upper Cretaceous) can only be adequately distinguished on palaeonotological evidence; lithological criteria are of limited application (Sprigg loc. cit.).

The Roma Formation which is exposed in the marginal areas of the basin consists of dark mudstones, siltstones, and occasional sandy bands and calcareous layers. In the Oodnadatta bore the sequence is 570 ft thick and contains several species of *Maccoyella* identical to those described from the four ammonite stages of Queensland (Sprigg loc. cit.). The Queensland ammonite stages have been correlated with four stages of the European Aptian by Whitehouse (1926) who demonstrated that, in the absence of ammonites, the evolutionary series of the maccoyellids can be used for zoning. Sprigg (loc. cit.) quotes that the four Queensland stages as well as an additional upper stage are represented in the Oodnadatta bore. Strata at 1,354 ft in Cootabarlow Bore No. 2 are believed to be Aptian on the basis of foraminifera (Ludbrook 1963a; South Australian Department of Mines Palaeontological Report 14/56, 1956 unpublished) and microplankton (Cookson and Eisenack 1958).

The Tambo Formation outcrops in the SW. part of the basin and includes richly fossiliferous calcareous shales with limestone layers and interbedded sandstones which total about 650 ft in thickness. In the Oodnadatta bore the basal beds, termed the 'Terebratella beds', rest conformably on the Roma Formation. The 'Terebratella beds' contain *Lingula* and *Terebratella* and are assigned to the Lower Albian (Sprigg loc. cit.). Stratigraphically higher beds contain a rich Middle and Upper Albian fauna characterized by *Falciferella, Aucellina, Inoceramus,* and *Dimitobelus* (Sprigg loc. cit.; Brunnschweiler 1959).

Exposures of the Winton Formation occur in the NE. part of the state and consist of shales, siltstones, sandstones, and interbedded layers of sandy limestones comprising a thickness of 350 ft. Freshwater molluscs (*Unio* sp.) and megaplant remains (*Brachyphyllum, Elatocladus*) have been recorded from the sediments which are considered to be early Upper Cretaceous (probably Cenomanian) in age (Sprigg loc. cit.; Sprigg in Cookson and Dettmann 1959b). Microfloras recovered from samples (Haddon Downs Bore No. 5) of this formation have not been described in detail; only previously described species, the majority of which occur also in the underlying formations, are recorded (see Tables 5, 6).

MURRAY BASIN

The Murray Basin embraces a large area in New South Wales and the adjoining areas in South Australia and Victoria (see Woods 1883; Ludbrook 1961b; Condon, Fisher, and Terpstra 1960; present study, Fig. 1). This area is covered by Tertiary strata, but Mesozoic sediments have been encountered in bores sunk at Loxton. Carbonaceous shales from 1,586 ft in one of these bores (Australian Oil and Gas Corporation, Loxton Bore) contain an impoverished and poorly preserved foraminiferal fauna, and 'on somewhat negative evidence, the age of the sediments was determined as Albian' (Ludbrook 1961b, p. 12). Two samples taken from above this level (at 1,465-70 ft and 1,410-15 ft) in the same bore have been investigated in the present study.

OTWAY BASIN

This basin, as recently defined (see McQueen 1961; Condon et al. 1960; present study, Fig. 1), occupies the area S. of the Padthaway Horst in South Australia (Gambier Sunklands) and SW. Victoria (Portland Sunklands). Non-marine Mesozoic sediments outcrop in the valley of the Glenelg River (Merino Group), the

Otway Ranges (Otway Group), and the Barrabool Hills (Barrabool Sandstone) and have been encountered in bores elsewhere in W. Victoria and SE. South Australia.

Bores sunk in Victoria, at Nelson, Port Campbell, and Port Fairy, have penetrated marine Upper Mesozoic strata which rest on probable equivalents of the Otway Group and which are overlain by Tertiary rocks. Cores retrieved from a bore at Port Fairy (Belfast Bore No. 4) contain several incomplete ammonite specimens of probable Upper Cretaceous age (Kenley 1959) and microplankton indicative of a Senonian age (Cookson and Eisenack 1961). Senonian microplankton assemblages occur in the Nelson Bore sediments between 5,304 ft and 6,233 ft (Cookson and Eisenack 1960a, 1962; see also Baker and Cookson 1955); the upper horizon of this interval also contains *Cyclammina* (Crespin 1954). Marine Upper Cretaceous strata have not been examined in the present study, since these sediments are being investigated palynologically by Dr P. R. Evans of the Bureau of Mineral Resources and Mr J. G. Douglas of the Mines Department of Victoria. Cookson and her collaborators and Douglas (1961a) have already recorded several spore and microplankton species from certain of the Upper Cretaceous horizons.

The Merino Group rests with angular unconformity on Palaeozoic rocks and consists of carbonaceous siltstones and mudstones (Moeamboro Member) disconformably overlain by felspathic sandstones and mudstones of the Runnymede Formation (Kenley 1954). Both units contain megafloras which, according to Kenley (loc. cit.) and Medwell (1954a, b), indicate a Lower-?Upper Jurassic age for the Mocamboro Member and a Lower Cretaceous age for the Runnymede Formation. Probable equivalents of the Merino Group have been intersected beneath Tertiary strata in bores at Penola, Robe, and Comaum in South Australia. Penola Bore No. 1 passed through almost 4,000 ft of Mesozoic sandstones, siltstones, mudstones, and subordinate coals before drilling was abandoned; the sediments below 4,200 ft are thought to be equivalents of the Moeamboro Member and those in the 1,054-4,200 ft interval probably represent the Runnymede Formation (Ludbrook 1963b; present study, Fig. 2). Ludbrook (1961b) tentatively suggested that the Runnymede Formation is represented both in Comaum Bore No. 2 (between 650 ft and 708 ft) and in Robe Bore No. 1 (between 1,400 ft and 4,300 ft).

(Note: The stratigraphic terms Runnymede Formation and Moeamboro Member have been used here in the sense of the O.D.N.L. Penola No. 1 well completion report (Cundill and Bollen 1961, Ludbrook 1963b). The present work provides no independent evidence as to the validity of the correlation of these units with beds at the type section, Killara Bluff, originally described by Kenley (1954).)

Sediments lithologically similar to those of the Merino Group form the Otway Group in the Otway Ranges and the Barrabool Sandstone in the Barrabool Hills. The latter unit also contains conglomerates near the base which rests on Silurian strata (Coulson 1930, 1960). Megafloras from both units were re-assessed by Medwell (1954a) who assigned the strata to the Lower Jurassic.

EASTERN VICTORIA

Mesozoic sediments of E. Victoria consist of a non-marine sequence of interbedded mudstones and felspathic sandstones together with minor amounts of grits, conglomerates, and bituminous coal seams (Edwards and Baker 1943). They outcrop over large areas in the Gippsland Highlands (Strzelecki Group), where the Wonthaggi Coal Measures are developed, and N. of the Latrobe River (Tyers Group). To the E. of Wonthaggi over 5,000 ft of non-marine Mesozoic sediments occur beneath Tertiary strata in the Gippsland Sunklands (Webb 1961; Boutakoff 1956). Cores (between 3,949 ft and 4,004 ft) from Bengworden South Bore No. 1

sunk in the Gippsland Sunklands have yielded Cretaceous foraminifera (Taylor in Webb 1961); one of the cores (from 3,977 ft) has been investigated in the present study.

Comprehensive accounts of the geology of the Strzelecki Group are given by Edwards and Baker (1943) and Edwards, Baker, and Knight (1944) who estimate that the strata total 4,000 ft in thickness. Plant megafossils occur in many horizons and have recently been estimated as indicative of a Lower Jurrasic age (Medwell 1954a).

As outlined by Philip (1958) the sediments of the Tyers Group total 2,000 ft in thickness and rest unconformably on Siluro-Devonian strata. Plant megafossils have been reported from several horizons, including the massive basal conglomerates (Douglas 1962; see also Medwell 1954a). Medwell assigned the megafloras that she investigated to the Lower Jurassic.

Victorian and South Australian Mesozoic Megafloras

Much has been written about Victorian Mesozoic megafloras (the Triassic Bacchus Marsh flora is excluded from this account), the ages and identifications of which have been subject to some controversy since the middle of the nineteenth century. An important contribution to our knowledge of megafloras contained in strata of the Strzelecki and Otway Groups was presented by Seward in 1904. However, a comprehensive account of Victorian Mesozoic megafloras was lacking until 1954 when Medwell re-examined all available material collected from the Tyers, Strzelecki, Otway, and Merino Groups and the Barrabool Sandstone. According to Medwell (1954a) the megaplants are preserved as carbonaccous impressions, and, with the exception of two gymnospermous species studied by Florin (1952) and Douglas (1961b), their cuticular structure is unknown. In situ spores have not been reported despite the fact that fertile filicean specimens were illustrated by Seward (1904).

The collection studied by Seward (1904, p. 183) includes 10 forms which he considered as 'almost indistinguishable' from types represented in the Inferior Oolite Series of England and the Rajmahal Formation of India. These comprise: **Lycopodites victoriae* Seward, **Coniopteris hymenophylloides* Brongn. var. *australica* Seward, *Taeniopteris daintreei* McCoy (= *T. spatulata* Oldham & Morris), **Cladophlebis denticulata* Brongn. var. *australis* Seward (= *C. australis* (Morris)), *Baiera australis* McCoy (= *Ginkgoites australis* (McCoy)), *B. delicata* Seward, *Nilssonia* sp., *Araucarites* sp., *Ginkgo* sp., and *Taxites* sp. On this evidence Seward assessed that the flora is of a Jurassic age. Three representatives of the Pteridophyta marked * above are now considered by Harris, T. M. (1961) to be distinct from the English Middle Jurassic species with which they originally were compared; Harris's forthcoming account of the Gymnospermae of the Yorkshire flora may well provide further information as to the precise identity of the Victorian gymnospermous species.

Medwell (1954a) after re-examining collections studied by McCoy (1867 and later), Chapman (1908, 1909), Seward (1904), and others concluded a Lower Jurassic age for the flora. This age estimation was based on the occurrence of 'both Triassic and Jurassic elements' (Medwell 1954a, p. 102). The 'Triassic elements' include *Neocalamites, Dicroidium, Thinnfeldia, Ginkgoites,* and *Czekanowskia* which occur in the Triassic floras of Tasmania and/or Queensland (Ipswich, Esk, Bundamba). However, *Neocalamites, Thinnfeldia, Ginkgoites,* and *Czekanowskia,* at least, are now known from Jurassic ('Walloon') and Lower Cretaceous (Blythesdale, Burrum, and Styx floras of Queensland (see Bryan and Jones 1946, Walkom

1928, Whitehouse 1955, Hill and Denmead 1960). The 'Jurassic elements' include *Sphenopteris hispoli* Oldham & Morris, *'Coniopteris hymenophylloides', Cladophlebis australis, Taeniopteris spatulata, T. crenata* McClelland, *Araucarites*, etc. As noted by Medwell the majority of these forms occur in the Indian Rajmahal Formation (see Sitholey 1955), from which Spath (1933) reported Lower Cretaceous ammonites. Arkell (1956) supports Spath and quotes an Upper Neocomian age, despite the persistent Indian belief (see Wadia 1953) that the Rajmahal Formation is Lower or Middle Jurassic in age. Within Australia *Taeniopteris spatulata* and *Cladophlebis australis* are particularly common in the Jurassic ('Walloon') and Lower Cretaceous (Blythesdale) floras of the Queensland portion of the Great Artesian Basin. Whitehouse (1955, p. 10) notes that the abundance of these two species 'is purely a facies flora; and that when other facies occur, a richer flora, even with *Thinnfeldia*, appears'. Whitehouse (loc. cit.) further quotes that, since *Thinnfeldia* and *Taeniopteris spatulata* range extensively within the Mesozoic, it is erroneous to assume that Australian '*Thinnfeldia* floras are Triassic and those with *Taeniopteris spatulata* are Jurassic, and Lower Cretaceous'. Thus, from the available evidence the Victorian megafloras may be Triassic, Jurassic, or Lower Cretaceous in age, although correlation with the Indian Rajmahal Formation suggests a Lower Cretaceous age.

Two small floras, believed to be younger than those of the Victorian 'Lower Jurassic', were described by Medwell (1954b) from the Merino Group. One, which was collected from upper horizons of the Mocamboro Member, contains an abundance of *Phyllopteroides dentatus* Medwell together with *Taeniopteris spatula* and *Sphenopteris* sp., and was estimated to be of a probable Upper Jurassic age. The other megaflora is from the Runnymede Formation and comprises *Phyllopteroides lanceolata* (Walkom), *Sphenopteris* cf. *S. burrumensis* Walkom, *Phoenicopsis elongatus* (Morris), *Araucarites cutchensis* Feistmantel, and two probable angiospermous leaves. Several of these species occur in the Queensland Lower Cretaceous Burrum flora, and Medwell suggested a similar age for the Runnymede flora.

The only megaplants that have been described (Glaessner and Rao 1955) from the South Australian portion of the Great Artesian Basin were collected from equivalents of the Blythesdale Group near Mt Babbage in the Flinders Ranges. On stratigraphical grounds (Woodard 1955), the flora is no younger than Aptian, and it was assigned to the Neocomian-Aptian on the basis of the following species: *Cladophlebis australis, Taeniopteris spatulata, Otozamites bengalensis* (Oldham & Morris), *Cycadites* sp., *Nilsonnia schaumburgensis* (Dunker), and *Elatocladus planus* (Feistmantel).

Specimens similar to one of the Blythesdale species, *Otozamites bengalensis*, have recently been recorded (Douglas 1962) from basal beds of the Tyers Group in Victoria.

Previous Investigations of Australian Upper Mesozoic Microfloras and Microplankton Assemblages

The first record of spores and pollen contained in Australian Upper Mesozoic sediments was made by Edwards, Baker, and Knight (1944) who illustrated and commented briefly upon several types present in coals from Wonthaggi, Victoria. De Jersey (1951, 1955) presented similar accounts of spores contained in the Burrum and Styx Coal Measures of Queensland, and Cookson (1953) described seven spore and pollen species from a boring at Comaum, South Australia. Cookson (1954) subsequently discussed the stratigraphical and geographical distribution of two of these species.

Balme (1956) recorded a Lower Cretaceous spore assemblage from the Donnybrook Sandstone in the Perth Basin, and subsequently (1957) presented an important contribution to our knowledge of Australian Mesozoic microfloras. All of the spores and pollen described in the 1957 paper were recovered from various localities in the Canning, Carnarvon, and Perth Basins. On a quantitative and qualitative basis Balme delineated three distinct microfloras indicative respectively of Lower Jurassic, Oxfordian-Kimeridgian, and Neocomian-Aptian ages. The successful application of these to correlative problems of Mesozoic sediments in Western Australia is an important outcome of Balme's investigations.

Balme's paper was quickly followed by a series of papers (Cookson and Dettmann 1958a, b; 1959a, b, c; 1961: Cookson 1961: Dettmann 1959) incorporating early results of palynological investigations of eastern Australian and Papuan Upper Mesozoic strata. These papers dealt chiefly with the description of both mega- and microspore species and included some preliminary stratigraphical findings. The majority of the samples investigated were collected from the Great Artesian and Otway Basins and E. Victoria, and all yielded microfloras which suggested a Cretaceous age. Further evidence for this age and the resemblance of the SE. Australian microfloras with those recorded from other parts of the world will be amplified subsequently.

Cookson and Balme have described recently (1962) pollen tetrads from Lower and early Upper Cretaceous strata in the Perth and Otway Basins.

Microplankton in Australian and Papuan Cretaceous strata were first reported by Deflandre and Cookson (1954) and Baker and Cookson (1955) and described by Deflandre and Cookson (1955) and Cookson (1956). Although only a few Cretaceous samples from remote localities were examined, these authors demonstrated the usefulness of microplankton in the inter- and extra-Australasian correlation of Mesozoic sediments. Cookson and Eisenack (1958) reaffirmed this in a substantial paper which deals with microplankton assemblages contained in Upper Jurassic and Cretaceous strata from Australia and Papua. Within several precisely dated bore sequences in the Carnarvon Basin and Papua, two Upper Jurassic, three Lower Cretaceous, and one Upper Cretaceous assemblages were recognized. Similar assemblages were recorded from less precisely dated deposits in the Canning, Perth, Great Artesian, and Styx River Basins, and the strata were tentatively correlated with the dated bore sequences.

The later publications of Cookson and Eisenack (1960a, b; 1961; 1962) and Eisenack and Cookson (1960) incorporate results of further investigations of Australasian Upper Jurassic and Cretaceous deposits. These studies have given a broad overall picture, as comprehensive as sampling permits, of the microplankton sequence in Australasian Upper Mesozoic strata (Oxfordian to Senonian). Correlation of the microplankton assemblages with microfloral assemblages (of Balme 1957; Cookson and Dettmann 1958b; present study) is not yet possible since no well-documented sequence has been investigated for both types of microfossils.

A recent paper by Douglas (1961a) deals with the description of Deflandreidae types present in marine Upper Cretaceous strata of western Victoria.

Methods of Study

The samples examined comprise a wide variety of lithological types, ranging from coals to fine-grained sandstones, and include continental, transitional, and marine sediments. Plant microfossils have been obtained from all lithological types, but, in general, the siltstones yielded the best preserved and most diverse spore assemblages. The plant material was extracted by one of two preparation techniques according to the lithological type (coals or clastics) at hand.

CLASTICS

Clastic samples were given a treatment involving the use of hydrofluoric acid, hydrochloric acid, Schulze solution (concentrated nitric acid and potassium chlorate), followed in some instances by weak alkali. An outline of the process is as follows:

1. Two to three grams of material were broken to a grain size of *c.* 5 mm and transferred to a polythene beaker.
2. Calcareous samples were treated with dilute (*c.* 20%) HCl for a period of 2 hours and subsequently washed several times in distilled water.
3. All samples were then allowed to stand for a period of 1-2 days in cold, 50-60% HF. After this time the acid was decanted and the residue transferred to a nickel crucible to which fresh HF was added and boiled for 30-45 minutes. The HF was removed and the residue washed several times in distilled water.
4. A subsequent treatment with warm, but not boiling, 50% HCl was carried out in order to dissolve the fluorides resulting from the HF treatment.
5. The washed residues, to which a few drops of non-ionic detergent together with *c.* 5 cc distilled water had been added, were subjected to a 5-8 seconds' treatment with an ultrasonic disintegrator (1 : 1 end ratio steel probe vibrating at 20 kilocycles per second). This treatment was most effective in disaggregating clumps consisting of spores and other organic and mineralogical matter, the fine particles of which were disseminated into solution. After disintegration the residues were rinsed and short-centrifuged several times until the top liquor remained clear.
6. Each of the samples was macerated in *c.* 15 cc of Schulze solution. The time for oxidation of individual samples was variable, ranging from 30 minutes to 8 hours. In general, it was found that oxidation was sufficiently advanced when the top liquor was deep chocolate-brown in colour. After maceration the residues were washed several times in distilled water.
7. Only the residues in which the spores were insufficiently concentrated were treated with 10 cc. of dilute ($\frac{1}{2}$-1%) NH_4OH or NaOH. Following addition of alkali, the residues were stirred, immediately centrifuged, and washed repeatedly with distilled water until the top liquor was clear. Treatment with more concentrated alkali solutions was found to result in disorganization or total destruction of spore exines.

COALS

Coals were subjected to the following treatment:

1. Approximately 1 gm of material, crushed to a grain size of *c.* 1 mm, was macerated in 25 cc of Schulze solution. Maceration time, which was longer than that required for clastic samples, ranged from 12 to 14 hours.
2. After removal of the acid solution and several rinses in distilled water, 25-30 cc of 2% NaOH were added to the material. In some instances a further treatment with 4-5% NaOH was necessary to thoroughly dissolve oxidized material, but excessive treatment with alkali usually caused damaged to the spores. Following alkali treatment the residues were rinsed repeatedly in distilled water.
3. Residues containing mineral matter were allowed to stand overnight in 50-60% HF.

The ultimate residues obtained by these methods were transferred for storage to plastic-stoppered glass vials containing 50 % glycerine and a few drops of phenol. Portions of each residue were mounted in either unstained or lightly stained (with safranin O) glycerine jelly on standard glass microscope slides. Two to four strew-slides were prepared from each residue and in addition several hundred spores were mounted singly. Cover slips (no. 0) were sealed with gold size at least 3 days after mounting.

From one to several representatives of 28 spore species were serial sectioned following the embedding and sectioning techniques of Wigglesworth (1959). A full outline of these procedures, in which the spores are double-embedded in agar and ester wax before sectioning, is given by Hughes, Dettmann, and Playford (1962, p. 247-48; Fig. 1). All spores that have been sectioned were obtained from preparations treated with Schulze solution and dilute alkali as follows:

Preparation No.	Section No.	Maceration period (hours)	Alkali solution
D139	S72b, c	12	4% NaOH
D217	S57-S60 incl.	8	1% NaOH
D226	S70, S73	2	< 1% NaOH
D247	S55, S56	½	< 1% NH_4OH
D272	S84, S85	3	< 1% NH_4OH
D286	S61, S62	8	< 1% NH_4OH
D289	S63-S69 incl.	1	1% NH_4OH
D302	S76-S82 incl.	2	1% NH_4OH

The sections were cut at 2-3 μ intervals transverse to the equatorial plane and are mounted in unstained glycerine jelly under cover slips sealed with gold size.

Strew-slides were first surveyed at a magnification of × 100, and all morphological analyses and identifications of species present were determined at magnifications of × 400 and × 1,000. After all productive samples had been examined the constituent spore species were described; the systematic descriptions set out below incorporate the morphological features observed in well-preserved and, in certain cases, corroded and sectioned specimens.

Quantitative analyses were carried out on all core and cutting samples, which yielded sufficiently well-preserved microfloras, from the reference successions in the Great Artesian Basin (Oodnadatta Bore No. 1 and Cootabarlow Bore No. 2) and Otway Basin (Penola Bore No. 1 and Robe Bore No. 1). The quantitative estimations were derived after 250 specimens from each sample had been counted under high power and the resulting percentages represent the relative abundance of each species in the individual samples.

Systematic Section

NOMENCLATURE AND CLASSIFICATION

Nomenclature of the fossil spores (unless otherwise indicated, the term is used here in the comprehensive sense and denotes spores *s. str.* and pollen) described in the present study is based upon the rules of priority and typification as laid down in the International Code of Botanical Nomenclature (1961, Montreal). The binomial designation is used for all formally named species, and the genera to which the species are referred are here regarded as artificial (form) taxa since they are based on morphological features of detached spores. The form genera and species are classed within suprageneric categories of an artificial classification; nomenclature of these suprageneric taxa does not come within the jurisdiction of the International Code of Botanical Nomenclature (see Art. 3). Natural botanical affinities, where known, are documented within the artificial categories of the system.

Although the majority of systematic palynologists working on pre-Quaternary material now adhere to the rules of typification and priority, considerable nomenclature confusion exists in spore taxonomy. This is not unexpected as a consequence of a rapidly evolving science, but much of the current nomenclatural chaos may have been avoided if the names of natural genera had not been applied in the binomial designations of artificial spore species. Certainly there appears to be no justification for the assignment (or identification) of fossil dispersed spores to natural plant genera on the basis of spore morphology alone. Many such identifications, when published, not only add to the prevailing nomenclatural confusion, but, as noted by Pierce (1961, p. 12), may also be a 'source of misinformation'.

As opposed to nomenclature, there are no established rules for the classification of dispersed-spore taxa. A variety of artificial classification schemes has been presented to date, including those by authors from Russia (Naumova 1939; Maljavikina 1949), Europe (Erdtman 1947; Erdtman and Straka 1961; Potonié and Kremp 1954, 1955, 1956, and Potonié 1956, 1958, 1960; Krutzsch 1959), England (Raistrick 1934), the Americas (Schopf, Wilson, and Bentall 1944; Rouse 1957; van der Hammen 1956a), and India (Pant 1954). However, because the frameworks of the majority of these systems lack uniformity and a means by which all spores can be methodically classified into automatically delineable units, only a few have received widespread use. Three of the most comprehensive, readily applied methods that have been formulated for the classification of dispersed spores are briefly outlined below.

The classification scheme presented by Naumova (1939, p. 354) 'is based, in the first place, on the mode of germination, and secondly, on the nature of the sculpture of the exine (Fig. 1)'. It should be noted that within her group Sporae, which includes spores (*s. str.*), Naumova also used the presence or absence of a 'margin' (p. 355) as a classificatory feature. Thus, the spore 'genera' recognized by Naumova are included within the following 'suprageneric' categories: Azonotriletes and Zonotriletes which comprise Triletes; Azonomonoletes and Zonomonletes of Monoletes; and Aletes. The classes recognized within her Pollina, which includes pollen, were established on the basis of the presence or absence of an aperture, type of aperture, and finally type of exinal sculpture. The scheme, which is fully outlined on Naumova's Fig. 1, is a readily applicable key, since only one diagnostic feature is used for subdivision of the groups at any one taxonomic level. The system was adopted by the majority of Russian authors concerned with Palaeozoic dispersed-spore studies (Naumova 1953, Ishchenko 1952, and others), and it was modified slightly by Maljavikina (1949) for the classification of Mesozoic spores. However, in recent years Naumova's 'generic' groups, some of which still lack type designation, have become considerably overloaded, and their circumscriptions have been broadened such that the taxa are no longer useful working units. Further, many Russian authors of Mesozoic and Tertiary spore species use the natural classification in preference to Naumova's scheme.

Van der Hammen's (1956a) key is also based on aperture and sculptural features and is provided with a built-in nomenclatural system. According to this system, the names of the generic categories incorporate the descriptive terms (of Iversen and Troels-Smith 1950) that are used to designate the diagnostic morphological features. Correct names of validly instituted, pre-existing genera assignable to the system were ignored by van der Hammen. Following these principles van der Hammen (1956a, 1956b) and Pierce (1961) applied the key for the codification of certain Upper Mesozoic and Tertiary dispersed-spore species, but no attempt has yet been made to allocate Palaeozoic forms to the system. As at present outlined the generic groups of Sporites, which includes spores (*s. str.*), incorporate diverse morphological forms since azonate and zonate forms are not necessarily segregated at generic level. The most serious defect of the scheme is that its nomenclature cannot be reconciled with the established principles laid down in the International Code of Botanical Nomenclature.

The morphological system instituted by Potonié and Kremp (1954) and subsequently amplified by these authors (1955, 1956) and Potonié (1956, 1958, 1960) is, in the writer's opinion, the most comprehensive and satisfactory classification scheme presented to date. The scheme is based on the larger majority of morphological forms described before and up to the late 1950's, and Potonié and Kremp seriously attempted to adopt only those names (of taxa of generic and lower rank) that comply with the rules of typification and priority. The genera are orderly grouped into artificial suprageneric categories of infraturma, subturma, turma, and anteturma rank, and the diagnostic features of each of the suprageneric categories are clearly specified. The features upon which the suprageneric taxa are based include aperture, wall stratification, thickening and/or extension of the exine, and exine sculpture. Certain of the categories delineated broadly correspond to the subdivisions of the schemes proposed by Naumova, van der Hammen, Pant (1954),

TABLE 1

Schematic outline of system instituted by Potonié and Kremp (1954) for classification of Sporites.

Diagnostic features	Category																		Rank
	SPORITES																		Anteturma
aperture lip features equatorial features	TRILETES							BARBATES	ZONALES					MONOLETES				CYSTITES	Turma
lip features stratification equatorial features	AZONOTRILETES			LAGENOTRILETES	PYROBOLOTRILETES	CAPULITRILETES	PERINOTRILITES		AURITOTRILETES		ZONOTRILETES			AZONOMONOLETES			ZONOMONOLETES		Subturma
lip features sculpture equatorial features	LAEVIGATI	APICULATI	MURORNATI	GULATI					AURICULATI	APPENDICIFERI	CINGULATI	ZONATI	PATINATI	LAEVIGATOMONOLETI	SCULPTATOMONOLETI	PERINOMONOLITI			Infraturma

and others. However, Potonié and Kremp were effectively the first to recognize the diagnostic value of wall stratification for the classification of fossil dispersed spores.

Because the morphological system presented by Potonié and Kremp represents a comprehensive, readily applied method for the classification of dispersed spores, it has found widespread acceptance among palynologists. Some authors, however, have found that the scheme contains certain inconsistencies in that spores of identical morphology can be grouped into more than one suprageneric category. These inconsistencies have resulted from the arbitrary and inconsistent use of more than one diagnostic criterion for the subdivision of the various suprageneric taxa.

Table 2

Outline of revised system for classification of Sporites.

<table>
<tr><th>Diagnostic feature</th><th colspan="13">Category</th><th>Rank</th></tr>
<tr><td></td><td colspan="13">SPORITES</td><td>Anteturma</td></tr>
<tr><td>aperture</td><td colspan="8">TRILETES</td><td colspan="4">MONOLETES</td><td>HILATES</td><td>Turma</td></tr>
<tr><td>stratification</td><td colspan="7">ACAVATITRILETES</td><td>PERINOTRILITES</td><td colspan="3">ACAVATOMONOLETES</td><td>PERINOMONOLITES</td><td></td><td>Suprasubturma</td></tr>
<tr><td>equatorial features</td><td colspan="3">AZONOTRILETES</td><td colspan="4">ZONOTRILETES</td><td></td><td colspan="2">AZONOMONOLETES</td><td>ZONOMONOLETES</td><td></td><td></td><td>Subturma</td></tr>
<tr><td>sculpture
equatorial thickening and/or extension</td><td>LAEVIGATI</td><td>APICULATI</td><td>MURORNATI</td><td>AURICULATI</td><td>TRICRASSATI</td><td>CINGULATI</td><td>PATINATI</td><td></td><td>LAEVIGATOMONOLETI</td><td>SCULPTATOMONOLETI</td><td></td><td></td><td></td><td>Infraturma</td></tr>
</table>

Consideration is given here only to the classification of spores grouped within the Anteturma Sporites H. Potonié. This group, as it is classified by Potonié and Kremp, is schematically outlined in Table 1. From this outline it will be seen that Sporites is subdivided into turma units on the basis of the inconsistent use of three diagnostic features, viz. aperture, lip, and equatorial features. Of the five turma units delineated by Potonié and Kremp, three at least are trilete (Triletes Reinsch, Zonales Bennie and Kidston, and Barbates Mädler), and the circumscriptions of the trilete categories are mutually overlapping: Barbates includes spores assignable also to both Triletes and Zonales, and Triletes incorporates lipped spores which conform with Barbates. Triletes is further subdivided on the basis of two diagnostic features, lip modification and wall stratification, and its five subturma taxa are not clearly distinguishable from one another: Perinotrilites Erdtman includes azonate or zonate trilete spores with a stratified, cavate wall; Azonotriletes Luber incorporates azonate, trilete forms which may be lipped and which may have a stratified cavate wall; and all of Capulitriletes Potonié, Pyrobolotriletes Potonié, and Lagenotriletes Potonié and Kremp are trilete megaspore units which conform also to Barbates and which are characterized by lip development. From this outline it is apparent that many of the suprageneric taxa, as diagnosed by Potonié and Kremp, are mutually overlapping.

For effective, orderly codification of dispersed spores, the system used must be composed of mutually exclusive taxonomic units, which, at any particular rank, are based on one diagnostic character only (see Erdtman and Straka 1961, Pierce 1961). This principle has been applied by the present writer for classifying the spores of Sporites. An outline of the scheme, thus formulated, is given in Table 2. It is based upon firstly, aperture characters; secondly, wall stratification; thirdly, equatorial thickening and/or extension of the wall; and finally, sculptural features. Further explanations of the scheme together with diagnoses of the various suprageneric taxa are given in the following pages. The diagnostic features of the taxa are designated by means of the descriptive terminology set out below.

GLOSSARY OF DESCRIPTIVE TERMS

The descriptive terms used in the systematic section below are mainly those which have been widely accepted and used in the same sense by previous authors. The terms employed are listed and defined under headings of the basic features which they describe: shape and polarity; the spore wall, its stratification, construction, sculpture, and structure. Many of the definitions have been extracted with little or no modification from the comprehensive glossaries given by Potonié (1934), Erdtman (1952), Harris, W. F. (1955), and Potonié and Kremp (1955), and reference is made to the authors of the definitions. Where the circumscription of a term has been revised by the present writer reference to the originator of the term is placed in brackets.

Polarity and Shape

Amb—Erdtman 1952, p. 459; the outline of a spore viewed from the direction of the polar axis.

Contact Face—Harris, W. F. 1955, p. 25: the area adjacent to the tetrad mark.

Dimensions—see Fig. 3. Unless otherwise specified the dimensions given in the systematic descriptions are based on at least 30 specimens; the bracketed figure is the mode.

Distal Pole—Erdtman 1952, p. 467: the point opposite the proximal pole.

Distal Surface—Erdtman 1952, p. 462: that part of the spore which is directed outwards in its tetrad.

Equator—Erdtman 1952, p. 467: the border line between the proximal and distal surfaces of a polar spore.

Equatorial Axis—Potonié and Kremp 1955, p. 10: any axis in the equatorial plane which intersects the polar axis.

Interradial Region: the region that includes the proximal area adjacent to the tetrad mark and the corresponding distal area (see Fig. 3a).

Krytome—Klaus 1960, Fig. 2: an abruptly convex exinal area in the proximal and equatorial radial regions; the limits of this area more or less parallel the tetrad mark (see Fig. 3b). In compressed spores the kyrtomes usually are reduced to arcuate folds which surround the laesurae.

Polar Axis—Erdtman 1952, p. 467: a line connecting the poles of a spore.

Polar Outline: the outline of the spore as seen in equatorial view (= profile of Harris, W. F. 1955, p. 26).

Proximal Surface—Erdtman 1952, p. 467: that part of the spore which is directed inwards in its tetrad.

Radial Region: the region comprising the proximal area in the immediate vicinity of the tetrad mark and the corresponding distal area (see Fig. 3a).

Tetrad Mark: the mark on that part of the proximal surface which was in contact with the other spores of the tetrad. In trilete and monolete spores the tetrad mark corresponds in position to the laesurae.

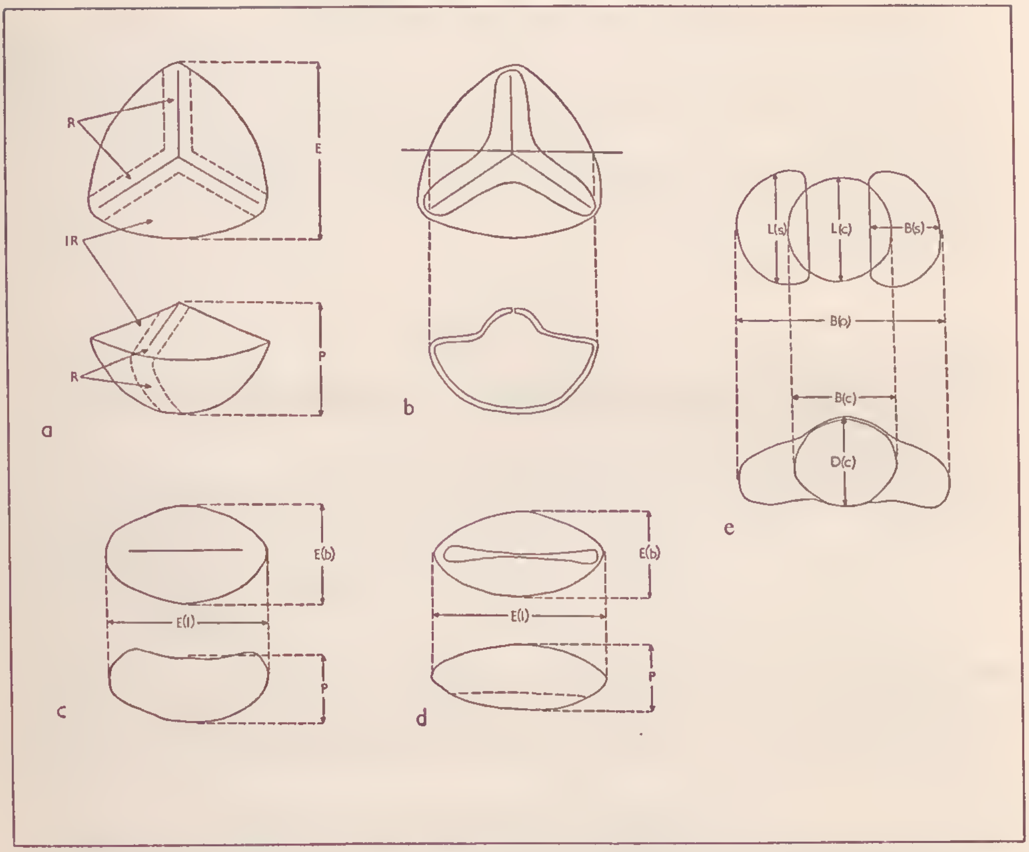

Fig. 3—(a) Showing dimensions measured on, and interradial and radial regions of, trilete spores; (b) Surface and sectional views of a trilete spore possessing kyrtomes; (c-e) Showing dimensions measured on monolete spores and tenuate and bisaccate grains.

R = radial regions; IR = interradial regions; E = equatorial diameter; E(b) = equatorial diameter (breadth); E(l) = equatorial diameter (length); P = polar diameter; B(o) = overall breadth; B(c) = corpus breadth; B(s) = saccus breadth; L(c) = corpus length; L(s) = saccus length; D(c) = corpus depth.

The Spore Wall (Sporoderm)

(A) Stratification

Exine—Erdtman 1952, p. 463: the main, outer, usually resistant layer of a sporoderm. Unless otherwise stated the measurements given in the systematic descriptions for the thickness of the exine were taken from optical or transverse sections and do not include the height of the sculptural elevations, if present.

Exoexine—Potonié and Kremp 1955, p. 17: the outer, sculptured layer of the exine. Where this layer is stratified, the terms Outer Exoexine and Inner Exoexine may be applied to the outer and inner layers respectively (see Hughes 1955, p. 207).

Intexine—Potonié and Kremp 1955, p. 17: the inner, non-sulptured layer of the exine.

Perine—Erdtman 1952, p. 466: the outermost, extraexinal, sporoderm layer in some spores. This layer is thought 'to be due to the activity of a periplasmodium' (Erdtman loc. cit., see also Harris, W. F. 1955, pp. 16-17) and is difficult to distinguish even in recent spores. Harris (loc. cit.) and others have demonstrated that in some plant species the perine is developed at a late stage in spore maturation (after or during separation of the spore-mother-cell), and that both mature, perinate and immature, aperinate spores may be shed from the same sporangium. These observations have led Harris (loc. cit.) to state 'One cannot be sure, apparently, of the correct application of such terms as ektexine' (exoexine) 'and perine without reference to the ontogeny of the spore, which, in the case of fossil spores would not be known'. For these reasons the term perine has not been used by the present writer; in the cases where the term may have been applicable the alternative phrase OUTER LAYER OF SCULPTINE (see Erdtman 1952, p. 18) is used.

SCLERINE—Erdtman 1952, p. 468: sporoderm except for intine. In aperinate spores the sclerine corresponds to the exine.

SCULPTINE—Erdtman 1952, p. 468; sclerine except for intexine. In aperinate spores the sculptine corresponds to the exoexine.

(B) Construction

(1) Apertures

LAESURA—Erdtman 1952, p. 12: the proximal APERTURE of trilete and monolete spores. Trilete spores possess three laesurae which radiate from the proximal pole, and monolete spores possess one laesura which has its centre at the proximal pole. (Note laesura sensu Erdtman = commissure of Harris 1955, p. 25).

HILUM—(Erdtman 1952, p. 12): the usually irregular, distal or proximal APERTURE of certain spores. The hilum forms as the result of a natural breakdown of the sclerine in an area showing structural and/or sculptural modification about the distal or proximal pole. E.g. *Aequitriradites* (Pl. XXII,, fig. 1-15; Pl. XXIII, fig. 1-3) and *Cooksonites* (Pl. XXI, fig. 8-11) exhibit a distal hilum; *Couperisporites* (Pl. XXI, fig. 12-19) is characterized by a proximal hilum. This type of aperture is found also in spores of certain living and fossil hepatic species, e.g. in the living *Geothallus tuberosus* Campbell (see Erdtman 1957, Fig. 26) and the fossil *Naiadita lanceolata* Buckman (see Harris, T. M. 1938, Fig. 21, 22; present study, Pl. XXVII, fig. 9-11).

TENUITAS—Erdtman 1952, p. 471; thin, more or less aperturoid exine area, not as distinctly delimited as true apertures. The term is here applied to the distal aperturoid area of certain bisaccate and monosulcate (sensu Couper 1958, p. 103) gymnospermous grains, e.g. *Alisporites similis* (Pl. XXV, fig. 5-7) and *Ginkgocycadophytus nitidus* (Pl. XXVI, fig. 8, 9).

(2) Thickenings and Extensions of the Spore Wall

AURICULAE—(Potonié and Kremp 1955, p. 15): radially situated extensions of the equatorial exine (or exoexine). E.g. *Tripartites* Schemel.

CAVATE—Dettmann 1961, p. 72: asaccate spores in which the wall layers are partially or almost completely separated from each other by a cavity. E.g. in *Crybelosporites stylosus* (Pl. XVIII, fig. 12-20) the outer layer of the sculptine is proximally separated from the inner layers by a cavity, whilst in *Densoisporites velatus* (Pl. XIX, fig. 4-8) the wall layers are distally and equatorially separated from each other by a cavity. The term also is applied here to denote the hollow condition of sculptural elevations and exinal thickenings and/or extensions, e.g. the cingulum and muri of *Contignisporites glebulentus* (Pl. XV, fig. 1-10).

CINGULUM—(Potonié and Kremp 1955, p. 12): a comprehensive thickening of the equatorial exine (or exoexine). As seen in transverse section the cingulum may taper sharply (*Cirratriradites elegans*; Hughes et al. 1962, Pl. 38, fig. 6, 7) or only slightly (*Murospora florida*; Pl. XIV, fig. 13, 14). Spores exhibiting a sharply tapering cingulum are often termed 'cingulizonate'.

CORONA—(Potonié 1956, p. 54): extensions of the equatorial exine (or exoexine) in the interradial regions. The extensions may be dissected and composed of fimbriate-like elements, e.g. in *Reinschospora* Schopf, Wilson, and Bentall.

LIMBUS: the term was used by Potonié and Kremp (1955, p. 19) to denote an equatorial thickening of the outer wall layer in cavate (monosaccate sensu Potonié and Kremp) spores. The term is replaced here by cingulum.

LIPS—(Potonié and Kremp 1955, p. 11): thickening and/or upturned extensions of the exine (or exoexine) about the laesurate margins (= margo of Harris, W. F. 1955, p. 26 and Couper 1958, p. 103). E.g. in *Biretisporites spectabilis* (Pl. II, fig. 3-8) the lips are narrow, elevated extensions of the proximal exine, and in *Klukisporites scaberis* (Pl. VIII, fig. 1-7) the lips are sculptured thickenings of the exine. The type of lips, and their height and width should always be denoted.

Interradial Crassitudes: thickenings of the equatorial exine (or exoexine) in the interradial regions. E.g. *Coronatispora perforata* (Pl. XIII, fig. 17-20).

Polar Crassitude: distal, polar, exinal (or exoexinal) thickening as in *Coronatispora perforata* (Pl. XIII, fig. 17-23). Compare patina of Butterworth and Williams (1958, p. 381) and patella and capsula of Staplin (1960, p. 28-29), which, however, are exinal thickenings that are developed over the entire distal hemisphere.

Saccus—Erdtman 1952, p. 468: more or less equatorially situated air sac (exoexine loosened from intexine; baculoid elements usually sticking to the under surface of the exoexine). Mono-, bi-, and poly-saccate forms are described herein; these are distinguishable from trilete, cavate forms in having baculoid rods and a distal tenuitas and in lacking a proximal aperture.

Valvae—Potonié and Kremp 1955, p. 15: thickenings of the equatorial exine (or exoexine) in the radial regions. E.g. *Matonisporites cooksoni* (Pl. XI, fig. 1-8).

Vesiculae—Harris W. F. 1955, p. 27: small air sacs. The term is used herein to denote small, hollow, more or less polar protuberances of saccate forms, e.g. *Tsugaepollenites trilobatus* (Pl. XXIV, fig. 6-10).

Zona—(Potonié and Kremp 1955, p. 15): a comprehensive extension of the equatorial exine (or exoexine). E.g. *Kraeuselisporites linearis* (Pl. XVII, fig. 1-4).

(3) Sculpture

Bacula—Potonié 1934, p. 11: straight-sided flat-topped elevations.

Capilli—Potonié and Kremp 1955, p. 14: projections in which the terminations are branched; column straight-sided or constricted; height greater than basal diameter.

Clavae—Harris, W. F. 1955, p. 19: projections in which the terminations are constricted; height greater than basal diameter.

Foveolae—Erdtman 1952, p. 463: small (up to 2 μ) depressions which are more or less rounded in surface view.

Granula—Erdtman 1952, p. 463: small (up to 1 μ) more or less isodiametric elevations.

Lumina—(Potonié 1934, p. 11): the spaces between the muri or rugulae in murornate spores; the muri may not necessarily be coalescent.

Muri—(Potonié 1934, p. 11): elevations which are elongated and straight-sided in basal outline (greatest basal diameter at least twice minimum basal diameter); sides parallel, converging, or diverging; crests flat, rounded, or pointed.

Rugulae—Harris, W. F. 1955, p. 20: elevations which are elongated and irregular in basal outline (maximum basal diameter at least twice minimum basal diameter); sides parallel, converging, or diverging; crests flat, rounded, or pointed.

Setulae—Harris, W. F. 1955, p. 19: straight-sided projections in which the terminations are bluntly tapered.

Spinae—cf. Erdtman 1952, p. 469: elevations in which the height is at least twice the basal diameter; apices pointed.

Spinulae—cf. Erdtman 1952, p. 469: elevations in which the height is less than twice the basal diameter; apices pointed.

Verrucae—Potonié 1934, p. 11: elevations in which the bases are more or less isodiametric and greater than 1 μ diameter.

(4) Structure

Structure—Faegri and Iversen 1950, p. 18: the form and arrangement of the individual elements within the sclerine.

Granulate Structure: the term is used herein to describe the structure of a wall layer that is composed of granules.

Homogeneous Structure: when no individual structural components are discernible, the wall is described as homogeneous.

Spongeous Structure: the structure of a wall layer that is composed of loosely-packed components.

NOTE ON DESCRIPTIVE PROCEDURE AND DESIGNATION OF TYPES

Unless otherwise indicated the dimensions (see Glossary of Descriptive Terms; Fig. 3) given in the systematic descriptions were derived from at least 30 suitably orientated specimens. All new species are based on at least 8 adequately preserved specimens. The holotypes together with at least one other representative of each new species, and one to several specimens of all previously described microspore species are illustrated by means of photographs; in addition some drawings, which have been drawn from photographs, are provided. Microtome sections of 28 of the species represented in the Australian material are illustrated. Holotypes are annotated as to their orientation in the microscope field, and the focus (or foci) depicted for all illustrated specimens is noted.

Australian Upper Mesozoic spore species are depicted on Plates I to XXVI inclusive and Fig. 4 to 6 inclusive. They are referred to by the preparation (prefixed 'D' or 'ICC')/section (prefixed 'S'), if applicable/slide number, followed by the 'E.-W.' and 'N.-S.' microscope vernier readings and the registered numbers (prefixed 'P') of the palaeontological collection of the National Museum of Victoria. The vernier readings are from Leitz Laborlux microscope No. 1 of the Sedgwick Museum, Cambridge: a master slide, with two reference points clearly marked and located by means of Leitz Laborlux No. 1 readings, has been deposited with the collection in the National Museum of Victoria; the registered number of this slide is P22604.

Type and other specimens of species described originally by Couper (1958) and Cookson (1947) are figured on Plate XXVII. Plate XXVII also incorporates illustrations of spores of two recent and one fossil hepatic species; these spores are described in Appendix I.

Systematic Descriptions

ANTETURMA SPORITES H. Potonié 1893

Spores attributable to this category possess one of the following aperture features:

(a) three proximal laesurae which radiate from the pole
(b) one proximal laesura which has its centre at the pole
(c) a distal or proximal polar, usually irregular hilum which forms as the result of a natural breakdown of the sclerine in an area showing structural and/or sculptural modification. Spores exhibiting this feature usually are further characterized by a proximal tetrad mark comprising three radial ridges.

REMARKS: The spores comprising Sporites H. Potonié are allocated to one of the three mutually exclusive taxonomic groups of turma rank on the basis of one spore feature alone, viz. the character of the aperture. Trilete spores are referred to Triletes Reinsch, monolete spores to Monoletes Ibrahim, and hilate spores to Hilates turma nov.

The alternative scheme (see Table 1) proposed by Potonié and Kremp (1954, 1955, 1956) and Potonié (1956, 1958, 1960) for grouping the spores of Sporites into turma units is dependent upon the inconsistent use of one to several spore features. Three, and possibly four, of the five turma units proposed by these authors include trilete spores, and the circumscriptions of these trilete categories are mutually overlapping such that spores of identical morphology may be allotted to two or more turmas. E.g. *Pyrobolospora* Hughes which is characterized by a trilete aperture enclosed within elevated, laesurate lips conforms with both Triletes and Barbates Mädler, and *Thomsonia* Mädler which possesses equatorial extensions (auriculae) and elevated laesurate lips surrounding the trilete aperture is attributable to either Zonales Bennie and Kidston or Barbates.

TURMA TRILETES Reinsch emend.

Triletes as used here incorporates spores having a proximal trilete aperture. The trilete aperture may be simple or lipped, the lips constituting thickened and/or upturned extensions of the proximal sclerine. In certain genera the lips are highly specialized proximal exinal extensions (e.g. *Pyrobolospora* and *Nathorstisporites* Jung) which may be fused to form a gula over the proximal pole (as in *Lagenicula* Bennie and Kidston ex Potonié and Kremp). It should be noted that a large number of the trilete forms show radial symmetry (symmetrical about the three laesurae).

REMARKS: Spores previously allocated by Potonié and Kremp (1954 and later) and Potonié (1956 and later) to the turma categories, Triletes, Zonales, and Barbates, and possibly those of Cystites Potonié and Kremp, are characterized by a trilete aperture and conform with Triletes as emended above.

It is recognized that the name of this category is the correct name of the genus *Triletes* Reinsch ex Schopf which some authors (see Schopf 1938 and Winslow 1959, and cf. Potonié and Kremp 1954, 1955) consider as validly based. However, the application of the name at generic level does not nullify Potonié and Kremp's (1954 and later) use of the name for a suprageneric category, as the laws of priority and typification only apply to form units of generic or lower rank (see International Code of Botanical Nomenclature 1961, Art. 3, 7).

As outlined in Table 2, trilete spores are here grouped into two suprasubturma categories according to the stratification and nature of the sclerine. Trilete spores characterized by a cavate sclerine (for definition see Glossary of Descriptive Terms) are assigned to Perinotrilites Erdtman, while those which possess an acavate sclerine are allocated to Acavatitriletes s.s. turma nov.

Suprasubturma ACAVATITRILETES s.s. turma nov.

Acavatitriletes is proposed for trilete spores which possess an acavate sclerine. The sclerine may be of uniform or differential thickness, the presence or absence of equatorial thickenings serving as a basis for subdivision of this group (see Table 2).

REMARKS: Acavate spores assigned to the turma units, Zonales and Barbates, and to the subturma categories, Azonotriletes Luber, Lagenotriletes Potonié and Kremp, Pyrobolotriletes Potonié, and Capulitriletes Potonié, of Triletes conform with Acavatitriletes.

Subturma AZONOTRILETES Luber emend.

Azonotriletes Luber is emended to include acavate, trilete spores in which the sclerine is more or less of uniform thickness (distal and equatorial sclerine unthickened). The laesurae may be simple or lipped.

REMARKS: The above emendation broadens the original circumscription of the group which now incorporates the azonate, trilete spores of Azonotriletes Luber sensu Potonié and Kremp (1954 and later) together with the azonate, trilete spores which are conspicuously lipped, of Pyrobolotriletes, Lagenotriletes, Capulitriletes, and Barbates.

As outlined by Potonié and Kremp (loc. cit.) and Potonié (1956 and later) this group is subdivided on the basis of sculptural features.

Infraturma LAEVIGATI Bennie & Kidston emend. Potonié 1956

Azonate, acavate, trilete spores comprising this taxon are characterized by a smooth or almost smooth exine and may have simple or lipped laesurae. Thus the essentially smooth-walled spores of Pyrobolotriletes, Lagenotriletes, and Capulitriletes conform with this infraturma.

Genus **Cyathidites** Couper 1953

TYPE SPECIES: *Cyathidites australis* Couper 1953.

REMARKS AND COMPARISON: Smooth or faintly patterned, trilete microspores having a concavely triangular amb are here attributed to *Cyathidites* Couper since the valid institution of this genus precedes the validation of *Alsophilidites* Cookson ex Potonié, *Cardioangulina* Maljavikina ex Potonié, and *Pyramidella* Maljavikina ex Potonié. *Concavisporites* Pflug, as emended by Delcourt and Sprumont (1955), differs from *Cyathidites* in having proximal kyrtomes (for definition see Glossary of Descriptive Terms). Some of the species assigned below to *Cyathidites* include uncompressed specimens in which the proximal polar exine shows slight differentiation in convexity, but compressed specimens of the same species lack arcuate folds in the proximal, interradial regions. As noted by Delcourt, Dettmann, and Hughes (1963) *Cyathidites* is distinct from *Deltoidospora* Miner which is characterized by a straight-sided triangular amb and *Leiotriletes* Naumova ex Potonié and Kremp which has a convexly triangular amb.

AFFINITY: Couper (1953, 1958) has fully discussed the possible affinity of *Cyathidites* with cyatheaceous and dicksoniaceous ferns; in particular of *C. minor* Couper with *Coniopteris hymenophylloides* (Brongn.), *C. tatungensis* Sze., *Eboracia lobifolia* (Phillips), and *Dicksonia mariopteris* Wilson and Yates. Comparable spores have been described more recently by Harris, T. M. (1961, p. 142-64) in *Coniopteris simplex* (L. & H.), *C. burejensis* (Zalessky), *C. bella* Harris, and *C. murrayana* (Brongn.). However, the closely related species *C. margaretae* Harris and *Dicksonia kendalli* Harris contain spores which are distinct from *Cyathidites* in showing membraneous, elevated, laesurate lips.

Several Russian authors have shown that other species now included within *Cyathidites* are comparable to some of the spores found in *Lygodium* Swartz, and these authors attribute the fossil dispersed spores to this modern genus.

Cyathidites australis Couper 1953

(Pl. I, fig. 1-3)

SELECTED SYNONYMY:

1953 *Cyathidites australis* Couper, p. 27; Pl. 2, fig. 11, 12.
1953 *Lygodiosporites adriennis* Potonié & Gelletich f. *mesozoicus* Thiergart: Cookson, p. 470; Pl. 2, fig. 29.
1956 *Cyathidites mesozoicus* (Thiergart) Potonié (pars), p. 14 (reference to specimen figured by Cookson in 1953).
1961 *Lygodiumsporites adriennis* Potonié & Gelletich: Bolkhovitina, p. 104-105; Pl. 31, fig. 3a (illustration of specimen figured by Cookson in 1953).

DIMENSIONS: Equatorial diameter 50 (59) 73 μ.

DISTRIBUTION: *Cyathidites australis* Couper has been frequently reported from Mesozoic strata and is common throughout the Upper Mesozoic of SE. Australia (see Tables 3-9).

Cyathidites minor Couper 1953

(Pl. I, fig. 4, 5)

SELECTED SYNONYMY:

1953 *Cyathidites minor* Couper, p. 28; Pl. 2, fig. 13.
1953 *Lygodiosporites adriennis* Potonié & Gelletich f. *mesozoicus* Thiergart: Cookson, p. 470; Pl. 2, fig. 30.

1956 *Cyathidites mesozoicus* (Thiergart) Potonié (pars), p. 14 (reference to specimen figured by Cookson in 1953).

1961 *Lygodiumsporites adriennis* Potonié & Gellitich: Bolkhovitina, p. 104-105; Pl. 31, fig. 3b (illustration of specimen figured by Cookson in 1953).

DIMENSIONS: Equatorial diameter 25 (33) 45 μ.

REMARKS: Smooth-walled, trilete microspores attributable to *Cyathidites minor* Couper are of common occurrence in many of the samples examined, particularly in those from eastern Victoria (see Tables 3-9). Their frequent occurrence may be a reflection of the cyatheaceous and dicksoniaceous elements (e.g. *Coniopteris hymenophylloides* (Brongn.) var. *australica* Seward) which are abundantly represented in the Victorian Mesozoic flora (see Medwell 1954a).

The species shows world-wide distribution in Mesozoic sediments. In Australasia it is known from Jurassic and Cretaceous sediments (Couper 1953; Balme 1957).

Cyathidites punctatus (Delcourt & Sprumont) Delcourt, Dettmann, & Hughes 1963

(Pl. I, fig. 6-9)

SYNONYMY: See Delcourt, Dettmann, and Hughes 1963, p. 283.

DESCRIPTION: Microspores trilete, elliptical in lateral view; amb concavely triangular with broadly rounded angles. Laesurae straight, length $\frac{2}{3}$ spore radius; in compressed specimens laesurae accompanied by 'lips' which narrow sharply at equatorial extremities of apertures and which constitute narrow, oblique exposures of the exine at laesurate margins. Exine 2-3 μ thick; with a distinct OL pattern in surface view and low undulations in optical section.

DIMENSIONS: Equatorial diameter 47 (63) 81 μ.

REMARKS AND COMPARISON: Only compressed specimens of the Australian representatives of this species possess 'lips' which are narrow, oblique exposures of the exine adjoining the laesurae (see Van Campo 1961, Fig. 5-8; Delcourt et al. 1963). Spores similar to, if not identical, with *Cyathidites punctatus* have been attributed to *Lygodium punctatituberculatum* Maljavikina, *L. fumatum* Verbitskaya, *L. scrobiculatum* Verbitskaya, *L. concors* Ivanova, and *L. granulatum* Ivanova. Some of these Russian and Siberian species probably include corroded representatives of *Cyathidites punctatus* (Pl. I, fig. 9).

On the other hand, *Cyathidites asper* (Bolkhovitina), to which Bolkhovitina (1961) referred *C. punctatus*, is clearly distinct in having a thicker exine, longer laesurae, and more acutely rounded amb-angles. *Cardioangulina tricancantha* Maljavikina differs from *C. punctatus* in possessing shorter laesurae and a smooth exine.

AFFINITY: On the basis of spore morphology Couper (1958) suggests that *C. punctatus* may have derived from cyatheaceous or dicksoniaceous plants, whereas Bolkhovitina (1961) implies that the species has an affinity with *Lygodium* Swartz.

DISTRIBUTION: The species was described from Wealden strata of Belgium (Delcourt & Sprumont 1955). Subsequent records include Wealden and Aptian of Britain (Couper 1958), Barremian-Aptian of U.S.S.R. (Bolkhovitina 1961), and Berriasian-Aptian of Canada (Pocock 1962). *C. punctatus* is widely distributed in SE. Australia (see Tables 4-9); in the Great Artesian Basin it first appears in the Blythesdale Group with a vertical extension into the Tambo Formation (Albian).

Cyathidites asper (Bolkhovitina) comb. nov.

(Pl. I, fig. 10-16)

1953 *Stenozonotriletes asper* Bolkhovitina, p. 49; Pl. 7, fig. 2.
1959 *Lygodium asper* (Bolkhovitina) Bolkhovitina; Pl. 10, fig. 4.
1961 *Lygodium asper* (Bolkhovitina) Bolkhovitina (pars), p. 86-87; Pl. 27, fig. 2, 3; Pl. 34, fig. 2e, g (? fig. 2a-d); Pl. 41, fig. 4.
1962 *Concavisporites parkinii* Pocock, p. 46; Pl. 4, fig. 71.

DESCRIPTION: Microspores trilete, elliptical in polar outline; amb triangular with weakly concave sides and rounded angles. Laesurae straight, length ¾ or almost equal to spore radius; with weakly thickened margins and, in compressed specimens, flanked by 'lips' which are narrow (2-3 μ wide), equatorially tapering, oblique exposures of the exine. Exine 3·5-5 μ thick, one-layered, homogeneous in structure, and with an OL surface pattern.

DIMENSIONS: Equatorial diameter 60 (71) 86 μ; polar diameter (4 specimens) 34 (37) 42 μ.

REMARKS AND COMPARISONS: Specimens which are considered to be corroded representatives of *Cyathidites asper* (Bolkhovitina) show a granulate surface pattern (Pl. 1, fig. 14), and resemble *Callispora potoniei* Dev.

As noted previously, the species is distinct from *C. punctatus* in having a thicker exine and longer laesurae. *Lygodium subsimplex* Bolkhovitina and *L. japoniciforme* Ivanova show a smooth exine.

AFFINITY: Several Russian authors have noted that the species closely resembles the spores of *Lygodium japonicum* (Thbq.), *L. flexuosum* (L.), and *L. cubense* H.B.K. (see Bolkhovitina 1961, p. 79-81; Pl. 23, fig. 5a-c; Pl. 24, fig. 4).

DISTRIBUTION: Bolkhovitina (1961) records the species in Upper Jurassic-Turonian strata of U.S.S.R., but this stratigraphical range includes that of *C. punctatus*. Pocock (1962) subsequently recorded identical spores in Berriasian-Aptian strata of Canada. The species is widely distributed in SE. Australian Upper Mesozoic sediments (see Tables 3-9); in the Great Artesian Basin it first appears in the Blythesdale Group, and it ranges into the Winton Formation (? Cenomanian).

Cyathidites concavus (Bolkhovitina) comb. nov.

(Pl. I, fig. 17-19)

1953 *Stenozonotriletes concavus* Bolkhovitina, p. 46; Pl. 6, fig. 7.

DESCRIPTION: Microspores trilete; biconvex, the proximal surface strongly convex especially about the laesurae. Amb concavely triangular with convex, somewhat pointed, radial extremities. Laesurae straight, extending to amb. Exine 2·5-3·5 μ thick, smooth to faintly scabrate.

DIMENSIONS: Equatorial diameter 28 (43) 50 μ.

COMPARISON: The Australian spores are identical with *Cyathidites concavus* as defined by Bolkhovitina (1953, p. 46). They are distinct from *Concavisporites juriensis* Balme (1957, p. 20) in having a thicker exine, and in the constant absence of 'arcuate folds or thickenings' bordering the laesurae. The characteristically pointed radial extremities of the concavely triangular amb distinguishes *C. concavus* from other south-eastern Australian species of *Cyathidites*.

DISTRIBUTION: Described by Bolkhovitina (1953) from Aptian strata of the Moscow Basin, Russia, and reported herein from samples of the Blythesdale Group and Roma Formation (Aptian) in the Great Artesian Basin and from the lower intervals of bores in the Otway Basin (see Tables 3, 4, 6, 7).

Genus **Stereisporites** Pflug 1953

1937 *Sphagnumsporites Raatz* (nom. nud.), p. 9.
1953 *Stereisporites* Pflug in Thomson & Pflug, p. 53.
1953 *Sphagnites* Cookson, p. 463.
1956 *Sphagnumsporites* Raatz ex Potonié, p. 17.
1961 *Sphagnum* (Dill.) Ehrh.: Drozhastchich (pars) in Samoilovitch et al., p. 13.

TYPE SPECIES: *Stereisporites stereoides* (Potonié & Venitz) Pflug 1953.

REMARKS: As noted by Manum (1962, p. 26) *Stereisporites* Pflug (in Thomson and Pflug, March 1953) has priority over *Sphagnumsporites* Raatz ex Potonié; *Sphagnites* Cookson was instituted during October 1953 and is thus a later synonym of *Stereisporites*.

The holotype of the type species, *S. stereoides* (Potonié & Venitz), appears to have a uniformly thick exine (see Potonié and Venitz 1934; Pl. 1, fig. 4), but other illustrated specimens allocated to the species show weak exinal thickenings in the equatorial, radial regions (see Potonié and Venitz 1934; Pl. 1, fig. 5: Thomson and Pflug 1953, Pl. 1, fig. 64, 65, 73). Similar exinal thickenings are exhibited by the Australian representatives of *S. antiquasporites* (Wilson & Webster), and these spores should eventually be assigned to the Auriculati.

Stereisporites antiquasporites (Wilson & Webster) comb. nov.

(Pl. I, fig. 20, 21)

SELECTED SYNONYMY:

1946 *Sphagnum antiquasporites* Wilson & Webster, p. 273; Fig. 2.
1953 cf. *Sphagnites australis* (Cookson) f. *parva* Cookson, p. 469; Pl. 2, fig. 25, 26.
1956 *Sphagnumsporites antiquasporites* (Wilson & Webster) Potonié, p. 17.
1957 *Sphagnites australis* Cookson: Balme (pars), p. 15; Pl. 1, fig. 1, 2.
1962 *Sphagnumsporites antiquasporites* (Wilson & Webster) Pocock (pars), p. 32; Pl. 1, fig. 1-3.

DESCRIPTION: Microspores trilete, biconvex; amb subcircular to subtriangular with convex sides and broadly rounded angles. Laesurae straight, simple, length ½-¾ spore radius. Exine smooth, 1-2 μ thick; with slight thickenings in the radial regions at the equator and a low, distal polar thickening which is circular in outline and 6-8 μ in diameter.

DIMENSIONS: Equatorial diameter 20 (27) 36 μ.

REMARKS AND COMPARISON: Some variation in the length of the laesurae is shown by the spores here assigned to *Stereisporites antiquasporites* (Wilson & Webster). However, all have a smooth exine and a low, circular, distal polar thickening which is more clearly discernible in safranin-stained spores. A similar distal feature is seen in Cookson's form *Sphagnites australis* (Cookson) f. *crassa*, but this form is uniformly thickened at the equator and is referred subsequently to *Cingutriletes clavus* (Balme). The distal polar thickening distinguishes *S. antiquasporites* from several other species of the genus, including the type species, *S. stereoides* (Potonié & Venitz).

DISTRIBUTION: The species was found in most of the samples examined, including those of the Winton Formation (? Cenomanian) in the Great Artesian Basin (see Tables 3-9); it is particularly common in certain highly carbonaceous samples. In Western Australia the species is known from Jurassic and Lower Cretaceous deposits (Balme 1957), and similar forms have been recorded frequently from Mesozoic and Tertiary strata in other parts of the world.

Genus **Biretisporites** Delcourt & Sprumont emend. Delcourt, Dettmann, & Hughes 1963

SYNONYMY: See Delcourt, Dettmann, and Hughes 1963, p. 283.

TYPE SPECIES: *Biretisporites potoniaei* Delcourt & Sprumont 1955.

OTHER MESOZOIC SPECIES:

(1) *Biretisporites* (al. *Hymenophyllumsporites*) *deltoidus* (Rouse 1957, p. 363; Pl. 3, fig. 54-56) comb. nov. Occurrence: western Canada; Upper Cretaceous.
(2) *Biretisporites* (al. *Cingulatisporites*) *psilatus* (Groot & Penny 1960, p. 231; Pl. 2, fig. 21) comb. nov. Occurrence: eastern U.S.A.; Lower Cretaceous.
(3) *Biretisporites spectabilis* sp. nov.

Several Tertiary species assigned to *Leiotriletes* Naumova ex Potonié & Kremp by Krutzsch (1959, 1962) appear to be conformable with *Biretisporites* Delcourt & Sprumont.

REMARKS: Delcourt et al. (1963, p. 284) have shown that the type species is characterized by 'a smooth, uniformly thick exine and a trilete aperture enclosed with elevated lips'. Comparable features are exhibited by the other Mesozoic species here attributed to *Biretisporites.*

AFFINITY: Rouse (1957) suggests a relationship of his species, *B. deltoidus*, with *Hymenophyllum* L.

Biretisporites cf. **B. potoniaei** Delcourt & Sprumont 1955

(Pl. II, fig. 1, 2)

DESCRIPTION: Microspores trilete, biconvex; amb convexly subtriangular. Laesurae straight, approximating amb, and with narrow (1-1·5 μ wide), elevated (2-3 μ high) lips. Exine 1·5-2 μ thick, smooth.

DIMENSIONS: Equatorial diameter 34 (43) 56 μ.

REMARKS: The Australian specimens are similar to *Biretisporites potoniaei* Delcourt & Sprumont except that they have a thinner exine and are smaller in size.

DISTRIBUTION: The species is known from Wealden strata of Belgium and France (Delcourt and Sprumont 1955, 1959) and from Neocomian beds of Canada (Pocock 1962). The similar spores described above are widely dispersed in Upper Mesozoic deposits of SE. Australia (see Tables 3-8).

Biretisporites spectabilis sp. nov.

(Pl. II, fig. 3-8)

DIAGNOSIS: Microspores trilete, plano-convex, the distal surface strongly convex; amb triangular with rounded angles and straight to weakly concave or convex sides. Laesurae straight, extending to equator, and with conspicuous lips; lips, as shown in transverse sections, are narrow (2-3 μ wide), elevated (11-14 μ high), proximal extensions of the exine. Exine one-layered, 3·5-5 μ thick, homogeneous in structure, and with a faint LO surface pattern under oil immersion.

DIMENSIONS: Equatorial diameter 77 (104) 122 μ; polar diameter (9 specimens) 42 (65) 81 μ.

HOLOTYPE: Preparation D289/3 46·5 123·8 P21977; Pl. II, fig. 3, 4. Proximal aspect. Amb triangular, 111 μ in diameter. Laesurae 56 μ long. Exine 4·5 μ thick.

LOCUS TYPICUS: South Australia, Cootabarlow Bore No. 2 at 1,367-77 ft.

COMPARISON: The species is distinct from *Biretisporites deltoidus* (Rouse) in having a thicker exine and a larger size. *Leiotriletes selectiformis* Bolkhovitina has shorter laesurae, whilst *Biretisporites psilatus* (Groot & Penny) is considerably smaller.

DISTRIBUTION: Recovered from lower horizons only of the Upper Mesozoic successions in the Great Artesian and Otway Basins and in eastern Victoria (see Tables 3, 4, 6-8).

Genus **Dictyophyllidites** Couper emend.

1958 *Dictyophyllidites* Couper, p. 140.

EMENDED DIAGNOSIS: Microspores trilete; amb triangular. Exine smooth to faintly patterned; thickened about the laesurate margins. Laesurae enclosed within membraneous, elevated lips.

TYPE SPECIES: *Dictyophyllidites harrisii* Couper 1958. Occurrence: Britain; Jurassic.

OTHER SELECTED SPECIES:

(1) *Dictyophyllidites* (al. *Matonisporites*) *equiexinus* (Couper 1958, p. 140; Pl. 20, fig. 13, 14) comb. nov. Occurrence: Britain; Jurassic-Lower Cretaceous.

(2) *Dictyophyllidites* (al. *Matonia*) *pectinataeformis* (Bolkhovitina 1953, p. 56; Pl. 8, fig. 23) comb. nov.

(3) *Dictyophyllidites crenatus* sp. nov.

Many of the Tertiary species assigned by Krutzsch (1959, 1962) to his genera *Torioisporis, Toripunctisporis* and *Toripustulatisporites* appear to be comparable to *Dictyophyllidites* Couper.

REMARKS AND COMPARISON: *Dictyophyllidites* is emended herein to include both thin- and thick-walled, smooth to faintly patterned, trilete microspores having membraneous, elevated lips and thickened laesurate margins. The genus is thereby extended to incorporate the comparatively thick-exined, non-valvate spores of *Matonisporites* sensu Couper (1958).

Dictyophyllidites is distinct from *Biretisporites* Delcourt & Sprumont which does not have exinal thickenings about the laesurate margins; *Crassulina* Maljavikina ex Potonié lacks membraneous, elevated lips, and is considered by Potonié (1958) to be characterized by a loosely enveloped intexine (mesospore).

AFFINITY: Couper (1958) demonstrated that the type species is comparable to the spores of the Jurassic *Dictyophyllum rugosum* L. & H., and that *Dictyophyllidites equiexinus* (Couper) is similar to the Mesozoic matoniaceous species, *Phlebopteris angustiloba* (Presl.) and *Matonidium goepperti* (Ett.). The resemblance of *D. pectinataeformis* to the spores of the living *Matonia pectinata* R. Br. has been noted by Bolkhovitina (1953). Other associated microspores that conform with *Dictyophyllidites* include the spores described by Harris, T. M. (1961, p. 104; Fig. 34) from *Phlebopteris polypodioides* Brongn.

Dictyophyllidites pectinataeformis (Bolkhovitina) comb. nov.

(Pl. II, fig. 9-12)

1953 *Matonia pectinataeformis* Bolkhovitina, p. 56; Pl. 8, fig. 23.

DESCRIPTION: Microspores trilete; amb triangular with straight or concave sides and rounded angles. Laesurae straight, extending to amb; enclosed within membraneous lips (1-2 μ high) and bordered by convex, granulate exinal areas (5-6 μ wide) which are thickened towards laesurate margins. Exine 3·5-5 μ thick; with perceptible sculptural elevations.

Dimensions: Equatorial diameter (10 specimens) 53 (58) 64 μ.

Comparison: This distinctive species is readily distinguishable from other species of *Dictyophyllidites* in having a finely sculptured exine.

Bolkhovitina (1953) noted that the species resembles the spores of *Matonia pectinata* R. Br.; these modern spores are described by Couper (1958, p. 117; Pl. 20, fig. 11, 12).

Distribution: The species was described from Cenomanian-Turonian strata of the southern Urals, Russia (Bolkhovitina 1953), and has been recovered from two samples of the Otway Basin (see Tables 5, 7).

Dictyophyllidites crenatus sp. nov.

(Pl. III, fig. 1-5)

Diagnosis: Microspores trilete, biconvex; amb triangular with concave to straight sides and rounded angles. Laesurae sinuous, length at least ¾ spore radius; bordered by crenate, weakly thickened margins and enclosed within membraneous, elevated (2-3 μ high) lips. Exine smooth, 2·5-3·5 μ thick.

Dimensions: Equatorial diameter 45 (55) 70 μ; polar diameter (6 specimens) 35 (38) 42 μ.

Holotype: Preparation D302/17 38·0 119·4 P21981; Pl. III, fig. 1, 2. Proximal aspect. Amb 49 μ in diameter, concavely triangular. Laesurae sinuous, 30 μ long, and with membraneous lips 3 μ high. Exine smooth, 3 μ thick but thicker about laesurae.

Locus Typicus: South Australia, Cootabarlow Bore No. 2 at 1,469-70 ft.

Comparison: *Dictyophyllidites crenatus* sp. nov. is distinct from *D. harrisii* Couper in having sinuous laesurae and a thicker exine. It resembles *D. equiexinus* (Couper) which, however, has a convexly triangular amb. *Trilites sinuatus* Couper shows a greater development of thickening about the laesurate margins. The illustrated specimen assigned to *Sporites adriennis* Potonié cf. *mesozoicus* Thiergart (1949, p. 11; Pl. 2, fig. 3) and that of *Concavisporites antweilerensis* Pflug (in Thomson and Pflug 1953, p. 50; Pl. 1, fig. 43) resemble *D. crenatus* but apparently lack elevated laesurate lips.

As discussed subsequently probable corroded representatives of *D. crenatus* conform with *Foveotriletes parviretus* (Balme).

Distribution: A widely distributed species in the Upper Mesozoic of SE. Australia (see Tables 3-9). It is more common in samples examined from E. Victoria and from the lower horizons of the Otway and Great Artesian Basins.

Infraturma Apiculati Bennie & Kidston emend. Potonié 1956

The azonate, acavate, trilete spores of this infraturma are sculptured with elevations including granula, verrucae, spinae, bacula, capilli, etc. The sculptural elevations usually are discrete and their bases are less than twice as long as wide. As in Laevigati Bennie & Kidston the laesurae may be simple or lipped; thus, the apiculate spores of Pyrobolotriletes, Capulitriletes, Lagenotriletes, and Barbates conform with the Infraturma Apiculati Bennie & Kidston.

Genus **Leptolepidites** Couper 1953

TYPE SPECIES: *Leptolepidites verrucatus* Couper 1953.

REMARKS: Trilete, verrucate microspores which are almost certainly identical to the type species of *Leptolepidites* Couper have been recovered in the present investigation. Contrary to the generic diagnosis, these spores are smooth proximally.

The genus appears to be similar to *Rubinella* Maljavikina ex Potonié, but the detailed morphology of the latter genus has not been illustrated precisely.

Leptolepidites verrucatus Couper 1953

(Pl. III, fig. 6-9)

DESCRIPTION: Microspores trilete, biconvex; amb sub-triangular with straight to convex sides. Laesurae indistinct, simple, straight, extending to equator. Exine thin; smooth proximally, verrucate both equatorially and distally. Large, closely-spaced verrucae, hemispherical to subhemispherical, 3-5 μ high, and 4-7 μ in basal diameter.

DIMENSIONS: Equatorial diameter (including sculpture) 28 (36) 45 μ.

COMPARISON: The SE. Australian specimens appear to be identical to those described from New Zealand by Couper (1953, p. 28; Pl. 2, fig. 14, 15), and they are devoid of proximal sculpture. *Leptolepidites verrucatus* Couper may be similar to *Rubinella bacciformis* Maljavikina, the illustration of which, however, depicts smaller and more crowded verrucae. *Leptolepia fossilis* Chlonova is distinct in having shorter laesurae and smaller verrucae.

Couper (1953) compared the species with the spores of *Leptolepia novae-zealandiae* (Col.), but, according to Erdtman (1957, p. 70; Fig. 131), these living spores show verrucae only on the perine. Potonié (1956, p. 27) suggests comparison with the specimen figured by Knox (1938, Fig. 77) of *Alsophila chimborazensis* Hk. (not *A. cooperi* F. Muell. which has spinose sculpture). Some of the spores which Knox (1950) included in her *Selaginella vaginata* group are not unlike the fossil species.

DISTRIBUTION: The species was described from probable Upper Jurassic of New Zealand (Couper 1953). Doubtful representatives of the species have subsequently been recorded by de Jersey (1959) from the Lower Jurassic Walloon Coal Measures of Queensland, and by Lantz (1958b) from the Corallian and Purbeckian of England. The species occurs in the majority of the samples examined in the present study (see Tables 3-9). Additional E. Australian occurrences, including an Upper Cretaceous one, are given by Cookson and Dettmann (1958b, 1959a) and Dettmann (1959).

Leptolepidites major Couper 1958

(Pl. III, fig. 10-12)

1958 *Leptolepidites major* Couper, p. 141; Pl. 21, fig. 7, 8.
1961 *Selaginella orbiculata* Krasnova in Samoilovitch et al. p. 23; Pl. 3, fig. 3-5 (? fig. 6).

DESCRIPTION: Microspores trilete, biconvex; amb circular to subcircular. Laesurae indistinct, straight, length ¾ spore radius. Exine verrucate, about 3 μ thick (inclusive of sculpture). Verrucae rather variable in size, dome-shaped, and with circular to irregular bases. Distal verrucae closely-spaced, 1-3 μ high, and 3-8 μ in basal diameter; proximal verrucae lower and usually linearly arranged along laesurate margins.

DIMENSIONS: Equatorial diameter (inclusive of sculpture) 36 (44) 50 μ.

COMPARISON: The specimen figured by Rouse (1957; Pl. 3, fig. 78) shows a striking resemblance to the species, but apparently differs in having 'more reticulate than setaceous sculpture'. *Leptolepidites major* Couper is distinct from *L. verrucatus* Couper which is smaller and which has a sub-triangular amb; *Selaginella granata* Bolkhovitina which has smaller and more uniform verrucae; and *Gemmatriletes morulus* Pierce which has gemmate sculpture. Furthermore, in its smaller size and smaller verrucae *L. major* is distinct from *Lygodium corrugatus* Bolkhovitina and *Hymenozonotriletes speciosus* Baldakyte-Vienozinskiene.

Krasnova (in Samoilovitch et al. 1961, p. 23) compares the species with spores of *Selaginella repanda* (Desv.) (see also Knox 1950, p. 269; Pl. 4, fig. 143).

DISTRIBUTION: The species has been reported from Middle Jurassic of Britain (Couper 1958) and Valanginian-?Cenomanian of W. Siberia (Samoilovitch et al. 1961). The similar specimen figured by Rouse (1957) is from the Upper Cretaceous of Canada. *L. major* shows wide distribution, both laterally and vertically, in the Upper Mesozoic of SE. Australia (see Tables 4-8).

Genus **Concavissimisporites** Delcourt & Sprumont emend.

Delcourt, Dettmann, & Hughes 1963

SYNONYMY: See Delcourt, Dettmann, and Hughes 1963, p. 284.

TYPE SPECIES: *Concavissimisporites verrucosus* Delcourt & Sprumont 1955.

REMARKS: After a reappraisal of the type species and following Potonié's (1956) informal proposal, Delcourt et al. (1963) emended the genus to incorporate trilete, azonate microspores characterized by a concavely triangular amb and verrucate sculpture. Details of the verrucae preserved in the type and other species, *Concavissimisporites verrucosus* Delcourt & Sprumont, *C. crassatus* (Delcourt & Sprumont), and *C. penolaensis* sp. nov., are shown in Fig. 4a-c (see also Delcourt et al. 1963; Pl. 42, fig. 6, 7, 10, 11). Unfortunately the sculptural features have not been clearly detailed and depicted for many of the species which appear to be conformable with the genus. Such species have been widely recognized in Upper Mesozoic sediments from many parts of the world, and many of those described from the U.S.S.R. have been assigned to the modern genus *Lygodium* Swartz (see Kara-Murza 1954, Maljavikina 1958, Bolkhovitina 1961, Samoilovitch et al. 1961, Verbitskaya 1962).

COMPARISON: *Concavissimisporites* Delcourt & Sprumont is distinct from *Trilobosporites* Pant ex Potonié which has a differentially thickened exine and/or larger sculptural elements about the radial regions at the equator. *Converrucosisporites* Potonié & Kremp shows similar sculptural features, but it includes spores in which the amb has 'weakly concave or also slightly to strongly convex sides' (Bhardwaj 1957b, p. 115). *Leptolepidites* Couper, *Rubinella* Maljavikina ex Potonié, and *Verrucosisporites* Ibrahim show a convexly triangular amb; and *Trilites* Erdtman ex Couper possesses a differentially thickened exine (see discussion herein of *Trilites*).

AFFINITY: Microspores morphologically comparable to *Concavissimisporites* have been described in various living species of *Cyathea* Smith, *Dicksonia* L'Herit, and *Lygodium* Swartz (see Harris, W. F. 1955, Erdtman 1957, Couper 1958, Bolkhovitina 1961).

Concavissimisporites penolaensis sp. nov.

(Pl. III, fig. 13-16; Fig. 4c)

Diagnosis: Microspores trilete; amb triangular with rounded angles and straight or weakly concave sides. Laesurae straight, length ¾ spore radius. Exine 3-4 μ thick, verrucate; verrucae 1-1·5 μ high and with polygonal or occasionally circular bases 2-4 μ in diameter. Verrucae usually more crowded on distal surface and linearly arranged about laesurate margins.

Dimensions: (20 specimens) Equatorial diameter 52 (64) 81 μ.

Holotype: Preparation D295/1 54·9 108·9 P21968; Pl. III, fig. 13-15. Proximal aspect. Amb triangular, 76 μ in diameter (maximum radial length 46 μ). Laesurae 37 μ long. Exine 3·5 μ thick; with low, polygonal-based verrucae which are more closely spaced distally.

Locus Typicus: South Australia, Penola Bore No. 1 at 1,610-20 ft.

Comparison: The species may be conspecific with *Lygodium inundatum* Kara-Murza, the illustration (see Bolkhovitina 1961; Pl. 30, fig. 3) of which, however, does not precisely depict the laesurate and sculptural features. The holotype of *Concavissimisporites minor* (Pocock) is insufficiently well preserved for detailed comparison with *C. penolaensis* sp. nov. A direct comparison of *C. penolaensis* with the type specimens of *C. crassatus* (Delcourt & Sprumont) and *Concavisporites variverrucatus* Couper reveals that the Australian species is distinct in having a more coarsely sculptured exine, shorter laesurae, and less broadly rounded amb-angles. Further, *Concavissimisporites penolaensis* is distinct from *C. baculatus* Lantz and Kara-Murza's species, *Lygodium gibberulum* and *L. valanjinensis*, in having low, polygonal-based verrucae. *L. cretaceum* Chlonova has rugulate sculpture and shorter laesurae, whilst *L. triangulatum* Ivanova possesses a differentially thickened exine.

The species differs only in sculpture from the Australian representatives of *Cyathidites asper* (Bolkhovitina). Spores comparable to both species have been described in *Lygodium flexuosum* (L.) (see Bolkhovitina 1961; Pl. 23, fig. 5a-c), and this may suggest that the fossil species originated in closely related plants.

Distribution: The species was recovered from only a few samples taken from the Otway Basin (see Tables 5, 7). The similar form, *Lygodium inundatum*, has been reported from Valanginian-Lower Aptian strata of Siberia (Bolkhovitina 1961).

Genus **Osmundacidites** Couper 1953

1953 *Osmundacidites* Couper, p. 20.
1959 *Baculatisporites* Thomson & Pflug: Krutzsch (pars), p. 138.
1960 *Conosmundacidites* Klaus, p. 127.
1961 *Osmunda* L.: Klimko (pars) in Samoilovitch et al., p. 112.

Type Species: *Osmundacidites wellmanii* Couper 1953.

Discussion: *Osmundacidites* Couper, *Baculatisporites* Thomson & Pflug, and *Rugulatisporites* Thomson & Pflug are similar in shape, but are distinguishable on their sculptural features. *Osmundacidites* possesses a predominantly granulate exine and is distinct from *Baculatisporites* which has baculate sculpture (cf. Krutzsch 1959) and *Rugulatisporites* which is characterized by a rugulate exine.

Conosmundacidites Klaus is almost certainly synonymous with *Osmundacidites*; the thickened lips seen in *C. othmari* Klaus comprise coalescent granules which are linearly arranged along the laesurate margins. A similar feature is exhibited by *O. wellmanii* Couper (1960; Pl. 1, fig. 1).

Affinity: Couper (1953, 1958, 1960) compared the type species with spores of several fossil representatives of the Osmundaceae (*Osmundopsis plectrophora* Harris, *Todites hartzi* Harris, and *T. undans* (Brongn.)). Comparable spores are known also in the fossil *Osmundopsis sturi* (Raciborski) (see Harris, T. M. 1961, p. 99, Fig. 32) and in the living *Osmunda japonicum* Thunberg and *O. claytonia* L. (see Nakamura and Shibasaki 1959).

Osmundacidites wellmanii Couper 1953

(Pl. III, fig. 19-21; Fig. 4g, h)

1953 *Osmundacidites wellmanii* Couper, p. 20; Pl. 1, fig. 5.
1959 *Baculatisporites wellmanii* (Couper) Krutzsch, p. 142.
1962 *Osmundacidites wellmanii* Couper: Pocock (pars), p. 35; Pl. 1, fig. 15.

Description: Microspores spherical, but often distorted and with arcuate folds; amb circular in undistorted specimens. Exine thin (0·5-1·5 μ thick), granulate; grana with irregular, sometimes confluent bases. Laesurae straight, length greater than ¾ spore radius, and with granulate margins.

Dimensions: Equatorial diameter 36 (51) 67 μ.

Remarks and Comparison: *Osmundacidites wellmanii*, as defined by Couper (1953, 1958), is a broad type, and the Australian spores described above show

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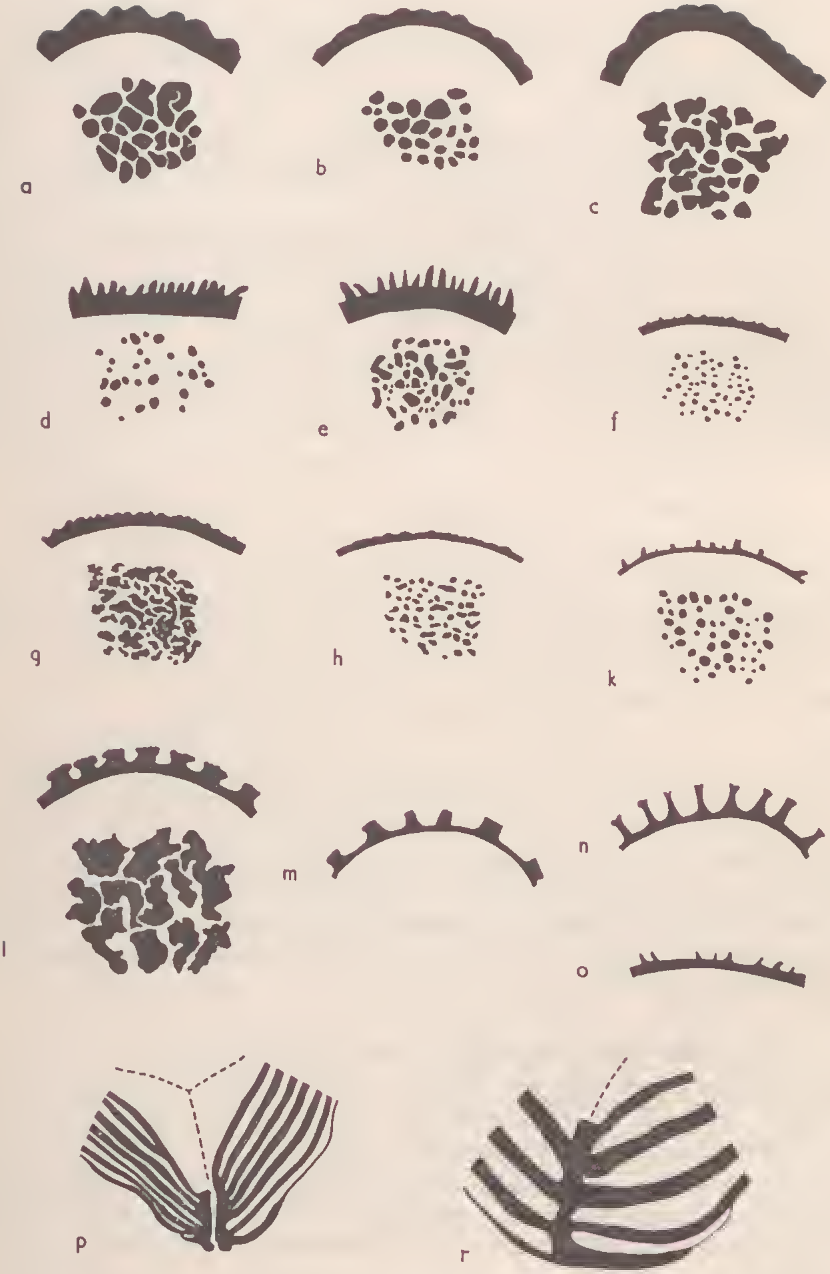
Fig. 4—Drawings from photographs; all magnifications × *c.* 850. (a) *Concavissimisporites verrucosus* Delcourt & Sprumont. Holotype; optical section and surface view of exine in equatorial, radial region (see also Delcourt et al. 1963; Pl. 42, fig. 6, 7); (b) *Concavissimisporites crassatus* (Delcourt & Sprumont). Holotype; optical section and surface view of exine in equatorial, radial region (see also Delcourt et al. 1963; Pl. 42, fig. 10, 11); (c) *Concavissimisporites penolaensis* sp. nov.; optical section and surface view of exine in equatorial, radial region (see also Pl. III, fig. 16) Robe Bore No. 1 at 1,400 ft, ICC60/4 40·7 119·0 (P21988); (d) *Pilosisporites notensis* Cookson & Dettmann; exine in section (see Pl. IV, fig. 5; Robe Bore No. 1 at 3,860 ft, D226/S70a/3 54·6 126·9 P21996) and surface view (Robe Bore at 3,860 ft, D226/11 40·7 117·3 P22583); (e) *Pilosisporites grandis* sp. nov.; optical section and surface view of exine in equatorial, radial region (see also Pl. V, fig. 3); Cootabarlow Bore No. 2 at 770-880 ft, D325/3 37·3 117·1 (P22000); (f) *Pilosisporites parvispinosus* sp. nov. Holotype; optical section and surface view of exine in equatorial, radial region (see also Pl. IV, fig. 6, 7); Comaum Bore No. 2 at 708 ft, D248/1 26·9 116·3 (P21997); (g) *Osmundacidites wellmanii* Couper; optical section and surface view of specimen having a thick exine and large, coalescent granules (see also Pl. III, fig. 19); Koppcramanna Bore at 2,970 ft, D241/3 44·4 122·3 (P21990); (h) *Osmundacidites wellmanii* Couper; optical section and surface view of specimen having a thin exine and small granules; Cootabarlow Bore No. 2 at 1,391-92 ft, D288/1 23·2 116·2 (P22144); (k) *Baculatisporites comaumensis* (Cookson); optical section and surface view of equatorial exine (see also Pl. III, fig. 22, 23); Barongarook Creek, sample P22585, D203/1 43·5 109·9 (P21992); (l) *Lycopodiacidites asperatus* sp. nov.; optical section and surface view of equatorial exine; Cootabarlow Bore No. 2 at 1,340 ft, D290/1 52·1 110·6 (P21991); (m) *Neoraistrickia truncatus* (Cookson); optical section of equatorial exine; Cape Paterson, sample P22601, D162/1 45·8 125·5 (P22019); (n) *Ceratosporites equalis* Cookson & Dettmann; optical section of equatorial exine (see also Pl. V, fig. 6); Cootabarlow Bore No. 2 at 1,469-70 ft, D302/1 32·1 126·9 (P22002); (o) *Foraminisporis wonthaggiensis* (Cookson & Dettmann) optical section of distal exine (see also Pl. XIV, fig. 19-21); Cootabarlow Bore No. 2 at 1,376-77 ft, D289/1 20·2 122·3 (P22038); (p) *Cicatricosisporites australiensis* (Cookson) surface view of equatorial, radial exine showing proximo-equatorial muri (see also Pl. IX, fig. 12, 13, 15); Robe Bore No. 1 at 2,630 ft, D259/4 38·7 120·1 (P22034); (r) *Cicatricosisporites hughesi* sp. nov.; surface view of equatorial, radial exine showing proximo-equatorial muri, Penola Bore No. 1 at 1,805-15 ft, D294/1 49·6 128·7 (P21965).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considerable variation in the thickness and sculpture of the exine. Specimens (Pl. III, fig. 20, 21) which have a thin (less than 1 μ thick) exine show small, widely-spaced granules, and those (Pl. III, fig. 19) in which the exine is thicker (1-1·5 μ) possess larger, usually coalescent granules. However, subdivision of the species into more restricted units has not been attempted owing to the occurrence of 'intermediate' forms.

An even broader definition of the species is given by Pocock (1962) who attributes to it both *Baculatisporites comaumensis* (Cookson) and *'Osmundasporites' elongatus* Rouse. *Osmundacidites wellmanii* is distinct from these species, however, in having granulate sculpture.

The species is similar to *Lophotriletes bjutainensis* Bolkhovitina, but differs in its smaller size and longer laesurae. *Osmunda tuberculata* Klimko has shorter laesurae, *Osmundacidites alpinus* Klaus is considerably smaller, and both *O. senectus* Balme and *Osmunda elongatus* Klimko have more conical sculptural elements.

DISTRIBUTION: The species is common throughout the Upper Mesozoic of SE. Australia (see Tables 3-9), and is known from Lower Jurassic strata of Queensland (de Jersey 1959). Its known geological range is Liassic to Middle Senonian (Couper 1960).

Osmundacidites mollis (Cookson & Dettmann) comb. nov.

(Pl. III, fig. 17, 18)

1958 *Lycospora mollis* Cookson & Dettmann, p. 111; Pl. 17, fig. 14-17.

DESCRIPTION: Microspores trilete, spheroidal. Laesurae straight, extending almost to amb, and with weakly thickened margins. Exine 1-1·5 μ thick, finely granulate. The 'subequatorial ridge' of Cookson and Dettmann (1958b, p. 111) constitutes a narrow, unthickened bulge in the equatorial exine.

DIMENSIONS: Equatorial diameter 28 (39) 48 μ; polar diameter 28 (31) 36 μ.

REMARKS AND COMPARISON: The unthickened nature of the equatorial exine is clearly seen in optical sections of spores situated in equatorial aspect (see Cookson and Dettmann 1958b; Pl. 17, fig. 16: present study; Pl. III, fig. 18). The species is distinct from *Osmundacidites wellmanii* Couper which has coarser and more closely spaced granules, and *Todisporites minor* Couper which possesses a smooth exine.

DISTRIBUTION: The species is of infrequent occurrence, and shows wide distribution in the Upper Mesozoic of SE. Australia (Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 4, 6-9).

Genus **Baculatisporites** Thomson & Pflug 1953

1953 *Baculatisporites* Thomson & Pflug, p. 56.
1959 *Baculatisporites* Thomson & Pflug: Krutzsch (pars), p. 138.

TYPE SPECIES: *Baculatisporites primarius* (Wolff) Thomson & Pflug 1953.

REMARKS: As noted previously, this genus is distinct from *Osmundacidites* Couper in having baculate, and not granulate, sculpture (cf. Krutzsch 1959). *Conbaculatisporites* Klaus shows similar baculate sculpture but differs in having a triangular amb.

AFFINITY: Morphologically comparable spores occur in the Osmundaceae e.g. in *Osmunda cinnamomea* L. and *O. bromerifolia* Copeland (see Nakamura and Shibasaki 1959).

Baculatisporites comaumensis (Cookson) Potonié 1956

(Pl. III, fig. 22, 23; Fig. 4k)

1953 *Trilites comaumensis* Cookson, p. 470; Pl. 2, fig. 27, 28.
1956 *Baculatisporites comaumensis* (Cookson) Potonié, p. 23.
1957 *Osmundacidites comaumensis* (Cookson) Balme, p. 25; Pl. 4, fig. 54-56.
1962 non *Osmundacidites wellmanii* Couper: Pocock, p. 35; Pl. 1, fig. 15.

DESCRIPTION: Microspores biconvex in undistorted specimens; amb circular. Exine *c.* 1 μ thick; sculptured with short, equidimensional bacula together with a few setulae and clavae. Sculptural elements 1-1·5 μ long and 1-1·5 μ in diameter; randomly disposed 1-3 μ apart, except along laesurate margins where they are linearly and more closely arranged. Laesurae straight, length ¾ spore radius.

DIMENSIONS: Equatorial diameter 27 (45) 62 μ.

COMPARISON: The species is similar to *Osmunda crassirimosa* Klimko and *Baculatisporites primarius* (Wolff), both of which, however, have smaller bacula. *B. comaumensis* (Cookson) is distinct from Krutzsch's (1959) Tertiary species on the form and size of its bacula.

Cookson (1953) compared the species with the spores of *Todea* Willd. and *Leptopteris* Presl.; it resembles also the spores of certain species of *Osmunda* L. e.g., *O. cinnamomea* L.

DISTRIBUTION: Balme (1957) recorded the species in Jurassic-Lower Cretaceous strata of Western Australia, and Klaus (1960) reports it from the Upper Triassic of Europe. It is of common occurrence throughout the Upper Mesozoic of SE. Australia (Cookson and Dettmann 1958b, 1959a; Dettmann 1959; present study, Tables 3-9), and similar spores are known from Quaternary strata of Victoria (Duigan and Cookson 1956).

Genus **Neoraistrickia** Potonié 1956

1949 *Cepulina* Maljavikina (pars), p. 73.
1956 *Neoraistrickia* Potonié, p. 34.
1959 *Reticulatisporites*? Ibrahim: Krutzsch, p. 162.

TYPE SPECIES: *Neoraistrickia truncatus* (Cookson) Potonié 1956.

DISCUSSION: Potonié (1956) instituted the genus to incorporate trilete, azonate, Mesozoic microspores which show a sculpture pattern composed solely of bacula. Comparable morphology is found in the more widely circumscribed genus *Cepulina* Maljavikina which is a partial synonym of *Neoraistrickia* Potonié (see Potonié 1960, p. 44). The type of *Anemiidites* Ross, as it is depicted in the original illustrations (Ross 1949; Pl. 1, fig. 17, 18), shows baculate sculptural elements, but these elements are described as 'spines about 2 μ long' (Ross 1949, p. 32).

The sculpture of *Neoraistrickia* is similar to that of the Palaeozoic genus *Raistrickia* Schopf, Wilson, & Bentall which, however, also includes forms with additional spinulae and/or coni (see Potonié 1956, p. 73; Bhardwaj 1957a, Fig. 4). Baculate sculpture is diagnosed for *Baculatisporites* Thomson & Pflug, but *Neoraistrickia* differs in its subtriangular amb and in having larger and more widely distributed bacula. The genus is distinct also from *Ceratosporites* Cookson & Dettmann which has a smooth proximal exine and narrow-based clavae, setulae, and capillae distally.

AFFINITY: Spores attributable to *Neoraistrickia* are similar to those found in modern *Selaginella* Spring e.g., in the *S. stolonifera* and *S. biformis* groups of Knox (1950), and in *Lycopodium densum* La Billard (see Couper 1958, Samoilovitch et al. 1961).

Neoraistrickia truncatus (Cookson) Potonié 1956

(Pl. V, fig. 4, 5; Fig. 4m)

1953 *Trilites truncatus* Cookson, p. 471; Pl. 2, fig. 36.
1956 *Neoraistrickia truncatus* (Cookson) Potonié, p. 34.
1957 *Baculatisporites truncatus* (Cookson) Balme, p. 18; Pl. 1, fig. 21, 22 (? fig. 20).
1958 *Lycopodiumsporites gristhorpensis* Couper, p. 135; Pl. 15, fig. 14, 15 (? fig. 16).
1959 *Reticulatisporites? truncatus* (Cookson) Krutzsch, p. 162.
1962 non *Lycopodiumsporites gristhorpensis* Couper: Pocock, p. 33; Pl. 1, fig. 9.

DESCRIPTION: Microspores trilete; amb roundly triangular. Laesurae straight, extending to amb, and with membraneous, elevated (1-2 μ high) lips. Exine 1·5-2 μ thick, baculate. Distal bacula spaced 4-7 μ apart; with circular bases 2-3 μ in diameter, constricted columns 2·5-4·5 μ high, and truncated distal extremities 1-2 μ in diameter. Proximal bacula inconspicuous and sparsely distributed.

DIMENSIONS: Equatorial diameter (including sculpture) 28 (34) 40 μ.

COMPARISON: The species is similar to *Neoraistrickia neozealandica* (Couper), *Selaginella rotundiformis* Kara-Murza, and *Raistrickia obtusispinosa* Rouse, but differs in showing smaller and more sparsely disposed bacula. *Lophotriletes testatus* Bolkhovitina and Rogalska's specimen (1956; Pl. 29, fig. 3) of *Spinosisporites minimus* Jachowicz are distinct in having shorter laesurae; *Selaginella rareverrucosa* Chlonova shows verrucate sculpture; and *Anemiidites echinatus* Ross has a concavely triangular amb.

Couper (1958, p. 133) states that the 'nearest living counterpart' of the British specimens are to be found in *Lycopodium densum* La Billard. Other spores which are similar to *Neoraistrickia truncatus* include those of Knox's (1950) *Selaginella biformis* group.

DISTRIBUTION: The species is widely distributed in the Upper Mesozoic of SE. Australia (Cookson 1953; Cookson and Dettmann 1958b, 1959a; Dettmann 1959; present study, Tables 3-9). Other documented occurrences include Upper Jurassic-Lower Cretaceous of Western Australia (Balme 1957) and Middle Jurassic of Britain (Couper 1958).

Genus **Ceratosporites** Cookson & Dettmann 1958

TYPE SPECIES: *Ceratosporites equalis* Cookson & Dettmann 1958.

COMPARISON: The genus is distinct from *Neoraistrickia* Potonié in having a smooth proximal exine together with clavae, setulae, and capillae distally.

AFFINITY: Cookson and Dettmann (1958b) compared the type species with the spores of the *Selaginella latifrons* group of Knox (1950).

Ceratosporites equalis Cookson & Dettmann 1958

(Pl. V, fig. 6-8; Fig. 4n)

DESCRIPTION: Microspores trilete, tetrahedral; distal surface convex, proximal surface pyramidal. Amb convexly subtriangular. Laesurae straight, extending almost to amb, and with membraneous, elevated (2-4 μ high) lips. Exine 1-1·5 μ thick, smooth to faintly scabrate proximally. Distal surface sculptured with slender clavate to capillate, and occasionally spinulate to setulate, elements. Elements spaced 3-4 μ apart; with narrow (1-2 μ wide) bases and slightly constricted columns (3-7 μ high) which broaden and sometimes bifurcate towards their distal extremities.

DIMENSIONS: Equatorial diameter (including sculpture) 34 (44) 56 μ; polar diameter (5 specimens) 34 (40) 45 μ.

COMPARISON: The species shows a striking resemblance to *Selaginella tenuispinulosa* Krasnova, which, however, includes spores with comprehensive spinose sculpture. *Ceratosporites equalis* Cookson & Dettmann is similar to Bolkhovitina's (1956) species, *Alsophila parvispinosa*, and to the spores which she previously (1953) assigned to *Acanthotriletes typicus* Naumova, but the Australian species is distinct in having longer sculptural elements. *C. equalis* is distinct also from *Acanthotriletes levidensis* Balme and *Selaginella diuturna* Bolkhovitina, both of which possess tapering spinae. *Pteris paleouncinnata* Bolkhovitina has shorter laesurae and more widely spaced sculptural elements, and *Lycopodiacidites baculatus* Pocock is larger and has reticulate sculpture.

DISTRIBUTION: A widely distributed species in SE. Australian Upper Mesozoic sediments (Cookson and Dettmann 1958b, 1959a; Dettmann 1959; present study, Tables 3-9).

Genus **Pilosisporites** Delcourt & Sprumont 1955

1955 *Pilosisporites* Delcourt & Sprumont, p. 34.
1961 *Lygodium* Swartz: Bolkhovitina (pars), p. 102.
1961 *Lygodium* Swartz: Ivanova (pars) in Samoilovitch et al., p. 90.

TYPE SPECIES: *Pilosisporites trichopapillosus* (Thiergart) Delcourt & Sprumont 1955.

AFFINITY: Definite evidence of the botanical affinity of this distinctive group of spores appears to be lacking; certainly there is no evidence for a schizaeaceous relationship (cf. Bolkhovitina 1961, Samoilovitch et al. 1961).

Pilosisporites notensis Cookson & Dettmann 1958

(Pl. IV, fig. 1-5; Fig. 4d)

1958 *Pilosisporites notensis* Cookson & Dettmann (pars), p. 102; Pl. 15, fig. 1, 3.
1961 *Lygodium notensis* (Cookson & Dettmann) Bolkhovitina, p. 103; Pl. 38, fig. 7.

DESCRIPTION: Microspores trilete, biconvex; amb triangular with concave to almost straight sides and broadly rounded angles. Laesurae straight, length about ⅔ spore radius; enclosed within membraneous, elevated (2-3 μ high) lips which have serrated crests. Exine one-layered, 2-3·5 μ thick, and sculptured with conical elements which are 1-2 μ in basal diameter and 2-4 μ high. Sculptural elements densely disposed about equatorial, radial regions and sparsely distributed over polar regions; closely-spaced and linearly arranged at laesurate margins.

DIMENSIONS: Equatorial diameter 76 (95) 111 μ; polar diameter (2 specimens) 76, 80 μ.

COMPARISON: One of the illustrated spores which Cookson and Dettmann (1958b; Pl. 15, fig. 2) included within their *Pilosisporites notensis* is now considered to represent a distinct species, and is subsequently allocated to *P. parvispinosus* sp. nov. *P. notensis* resembles one of the illustrated specimens of *Lygodium setiferum* Verbitskaya (1962; Pl. 11, fig. 53b), but the holotype (loc. cit.; Pl. 11, fig. 53c) of the Russian species is distinct from *P. notensis* in having longer and more crowded elements which are straight sided. *P. notensis* is distinct from *P. verus* Delcourt & Sprumont in having shorter and more evenly distributed conical elements and from *Lygodium calvum* Ivanova which has a thinner exine and smaller and more sparsely disposed elements about the laesurae.

Distribution: The species shows wide lateral distribution in the Upper Mesozoic of SE. Australia (see Tables 4-9); in the Great Artesian Basin it was found only in samples of the Blythesdale Group and Roma Formation (Aptian). Previous records (Cookson and Dettmann 1958b, 1959a; Dettmann 1959) include occurrences of *P. notensis*, *P. parvispinosus*, and *P. grandis* sp. nov.

Pilosisporites parvispinosus sp. nov.

(Pl. IV, fig. 6-8; Fig. 4f)

1958 *Pilosisporites notensis* Cookson & Dettman (pars), p. 102; Pl. 15, fig. 1.

Diagnosis: Microspores trilete, biconvex; amb concavely triangular. Laesurae straight, length ⅔ spore radius, and with membraneous, elevated (2-5 μ high) lips. Exine 2-3 μ thick, spinulate; small blunt to pointed spinules (1-2 μ high, 1 μ in basal diameter) more closely spaced in equatorial, radial regions and linearly arranged about laesurae.

Dimensions: Equatorial diameter (19 specimens) 78 (98) 117 μ.

Holotype: Preparation D248/1 26·9 116·3 P21997; Pl. IV, fig. 6, 7; Fig. 4f. Proximal aspect. Amb concavely triangular, 111 μ in diameter (62 μ in maximum radial length). Laesurae 39 μ long. Exine 2 μ thick; spinules more crowded in equatorial, radial regions and linearly arranged about, and 5 μ from, laesurate margins.

Locus Typicus: South Australia, Comaum Bore No. 2 at 708 ft.

Comparison: The species may be comparable to the specimen depicted by Verbitskaya (1962; Pl. 11, fig. 53a) of her species *Lygodium setiferum*. *Pilosisporites parvispinosus* sp. nov. is distinct from *P. notensis* Cookson & Dettmann in having shorter and more widely spaced spinules.

Distribution: The species is widely dispersed in SE. Australia (see Tables 4-9); it appears to be restricted to the Roma (Aptian) and Tambo (Albian) Formations in the Great Artesian Basin.

Pilosisporites grandis sp. nov.

(Pl. V, fig. 1-3; Fig. 4e)

Diagnosis: Microspores trilete; amb concavely triangular. Laesurae straight, length ⅔ spore radius, and with membraneous, elevated lips 2-3 μ high. Exine 4·5-5·5 μ thick; with closely-packed, sometimes coalescent, tapering spines which are 3-5 μ high and which have circular to irregular bases 1-3 μ in diameter. Spines more crowded on distal surface.

Dimensions: Equatorial diameter (19 specimens) 100 (117) 142 μ; polar diameter (1 specimen) 88 μ.

Holotype: Preparation 1CC/1 41·3 111·8 P22098; Pl. V, fig. 1, 2. Distal aspect. Amb concavely triangular, 136 μ in diameter (maximum radial length 78 μ). Laesurae 50 μ long. Exine 5·5 μ thick; spines 3-5 μ high; 1-3 μ in basal diameter.

Locus Typicus: Victoria, Pretty Hill Bore No. 1 at 2,928-80 ft.

Comparison: *Lygodium echinaceum* Verbitskaya and the figured specimens attributed to *Lygodium* sp. by Zauer and Mtchedlishvili (1954; Pl. 11, fig. 18, 19) resemble *Pilosisporites grandis* sp. nov. which is distinct, however, in having a larger size, thicker exine, and irregularly based spines.

Distribution: The species has been recovered from the uppermost horizons examined of the Upper Mesozoic sequences in the Great Artesian and Otway Basins (see Tables 5-7, 9).

Genus **Kuylisporites** Potonié 1956

TYPE SPECIES: *Kuylisporites waterbolki* Potonié 1956. Occurrence: Trinidad; Lower Tertiary: Holland; Senonian (after Krutzsch 1959).

OTHER SPECIES:

(1) *Kuylisporites mirabilis* (Bolkhovitina) Potonié 1958. Occurrence: U.S.S.R.; Cenomanian.
(2) *Kuylisporites* (al. *Hemitelia*) *separatus* (Chlonova 1960, p. 11; Pl. 1, fig. 6, 7) comb. nov. Occurrence: U.S.S.R.; Maastrichtian-Palaeocene (after Chlonova 1960, 1961).
(3) *Kuylisporites* (al. *Hemitelia*) sp. Samoilovitch et al. 1961; Pl. 79, fig. 4. Occurrence: U.S.S.R.; Maastrichtian.

The following species are not entirely conformable with *Kuylisporites*:

(1) *Kuylisporites lunaris* Cookson & Dettman 1958.
(2) *Brochotriletes degradatus* Verbitskaya 1958; Pl. 4, fig. 67; 1962, p. 118; Pl. 16, fig. 87a, b. Occurrence: U.S.S.R.; Aptian.

DISCUSSION: Krutzsch (1959, p. 190) claims that the genus is typified by *Kuylisporites mirabilis* (Bolkhovitina) because he considers that this species is homotaxial with *K. waterbolki* Potonié. It seems evident from the illustrations and description, however, that *K. waterbolki* is distinct from *K. mirabilis* in showing distal as well as equatorial scutula.

Dulhuntyispora Potonié has equatorial scutula, but *Kuylisporites* Potonié is distinguishable in the form of its lumina and in having lenticulate scutula. *Kuylisporites* is distinct also from *Camursporis* Chlonova in which the equatorial structures appear to be comparable to the 'colpoid' areas seen in *Triporoletes* Mtchedlishvili.

AFFINITY: Kuyl, Muller, and Waterbolk (1955), Potonié (1956), and others have demonstrated that the type and other Upper Cretaceous species are comparable to certain spores of *Hemitelia* R. Brown, a member of the Cyatheaceae. The Australian species, *K. lunaris*, shows slight resemblance to *Alsophila blechnoides* (Rich.) also of the Cyatheaceae (see Erdtman 1957; Fig. 79).

Kuylisporites lunaris Cookson & Dettmann 1958

(Pl. V, fig. 9-12)

DESCRIPTION: Microspores trilete, biconvex; amb subcircular, subtriangular, or subquadrangular with straight or convex sides. Laesurae straight, extending to equator, and bordered by weakly thickened lips (1-2 μ wide). Exine 1·5-2·5 μ thick, slightly thicker (2-3·5 μ) at the equator where a few widely-scattered, shallow foveolae occur; surface finely granulate to microreticulate under oil immersion (Pl. V, fig. 12). Conspicuous, crescentic-shaped elevations (scutula of Potonié 1956, p. 38), which delimit and partially enclose circular to elliptical, shallow lumina (3-8 μ in diameter), usually confined to distal surface. Central area of each contact face granulate and occasionally with small scutula. Total number of scutula observed on individual specimens varies from 3 to 25.

DIMENSIONS: Equatorial diameter 39 (48) 67 μ.

COMPARISON: The species is weakly thickened equatorially, and is not entirely conformable with *Kuylisporites*. *K. lunaris* Cookson & Dettmann is similar to *Brochotriletes degradatus* Verbitskaya, but has longer laesurae and a thicker equatorial exine. It is distinct from *K. waterbolki* Potonié, *K. mirabilis* (Bolkhovitina), and *K. separatus* (Chlonova), all of which have equatorially situated scutula and shorter laesurae.

Distribution: The species shows wide lateral distribution, and appears to have some stratigraphical value in the Upper Mesozoic of SE. Australia (Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 4-9).

Infraturma Murornati Potonié & Kremp 1954

Azonate, acavate, trilete spores having simple or lipped apertures and a sculpture of elongated elevations or depressions are allocated to this infraturma. The sculptural elements include foveolae, lumina, muri, rugulae, etc.: the elevations, as seen in surface view, are at least twice as long as wide and may be coalescent.

The murornate spores of Pyrobolotriletes, Lagenotriletes, and Barbates conform with Murornati Potonié & Kremp. Spores attributed by Neves (1961) to his series, Pseudocingulati, appear to be comparable to the Infraturma Murornati.

Genus **Lycopodiacidites** Couper emend. Potonié 1956

1953 *Lycopodiacidites* Couper, p. 26.
1956 *Lycopodiacidites* Couper emend. Potonié, p. 39.
1961 *Iniquiornatisporis* Dev, p. 44.

Remarks: This genus was emended by Potonié (1956) to incorporate trilete, azonate microspores having a subcircular amb and verrucate to rugulate sculpture distally. The Australian species described below has proximal sculpture, and is not strictly conformable, therefore, with *Lycopodiacidites* Couper.

Lycopodiacidites asperatus sp. nov.

(Pl. VI, fig. 1-3; Fig. 41)

Diagnosis: Microspores trilete, spheroidal; amb circular to convexly subtriangular. Laesurae straight, length ¾ amb radius. Exine thick, coarsely rugulate; closely-spaced, sinuous rugulae 2-5 μ high, 2-3 μ in greatest basal diameter, and with broader (2-4 μ wide), truncated, granulate crests. Sculpture slightly reduced about laesurate margins.

Dimensions: (inclusive of sculpture) Equatorial diameter 49 (60) 73 μ; polar diameter (7 specimens) 46 (51) 56 μ.

Holotype: Preparation D241/4 36·5 118·3 P22008; Pl. VI, fig. 1, 2. Proximal aspect. Amb circular, 51 μ in diameter; laesurae 20 μ long. Exine with sinuous rugulae which have granulate crests 2-3 μ wide.

Locus Typicus: South Australia, Kopperamanna Bore No. 1 at 2,970 ft.

Comparison: The species resembles *Camptotriletes clivosus* Bolkhovitina, but differs in having larger rugulae which are granulate. *Lycopodiacidites asperatus* sp. nov. is distinguishable from *Lygodioisporites perverrucatus* Couper, *Trilites verrucatus* Couper, *Dicksonia crocina* Bolkhovitina, and *Lophotriletes barbarus* Bolkhovitina in possessing rugulate, and not verrucate, sculpture.

The spores of *Botrychium palmatum* Presl. are similar to *Lycopodiacidites asperatus* (see Nakamura and Shibasaki 1959, p. 6; Pl. 3, fig. 10).

Distribution: The species occurred sporadically in many of the samples examined (see Tables 3-9).

Genus **Tripartina** Maljavikina ex Potonié 1960

1949 *Tripartina* Maljavikina (pars), p. 48.
1960 *Tripartina* Maljavikina ex Potonié, p. 48.

Type Species: *Tripartina variabilis* Maljavikina 1949.

Remarks: Potonié (1960) validated and emended the genus which incorporates trilete microspores having a triangular amb and radially disposed sculptural elements. Morphologically similar spores had been assigned previously (Pflug in Thomson and Pflug 1953, Krutzsch 1959) to *Undulatisporites* Pflug, but the holotype of Pflug's genus is distinct from *Tripartina* Maljavikina ex Potonié in having a smooth exine (see Thomson and Pflug 1953, p. 52; Pl. 1, fig. 81: Potonié 1956, p. 19).

Tripartina cf. **T. variabilis** Maljavikina 1949

(Pl. V, fig. 13-15)

Description: Microspores trilete; amb concavely triangular with sharply pointed angles. Laesurae weakly sinuous, extending to amb, and accompanied by undulate lips 1-2 μ high and 3 μ wide. Exine 1·5-2 μ thick; distal surface with radially disposed, narrow, sinuous channels (lumina) which emanate from pole and which are separated by smooth intervening areas 2-3 μ wide. Proximal exine smooth.

Dimensions: Equatorial diameter 28 (36) 50 μ.

Comparison: The Australian spores are similar to *Tripartina variabilis* Maljavikina and are distinct from *Undulatisporites pseudobrasiliensis* Krutzsch which has a 'fossulate' proximal exine and a straight-sided triangular amb.

Distribution: The species was described from Middle Jurassic strata of the U.S.S.R. (Maljavikina 1949). The similar Australian form has been recovered from many of the samples investigated (see Tables 3-9).

Genus **Cyclosporites** Cookson & Dettmann 1959

1958 *Radiatisporites* Cookson & Dettmann, p. 103 non Potonié & Kremp 1954.
1959 *Cyclosporites* Cookson & Dettmann, p. 260.

Type Species: *Cyclosporites hugesi* (Cookson & Dettmann) Cookson & Dettmann 1959.

Remarks: The genus is distinct from *Tripartina* Maljavikina ex Potonié and *Tigrisporites* Klaus in having proximal, instead of distal, radially disposed sculptural elements.

Bolkhovitina's species, *Leiotriletes eximius* and *Lygodium reticulatiformis*, appear to be conformable with *Cyclosporites* Cookson & Dettmann.

Cyclosporites hughesi (Cookson & Dettmann) Cookson & Dettmann 1959

(Pl. VI, fig. 4-7)

1958 *Radiatisporites hughesi* Cookson & Dettmann, p. 103; Pl. 15, fig. 4-6.
1959 *Cyclosporites hughesi* (Cookson & Dettmann) Cookson & Dettmann, p. 260.

Description: Microspores trilete, biconvex; amb subcircular to convexly subtriangular. Laesurae straight, length ¾ spore radius; enclosed within membraneous, elevated (2-3 μ high) lips. Exine 1·5 μ thick; with an open-meshed reticulum composed of narrow (2 μ in basal diameter), sharply-crested, high (4-7 μ), elongated muri which are separated by lumina 5-6 μ wide. Proximal muri radially arranged, emanating from laesurate margins and bifurcating towards amb; distal muri sinuous, arranged obliquely or tangentially to amb.

Dimensions: Equatorial diameter (including sculpture) 42 (52) 64 μ.

Comparison: *Leiotriletes eximius* Bolkhovitina and *Lygodium reticulatiformis* Bolkhovitina have radially arranged proximal muri, but both species are distinct from *Cyclosporites hughesi* (Cookson & Dettmann) in having wider and more closely spaced muri.

Distribution: A widely distributed species in SE. Australia where it seems to have undoubted stratigraphical importance (Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 3, 4, 6-8).

Genus **Foveotriletes** van der Hammen ex Potonié 1956

Type Species: *Foveotriletes scrobiculatus* (Ross) Potonié 1956.

Fovetriletes parviretus (Balme) comb. nov.

(Pl. VI, fig. 8-13)

1957 *Microreticulatisporites parviretus* Balme, p. 24-25; Pl. 4, fig. 50, 51.

Description: Microspores trilete, biconvex; amb triangular with straight to concave sides. Laesurae straight to sinuous, length ¾ spore radius, and occasionally with membraneous, elevated lips. Exine 2-3·5 μ thick, foveolate to foveo-reticulate; foveolae deep to shallow, irregular in outline, 0·5-2 μ in maximum diameter, and separated by smooth intervening areas.

Dimensions: Equatorial diameter 45 (57) 67 μ.

Remarks: Considerable variation in the diameter and depth of the foveolae exists among the spores which are assigned here to *Foveotriletes parviretus* (Balme), and which may well be corroded representatives of smooth-walled species, such as *Dictyophyllidites crenatus* sp. nov. In some specimens (Pl. VI, fig. 8-12) the foveolae are deep and closely spaced; other examples (Pl. VI, fig. 13) have shallow, imperceptible foveolae which are more widely spaced on an otherwise smooth exine. The lightly 'sculptured' specimens usually possess membraneous, laesurate lips and closely resemble *D. crenatus* which is of common occurrence in all the samples from which *F. parviretus* has been recovered.

Comparison: The species has a thinner exine and is smaller than *Foveotriletes microreticulatus* Couper; *Cybotiumidites mesopunctatus* Maljavikina is larger and has shorter laesurae. Corroded examples of *Cyathidites punctatus* (Delcourt & Sprumont) and *C. asper* (Bolkhovitina) differ from *F. parviretus* in having 'granulate sculpture'.

Distribution: Balme (1957) described the species from Neocomian-Aptian deposits of Western Australia. In the present study it has only been isolated from samples in which *Dictyophyllidites crenatus* is also present (see Tables 3-9).

Genus **Foveosporites** Balme 1957

1957 *Foveosporites* Balme, p. 17.
1959 *Foveasporis* Krutzsch (pars), p. 162.

Type Species: *Foveosporites canalis* Balme 1957.

Other Species: The following Mesozoic and Tertiary species conform with *Foveosporites* Balme:

(1) *Foveosporites* (al. *Foveasporis*) *fovearis* (Krutzsch 1959, p. 163; Pl. 30, fig. 332, 333) comb. nov. Occurrence: Germany; Middle Eocene.
(2) *Foveosporites* (al. *Foveasporis*) *linearis* (Krutzsch 1959, p. 166; Pl. 31, fig. 343-45) comb. nov. Occurrence: Germany; Middle Eocene.
(3) *Foveosporites* (al. *Ophioglossum*) *senomanicum* (Chlonova 1960, p. 30; Pl. 3, fig. 13-15) comb. nov. Occurrence: Siberia; Cenomanian-Turonian.
(4) *Foveosporites* (al. *Foveotriletes*) *budejovicensis* (Pacltova 1961, p. 10; Pl. 6, fig. 1-3) comb. nov. Occurrence: Czechoslovakia; Senonian.
(5) *Foveosporites* (al. *Ophioglossum*) *fulvaster* (Bolkhovitina 1956, p. 63; Pl. 8, fig. 105a) comb. nov. Occurrence: Siberia; Upper Jurassic.
(6) *Foveosporites* (al. *Ophioglossum*) *fuscus* (Bolkhovitina 1956, p. 64; Pl. 8, fig. 107) comb. nov. Occurrence: Siberia; Lower Cretaceous.
(7) *Foveosporites* (al. *Ophioglossum*) *delectus* (Bolkhovitina 1956, p. 65; Pl. 8, fig. 108) comb. nov. Occurrence: Siberia; Lower Jurassic.
(8) *Foveosporites* (al. *Ophioglossum*) *multicavus* (Bolkhovitina 1956, p. 65; Pl. 8, fig. 109) comb. nov. Occurrence: Siberia; Lower Cretaceous.

COMPARISON AND AFFINITY: The genus, as defined by Balme (1957), is characterized by foveolate sculpture and a circular to convexly triangular amb. *Foveotriletes* van der Hammen ex Potonié is distinct in having a concavely triangular amb, and *Microreticulatisporites* (Knox) is readily distinguishable by its reticulate sculpture. *Microfoveolatisporis* Krutzsch may be comparable to *Foveosporites* Balme but the illustrations of the type species, *M. tuemmlitzensis* Krutzsch (1962, p. 58; Pl. 22, fig. 1-3), do not depict the sculptural features clearly.

Balme (1957) noted that the type species *Foveosporites canalis*, resembles the spores of the *Lycopodium verticillatum* group of Knox (1950).

Foveosporites canalis Balme 1957

(Pl. VI, fig. 14-17)

DESCRIPTION: Microspores trilete, biconvex; amb subcircular to convexly subtriangular. Laesurae straight, extending almost to equator, and with thin, low (1-2 μ high) lips. Exine 2 μ thick, foveolate; foveolae circular in outline, *c.* 1 μ in diameter, and spaced 3-4 μ apart. Proximal foveolae usually coalescent, occurring in groups of two to four.

DIMENSIONS: Equatorial diameter 34 (43) 53 μ.

COMPARISON: Except for their greater size, the SE. Australian specimens conform with Balme's (1957) diagnosis of *Foveosporites canalis*. The species shows some resemblance to *F. senomanicum* (Chlonova), *F. delectus* (Bolkhovitina), and *F. multicavus* (Bolkhovitina), but differs in its longer laesurae and coalescent proximal foveolae. *F. budejovicensis* (Pacltova) is distinct in having larger, discrete foveolae.

DISTRIBUTION: Balme (1957) described the species from Western Australia, where it occurs in Neocomian-Aptian deposits and has been recorded doubtfully from Oxfordian-Kimeridgian strata. Records made during the present study and previously (Dettmann 1959) indicate that it is widely distributed in the Upper Mesozoic of SE. Australia (see Tables 3-9).

Genus **Lycopodiumsporites** Thiergart ex Delcourt & Sprumont 1955

TYPE SPECIES: *Lycopodiumsporites agathoecus* (Potonié) Thiergart 1938.

REMARKS: Trilete, azonate microspores having distal reticulate sculpture and membraneous laesurate lips are here assigned to *Lycopodiumsporites* Thiergart ex

Delcourt & Sprumont. It is recognized that this genus is of insecure validity (see Krutzsch 1959, p. 159, 164; and cf. Manum 1962, p. 25; Delcourt et al. 1963, p. 286), and that its type species, *Lycopodiumsporites agathoecus* (Potonié), is now believed to be characterized by foveo-reticulate sculpture (loc. cit.). However, the institution of a new genus to accommodate the Australian species seems undesirable until *Lycopodiumsporites* and other morphologically related genera have received detailed revision.

Several of the species described herein are comparable to the spores found in certain modern *Lycopodium* species that are grouped into the *Lycopodium clavatum* group of Knox (1950) and Group IV of Harris, W. F. (1955).

Lycopodiumsporites austroclavatidites (Cookson) Potonié 1956

(Pl. VI, fig. 18-21)

1950 cf. *Lycopodium annotinum* L.; Reissinger, p. 103; Pl. 18, fig. 1.
1953 *Lycopodium austroclavatidites* Cookson, p. 469, Pl. 2, fig. 35.
1956 *Lycopodiumsporites austroclavatidites* (Cookson) Potonié, p. 46.
1956 *Lycopodium perplicatum* Bolkhovitina, p. 63; Pl. 8, fig. 104a-b.
1957 *Lycopodiumsporites* cf. *austroclavatidites* (Cookson) Potonié: Delcourt & Sprumont; Pl. 3, fig. 27.
1957 *Lycopodium austroclavatidites* Cookson: Balme, p. 16; Pl. 1, fig. 8.
1958 *Lycopodiumsporites clavatoides* Couper (pars), p. 132; Pl. 15, fig. 12, 13.
1958 *Lycopodiumsporites clavatoides* Couper: Lantz, p. 923; Pl. 2, fig. 18.
1958 *Lycopodium* cf. *magellanicum* Sw.: Verbitskaya; Pl. 1, fig. 9.
1959 *Lycopodiumsporites reticulumsporites* Rouse (pars), p. 309; Pl. 1, fig. 3.
1959 *Lycopodium mediocris* Bolkhovitina, p. 83; Pl. 1, fig. 5.
1960 *Lycopodium marginatum* Kara-Murza var. *rotunda* Kara-Murza; Pl. 16, fig. 2.
1961 non *Lycopodium* aff. *clavatum* L.: Chlonova, p. 39; Pl. 1, fig. 6.

Description: Microspores trilete, plano-convex, the distal surface strongly convex; amb subcircular to convexly subtriangular. Laesurae straight, length about ¾ spore radius; enclosed within membraneous, elevated (2-3 μ high) lips. Exine 1·5-2 μ thick; smooth proximally and reticulate both distally and equatorially. Perfect reticulum composed of narrow (*c.* 1 μ wide), projecting (2-3 μ high) muri which, in optical section, have straight to concave sides; lumina hexagonal to pentagonal in outline and 7-12 μ in diameter.

Dimensions: (inclusive of sculpture) Equatorial diameter 34 (43) 58 μ; polar diameter (2 specimens) 32, 42 μ.

Remarks: The species is characterized by a regular, coarse-meshed, perfect reticulum, the thin, projecting muri of which simulate a membraneous flange at the equator (cf. Couper 1958, p. 132).

Cookson (1953) and Couper (1958) noted that the species is comparable to the modern spores of the *Lycopodium clavatum* group of Knox (1950), and suggested a related origin of the fossil spores.

Distribution: A widely-distributed species in Jurassic and Cretaceous sediments. It is common in the Upper Mesozoic of SE. Australia (see Tables 3-9).

Lycopodiumsporites circolumenus Cookson & Dettmann 1958

(Pl. VII, fig. 1-3)

Description: Microspores trilete, biconvex; amb convexly subtriangular to subcircular. Laesurae straight, approximating equator, and with narrow (*c.* 1 μ wide), elevated (2-5 μ high) lips. Exine 2-3 μ thick; proximal surface smooth, except in the central area of each contact face where a cluster of two to four, small verrucae or rugulae are developed. Distal exine with a regular reticulum composed of low (2 μ high), anastomosing muri which have narrow (1-2 μ wide), straight sides and broader (2-3 μ), flat-topped crests. Lumina circular to polygonal in outline and 4-7 μ in diameter.

Dimensions: Equatorial diameter (inclusive of sculpture) 34 (45) 62 μ.

Comparison: The species is distinct from *Lycopodiumsporites austroclavatidites* (Cookson) in having wider muri and more rounded lumina. *Dictyotriletes southeyensis* Pocock has a larger meshed, imperfect reticulum.

The species does not exactly correspond with any of the modern *Lycopodium* spores described by Knox (1950), Harris, W. F. (1955), and Erdtman (1957).

Distribution: Although never common, the species shows widespread lateral distribution in SE. Australia (Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 3-8). It is known also from Upper Jurassic and Aptian sediments of Western Australia (Cookson and Dettmann 1958b).

Lycopodiumsporites reticulumsporites (Rouse) comb. nov.

(Pl. VII, fig. 4-7)

1958 *Lycopodiumsporites clavatoides* Couper: Lantz, p. 923; Pl. 2, fig. 17.
1959 *Lycopodium reticulumsporites* Rouse (pars), p. 309; Pl. 2, fig. 1, 2 (holotype).
1962 non *Lycopodiumsporites austroclavatidites* (Cookson): Pocock, p. 33; Pl. 1, fig. 5-6.

Description: Microspores trilete, biconvex; amb subcircular to convexly triangular. Laesurae indistinct, straight, length $\frac{2}{3}$ spore radius; with membraneous, elevated (*c.* 1 μ high) lips. Exine *c.* 1 μ thick, reticulate. Distal and equatorial reticulum composed of narrow (less than 1 μ wide), low (*c.* 1 μ high), straight-sided muri which usually coalesce to enclose hexagonal or pentagonal lumina 2-6 μ in diameter. Proximal surface with reduced sculpture of low, narrow, elongate muri which terminate freely or anastomose to enclose rectilinear lumina 7 μ in maximum length.

Dimensions: Equatorial diameter (including sculpture) 25 (31) 39 μ.

Comparison: The species may be conspecific with *Lycopodium parvireticulatum* (Naumova), L. cf. *clavatum* L. (Verbitskaya 1958; Pl. 1, fig. 4: 1962; Pl. 1, fig. 4a, b), and *Lycopodium* sp. (Reissinger 1950; Pl. 12, fig. 27), but the proximal sculpture of these spores has not been described. *Lycopodiumsporites reticulumsporites* is distinct from *L. austroclavatidites* (Cookson) f. *tenuis* Balme and *L. rosewoodensis* de Jersey in showing proximal sculpture. It is distinct also from *Retitriletes globosus* Pierce which has a coarser meshed reticulum.

The species resembles the modern spores of *Lycopodium annotonium* L., *L. obscura* L., and *L. sprucei* Baker (see Knox 1950).

Distribution: Previously recorded from the Bathonian of England (Lantz 1958b) and from probable Upper Jurassic strata of Canada (Rouse 1959). The species was recovered from most of the Australian samples examined, and was common in those from E. Victoria (see Tables 3-9).

Lycopodiumsporites eminulus sp. nov.

(Pl. VII, fig. 8-12)

1960 *Lycopodium* aff. *clavatum* L.: Chlonova, p. 28; Pl. 3, fig. 7.

Diagnosis: Microspores trilete; amb subcircular to convexly subtriangular; proximal surface pyramidal, distal surface convex. Laesurae straight, length $\frac{3}{4}$ spore radius; enclosed within narrow (1-2 μ wide), elevated (1-2 μ high) lips. Exine 2 μ thick, smooth proximally, and with a perfect, regular reticulum distally. Muri membraneous, 1-2 μ high; with straight sides and expanded, flat-topped crests. Lumina subcircular to polygonal in outline and 2-6 μ in diameter.

Dimensions: (including sculpture) Equatorial diameter 28 (37) 49 μ; polar diameter (1 specimen) 34 μ.

Holotype: Preparation D141/1 38·9 121·4 P21964; Pl. VII, fig. 11, 12. Distal aspect. Amb subcircular, 31 μ in diameter. Laesurae 11 μ long. Exine 2 μ thick, smooth proximally, and reticulate distally. Muri 1-2 μ high; lumina 2-5 μ in diameter.

Locus Typicus: Victoria, Wonthaggi State Coal Mine Area; No. 20 shaft, bottom seam 1 E. (SE. dip); sample P22593.

Comparison: The species may be conspecific with the spores figured by Weyland and Greifeld (1953, p. 41; Pl. 10, fig. 41, 43, 47) of *Reticulatisporites potoniei* Pflug & Thomson. *Lycopodiumsporites eminulus* sp. nov. is distinguishable from *L. austroclavatidites* (Cookson) in having smaller lumina, lower muri, and wider lips; and from *L. reticulumsporites* (Rouse) in its higher muri and smooth proximal exine. It is distinct also from *L. gracilis* Nilsson which has a thinner exine and inconspicuous lips, and *Lycopodium* aff. *undulatum* L. (in Bolkhovitina 1959, p. 82; Pl. 1, fig. 4) which shows wider muri.

Lycopodiumsporites eminulus resembles the spores found in living *Lycopodium paniculatum* Desv. (see Knox 1950).

Distribution: The specimens described by Chlonova (1960) are from the Upper Cretaceous of Siberia. The species is widely distributed in SE. Australia, and is common in the stratigraphically lower sediments examined from the Otway Basin and E. Victoria (see Tables 3-9).

Lycopodiumsporites nodosus sp. nov.

(Pl. VII, fig. 13-16)

Diagnosis: Microspores trilete; amb convexly subtriangular to circular; distal surface convex, proximal surface pyramidal. Laesurae straight, length ¾ spore radius; enclosed within membraneous, elevated (2-3 μ high) lips. Exine 2·5-3·5 μ thick, coarsely granulate overall, and reticulate both distally and equatorially. Regular reticulum composed of narrow (1-2 μ wide), straight-sided, granulate muri (3-5 μ high) which enclose polygonal lumina 6-12 μ in diameter. Granules smaller and more widely spaced on proximal surface where two to three, narrow, low, freely terminating muri are usually developed.

Dimensions: Equatorial diameter (including sculpture) 42 (50) 62 μ.

Holotype: Preparation D276/1 26·9 118·7 P22018; Pl. VII, fig. 13, 14. Proximal aspect. Amb subcircular, 53 μ in diameter. Laesurae 22 μ long. Exine 2·5 μ thick; muri 4 μ high, 1 μ wide; lumina 6-12 μ in diameter.

Locus Typicus: South Australia, Penola Bore No. 1 at 3,850-55 ft.

Comparison: This distinctive species is readily distinguishable from other SE. Australian representatives of *Lycopodiumsporites* in having coarsely granulate sculpture.

Distribution: The species is of common occurrence and shows wide distribution in the sediments examined from the Upper Mesozoic of SE. Australia (see Tables 3-9).

Lycopodiumsporites facetus sp. nov.

(Pl. VII, fig. 17-22)

Diagnosis: Microspores trilete, biconvex; amb subcircular to circular. Laesurae straight, extending almost to periphery, and with membraneous lips *c.* 1 μ high. Exine 3-4·5 μ thick, two-layered; consisting of a thin (*c.* 1 μ thick) intexine and a thicker (2-3 μ) sculptured exoexine which is composed of randomly arranged granules. Exoexine both finely granulate and reticulate overall. Perfect reticulum with high (5-8 μ), straight-sided, membraneous muri which enclose subcircular to polygonal lumina (7-17 μ in diameter) distally; proximal muri enclose radially arranged, rectangular lumina 17 μ in maximum diameter.

Dimensions: Equatorial diameter (including sculpture) 53 (68) 83 μ.

Holotype: Preparation D139/2 24·6 110·2 P21984; Pl. VII, fig. 17-20. Proximal aspect. Amb subcircular, 65 μ in diameter; laesurae 24 μ long. Exine 3 μ thick; exoexine finely granulate, and with mebraneous muri (5-7 μ high) which enclose polygonal lumina distally and rectangular lumina proximally; lumina 7-17 μ in diameter.

Locus Typicus: Victoria, Wonthaggi State Coal Mine Area; Kirrak Area, coal in W. heading (41^2); sample P22599.

Comparison: The species has a closed-meshed reticulum; therefore it does not conform with *Cyclosporites* Cookson & Dettmann. *Lycopodiumsporites facetus* sp. nov. resembles *Reticulatisporites castellatus* Pocock, but differs in having smaller lumina, lower muri, and clearly defined laesurae. *Peromonolites reticulatus* Lantz has smaller lumina and a monolete aperture, whilst *Lycopodiumsporites nodosus* sp. nov. lacks proximal reticulate sculpture.

Distribution: The species is of infrequent occurrence, and is widely distributed in the sediments examined from the Upper Mesozoic of SE. Australia (see Tables 3-8).

Genus **Reticulatisporites** Ibrahim emend. Potonié & Kremp 1954

Type Species: *Reticulatisporites reticulatus* Ibrahim 1933.

Reticulatisporites pudens Balme 1957

(Pl. VII, fig. 23-26)

Description: Microspores trilete, biconvex; amb subcircular to convexly triangular. Laesurae straight, simple, length ¾ spore radius. Exine 2-3 μ thick, smooth proximally, and reticulate distally. Reticulum with low (1-2 μ high), rounded muri (2-4 μ wide) and subcircular to irregular lumina 1-5 μ in maximum diameter.

Dimensions: Equatorial diameter (including sculpture) 20 (28) 34 μ.

Remarks: The SE. Australian specimens conform with the original diagnosis except that they are larger in size.

Distribution: Balme (1957) described the species from Neocomian-Aptian sediments of Western Australia. It ocurs frequently in many of the samples examined from SE. Australia (Dettmann 1959; present study, Tables 3-9).

Genus **Klukisporites** Couper 1958

Type Species: *Klukisporites variegatus* Couper 1958.

Remarks: This genus incorporates trilete, distally foveoreticulate microspores, some of which are attributable also to the mutually overlapping genera, *Reticuli-*

sporites Potonié & Kremp, *Lycopodiumsporites* Thiergart ex Delcourt & Sprumont, *Dictyotriletes* Naumova, and *Reticulatisporites* Ibrahim. Nevertheless, the type species *Klukisporites variegatus* Couper, is morphologically distinct from all these genera in having coarse foveo-reticulate sculpture distally together with proximal granules or verrucae. Comparable features are exhibited by the Australian microspores here assigned to *Klukisporites* Couper.

Ischyosporites Balme differs from *Klukisporites* in having a valvate exine.

Affinity: Couper (1958) has demonstrated that the type species closely resembles the microspores found in the schizaeaceous species, *Klukia exilis* (Phillips) and *Stachypteris hallei* Thomas. Comparable spores have been described by Harris, T. M. (1961, p. 137) from the closely related species *S. spicans* Pomel.

Klukisporites scaberis (Cookson & Dettmann) comb. nov.

(Pl. VIII, fig. 1-7)

1958 *Ischyosporites scaberis* Cookson & Dettman, p. 104; Pl. 15, fig. 7-9.

Description: Microspores trilete, biconvex; amb subcircular to convexly triangular. Laesurae straight, extending almost to amb, and encompassed by thickened, granulate to verrucate lips 2-3 μ wide. Exine one-layered, 2-3 μ thick (exclusive of sculpture); with granulate sculpture overall and reticulate sculpture distally. Distal reticulum composed of low (2-3 μ high), wide (5-8 μ), usually anastomosing muri and subcircular to polygonal lumina 4-10 μ in diameter. Proximal granules coarse, closely spaced; distal granules smaller and confined to bases of lumina.

Dimensions: Equatorial diameter 39 (51) 64 μ; polar diameter (2 specimens) 34μ, 39 μ.

Comparison: *Klukisporites scaberis* (Cookson & Dettmann) is closely similar to *K. variegatus* Couper and the spores of both *Stachypteris spicans* Pomel and *Klukia exilis* (Phillips). However, the Australian spores are distinguishable in their smaller size and more rounded lumina, which are granulate, together with the absence of membraneous laesurate lips (raised commissures of Couper 1958). *K. scaberis* also is distinct from *K. visibilis* (Bolkhovitina) which has a triangular amb and lacks granulate lumina; *Dictyotriletes granulatus* Pocock has considerably narrower granulate muri.

Distribution: The species is widely distributed in the Upper Mesozoic of SE. Australia (Cookson and Dettmann 1958b, 1959a; Dettmann 1959; present study, Tables 3-9), and it is a common element in samples examined from E. Victoria and the Otway Basin.

Genus **Dictyotosporites** Cookson & Dettmann 1958

Restated Diagnosis: Microspores trilete. Exine with a surface reticulum composed of the terminal branches of, and supported on the columns of, discrete or coalescent, branched elevations.

Type Species: *Dictyotosporites speciosus* Cookson & Dettmann 1958.

Remarks: Cookson and Dettmann (1958b) defined the genus to accommodate trilete microspores having a sculpture of two or more superimposed reticula. Microtome sections of the type species confirm that the muri of the open-meshed primary reticulum bifurcate towards their crests, and that the bifurcations anastomose to form the secondary reticulum. Similar sculptural features are exhibited by *Dictyotosporites complex* Cookson & Dettmann and *D. filosus* sp. nov., except that the primary sculptural elements are discrete capilli and not coalescent muri.

Distyotosporites speciosus Cookson & Dettmann 1958

(Pl. VIII, fig. 8-14)

DESCRIPTION: Microspores trilete, plano-convex, the distal surface convex; amb roundly triangular to subcircular. Laesurae straight, simple, approximating amb. Exine 2 μ thick (5-10 μ thick inclusive of sculpture) one-layered, homogeneous in structure; sculpture of two superimposed reticula. Primary, imperfect reticulum consists of polygonal lumina 5-10 μ in diameter and anastomosing or freely terminating muri (3-8 μ high, 2-3 μ basal diameter) which taper towards their crests where they bifurcate. Bifurcations form narrow, low, anastomosing muri of the lace-like secondary reticulum the shallow, polygonal lumina of which are 1-3 μ in diameter.

DIMENSIONS: Overall equatorial diameter 42 (56) 73 μ.

COMPARISON: The species appears to be distinct from other Mesozoic spores described in the available literature. Some of the microspores borne by *Hemionitis* L., for example those of *H. arifolia* (Burm.) (see Erdtmann 1957; Fig. 111), show bifurcating sculptural elevations but these do not anastomose to form superimposed reticula.

DISTRIBUTION: Widely distributed in the Upper Mesozoic of SE. Australia where it appears to be of undoubted stratigraphical importance (see Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 4-8).

Dictyotosporites complex Cookson & Dettmann 1958

(Pl. IX, fig. 1-7)

1958 *Dictyotosporites complex* Cookson & Dettmann (pars), p. 107; Pl. 16, fig. 11, 15, 16.
1958 *Dictyotosporites* cf. *complex* Cookson & Dettmann, p. 107; Pl. 16, fig. 12, 13.

DESCRIPTION: Microspores trilete, plano-convex, the distal surface strongly convex; amb circular to subcircular in uncompressed specimens and irregular in flattened specimens. Exine one-layered, 1-1·5 μ thick; with a surface reticulum composed of the terminal branches of, and supported on the columns of, thread-like capilli. Capilli 3-5 μ high, *c.* 1 μ in basal diameter; terminal branches anastomose to enclose polygonal to circular lumina 1-3 μ in diameter. Laesurae indistinct, straight or slightly sinuous, length ½ spore radius, and with thin, low (*c.* 1 μ high) lips.

DIMENSIONS: Equatorial diameter; overall 42 (51) 63 μ, exclusive of sculpture 32 (38) 44 μ.

HOLOTYPE: P17619. Cookson and Dettmann 1958b; Pl. 16, fig. 11: present study; Pl. IX, fig. 1, 2. Distal aspect. Amb irregular, 59 μ in maximum diameter; laesurae weakly sinuous, 14 μ long. Exine 1·5 μ thick, capilli *c.* 1 μ in basal diameter, 3-5 μ high, and with short terminal branches. Surface reticulum composed of narrow, anastomosing muri and polygonal to circular lumina 1-3 μ in diameter.

LOCUS TYPICUS: South Australia, Robe Bore No. 1 at 3,860 ft.

REMARKS AND COMPARISON: The bifurcating exinous processes (capilli) which support and form the surface reticulum of the one-layered exine are not represented in one of the specimens depicted by Cookson and Dettmann (1958b; Pl. 18, fig. 1). This spore is comparable to *Densoisporites velatus* Weyland & Krieger which has a stratified, cavate exine. *Dictyotosporites complex* Cookson & Dettmann differs from *D. speciosus* Cookson & Dettmann in having thread-like, primary sculptural elevations.

DISTRIBUTION: The species is now known to have wide distribution, both laterally and vertically, in the Upper Mesozoic of SE. Australia (see Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 3-8). It has been recorded also from probable uppermost Jurassic strata of Western Australia (Cookson and Dettmann 1958b).

Dictyotosporites filosus sp. nov.

(Pl. VIII, fig. 15-20)

DIAGNOSIS: Microspores trilete, plano-convex, the distal surface strongly arched; amb subcircular to convexly subtriangular. Laesurae straight, simple, length ¾ spore radius. Exine 1·5 μ thick (3-4 μ thick inclusive of sculpture); primary sculptural elements include tightly-packed, low (1 μ high), narrow (1 μ basal diameter) capilli. Terminal branches of capilli anastomose to form narrow, sinuous muri which enclose polygonal lumina 2-5 μ in diameter; distal lumina characteristically pentagonal or hexagonal in outline.

DIMENSIONS: Overall equatorial diameter (18 specimens) 48 (53) 62 μ; polar diameter (1 specimen) 45 μ.

HOLOTYPE: Preparation D346/9 31·2 121·6 P22029; Pl. VIII, fig. 15-17. Proximal aspect. Amb 51 μ in diameter; laesurae straight, 20 μ long. Exine 4 μ thick (inclusive of sculpture).

LOCUS TYPICUS: South Australia, Penola Bore No. 1 at 3,180-90 ft.

COMPARISON: The species differs from *Dictyotosporites speciosus* Cookson & Dettmann and *D. complex* Cookson & Dettmann in having a coarser-meshed secondary reticulum and shorter primary capilli.

DISTRIBUTION: Of infrequent occurrence in certain horizons of the Great Artesian, Murray, and Otway Basins and in E. Victoria (see Tables 4-8).

Genus **Januasporites** Pocock 1962

TYPE SPECIES: *Januasporites reticularis* Pocock 1962.

REMARKS: The genus, as diagnosed by Pocock (1962, p. 56), includes alete, distally 'porate' microspores having a membraneous, reticulate outer layer. Australian specimens here allocated to the genus are inconspicuously trilete and lack a 'distal pore', but they appear to be similar, if not identical, to the illustrated specimen of the type species. Cretaceous microspores assigned to *Woodsia reticulata* Bolkhovitina also may be comparable to *Januasporites* Pocock.

Januasporites spinulosus sp. nov.

(Pl. X, fig. 17-20)

DIAGNOSIS: Microspores trilete, biconvex; amb subcircular. Laesurae indistinct, straight, extending to amb of spore cavity. Sclerine two-layered; inner layer 1·5-2 μ thick, scabrate. Enveloping outer layer membraneous, reticulate distally, and spinulose proximally. Distal reticulum composed of high (8-11 μ), membraneous muri, which usually have serrate crests, and pentagonal or hexagonal lumina 11-14 μ in diameter. Proximal spinules *c.* 1 μ high, 1 μ in basal diameter, and spaced 2-3 μ apart except at laesurate margins where they are coalescent.

DIMENSIONS: Equatorial diameter; overall 50 (63) 78 μ, spore cavity 42 (52) 62 μ. Polar diameter (1 specimen) 39 μ.

HOLOTYPE: Preparation D289/43 39·5 117·8 P22045; Pl. X, fig. 17-19. Distal aspect. Amb subcircular, 73 μ in diameter; spore cavity 53 μ in diameter. Laesurae 25 μ long. Distal muri 11 μ high; lumina 14 μ in diameter. Scabrate inner layer 2 μ thick.

LOCUS TYPICUS: South Australia, Cootabarlow Bore No. 2 at 1,376-77 ft.

COMPARISON: As noted above, the species shows a striking resemblance to *Januasporites reticularis* Pocock. *Woodsia reticulata* Bolkhovitina is distinct in its coarser-meshed reticulum.

DISTRIBUTION: Recovered from several samples of the Otway and Great Artesian Basins (see Tables 4-7, 9).

Genus **Staplinisporites** Pocock 1962

TYPE SPECIES: *Staplinisporites caminus* (Balme) Pocock 1962.

REMARKS: Pocock's (1962) diagnosis of the genus conforms with the acingulate holotype and paratype of *Staplinisporites caminus* (Balme). However, as noted subsequently, the illustrated Canadian specimens which Pocock (1962) assigned to the species have equatorial thickenings (interradial crassitudes), and are distinct from *Staplinisporites* Pocock.

COMPARISON: The genus is characterized by both radially and concentrically arranged distal elevations (or thickenings). It differs, therefore, from *Neochomotriletes* Reinhardt, *Taurocusporites* Stover, *Distalanulisporites* Klaus, and *Annulispora* de Jersey, all of which have circumpolar elevations only on the distal hemisphere; and from *Tigrisporites* Klaus which has radially disposed rugulae only on the distal surface.

Selaginella multiradiata Verbitskaya and *Euryzonotrilites microdiscus* var. *fimbriata* Kara-Murza almost certainly are identical to the genus. *Striatriletes coronarius* shows some resemblance to *Staplinisporites*, but, according to the diagnosis (Pierce 1961, p. 32), it is distinct in having an 'equatorial flange'.

The spores of the modern bryophyte species, *Encalypta ciliata* Hedw. resemble *Staplinisporites* (see Erdtman 1957; Fig. 210B).

Staplinisporites caminus (Balme) Pocock 1962

(Pl. IX, fig. 8, 9)

1957 *Cingulatisporites caminus* Balme, p. 27; Pl. 5, fig. 62, 63.
1958 *Cingulatisporites* cf. *caminus* Balme: Lantz, p. 924; Pl. 3, fig. 29.
1962 non *Staplinisporites caminus* (Balme) Pocock, p. 49; Pl. 5, fig. 87; Pl. 6, fig. 88-90.

DIAGNOSIS: Microspores trilete, plano-convex, the distal surface convex; amb convexly triangular to subcircular. Laesurae straight or weakly sinuous, extending to amb, and with thin (*c.* 1 μ thick), low lips. Exine 2 μ thick, smooth or faintly granulate proximally. Equatorial region of distal surface with low (*c.* 1 μ high), radially disposed elevations which extend from equator to a narrow, low, circumpolar ridge; ridge concentric with, and ⅔ radius of, amb. Distal exine enclosed within circumpolar ridge faintly granulate and thickened in a circular area (8-10 μ in diameter) about the pole.

DIMENSIONS: Equatorial diameter (2 specimens) 39 μ, 45 μ.

REMARKS: Although Pocock (1962) recognized that *Staplinisporites caminus* (Balme) is acingulate, the illustrated Canadian specimens which he equated to the species have equatorial thickenings (interradial crassitudes). Moreover, the Canadian spores show radially disposed elevations on the distal area bound by the polar and circumpolar thickenings, and are comparable to *Coronatispora valdensis* (Couper).

COMPARISON: The species is similar, and may be identical, to *Selaginella multiradiata* Verbitskaya. *Euryzonotriletes microdiscus* var. *fimbriata* was figured, but not described, by Kara-Murza (1960; Pl. 1, fig. 10); therefore, a more precise comparison is precluded. *Leiotriletes incertus* Bolkhovitina does not have a distal, circumpolar ridge.

DISTRIBUTION: Balme (1957) described the species from Western Australia where it occurs in Oxfordian-Kimeridgian strata, and is doubtfully known from Neocomian-Aptian deposits. Lantz's (1958b) subsequent record is from the Corallian of England, and the similar spores described by Verbitskaya (1958, 1962) are from Hauterivian-Barremian strata of Russia. Two specimens of *Staplinisporites caminus* have been recovered in the present investigation (see Tables 4, 6, 7).

Genus **Cicatricosisporites** Potonié & Gelletich 1933

1933 *Cicatricosisporites* Potonié & Gelletich, p. 522.
1949 *Trilaterina* Maljavikina, p. 48.
1950 *Mohrioidites* Thiergart, p. 84.
1951 *Mohrioisporites* Potonié, p. 114.
1955 *Liratosporites* Vishnu-Mittre, p. 119.
1961 *Mohria* Swartz: Markova (pars) in Samoilovitch et al., p. 84.

TYPE SPECIES: *Cicatricosisporites dorogensis* Potonié & Gelletich 1933.

Microspores referable to *Cicatricosisporites* Potonié & Gelletich have been reported widely from Upper Mesozoic and Tertiary sediments, and are comparable morphologically to some of the spores found in the Schizaeaceae. They are characterized by distal and equatorial sculpture of more or less parallel muri. In the type species, three series of parallel muri are arranged about a centre on the distal hemisphere and at an angle to the equator; the equatorial muri terminate in the proximo-equatorial, radial regions where they coalesce with adjacent muri of the same series (see Potonié 1951; Pl. 20, fig. 14; Kedves 1960; Pl. 4, fig. 14; Kedves 1961; Pl. 5, fig. 4). Similar sculptural features (particularly in the arrangement of the proximal terminations of the muri (see Fig. 4p)) are exhibited by *Cicatricosisporites australiensis* (Cookson), *C. ludbrooki* sp. nov., and the spores of *Ruffordia goepperti* (Dunk).

Distinct sculpturing is shown by the other *sporae dispersae* which are herein assigned to *Cicatricosisporites*, and which resemble some modern spores of *Anemia* Swartz (e.g., *A. jaliscana* Maxon and *A. dregeana* Kunze). The muri of these spores all terminate along the amb-angle bisectors where they fuse with alternate muri of neighbouring mural series (Fig. 4r). The terminations of the equatorial muri (as seen in spores situated in full polar aspect) simulate radial exinal thickenings, and the spores appear to be comparable to *Plicatella* Maljavikina ex Potonié and *Appendicisporites* Weyland & Krieger. The type species of these two genera are clearly distinct from *Cicatricosisporites*, however, in that their equatorial muri fuse, one with another, and form one only, projecting appendix in each equatorial, radial region.

The four species recovered from the SE. Australian deposits show radial symmetry, and their muri parallel the interradial margins of the amb. Following Delcourt and Sprumont (1955) and Kedves (1961), the criteria used in the distinction of the species include: shape of muri, both in optical section and surface view; width of four adjacent muri and lumina in distal, interradial regions;

relative width of muri and lumina; arrangement of muri; length of laesurae; and shape of amb. As far as it has been possible, all these features are detailed in the photographs which accompany the specific descriptions.

Cicatricosisporites australiensis (Cookson) Potonié 1956

(Pl. IX, fig. 10-16; Fig. 4p)

1953 *Mohrioisporites australiensis* Cookson, p. 470; Pl. 2, fig. 29-34.
1955 *Liratosporites* Type 1 Vishnu-Mittre, p. 119; Pl. 1, fig. 14, 15.
1956 *Cicatricosisporites australiensis* (Cookson) Potonié, p. 48.
1958 *Cicatricosisporites mohrioides* Delcourt & Sprumont: Lantz, p. 923; Pl. 2, fig. 19, 20.
1961 *Ruffordia goepperti* Seward: Bolkhovitina, p. 13, Pl. 1, fig. 9c-e.
1961 *Cicatricosisporites dorogensis* Potonié & Gelletich: Bolkhovitina, p. 70; Pl. 20, fig. 3a-c; Pl. 21, fig. 2d, e.
1962 *Cicatricosisporites dorogensis* Potonié & Gelletich: Pocock, p. 39; Pl. 2, fig. 36.

DESCRIPTION: Microspores trilete, tetrahedral, radially symmetrical; amb triangular, with straight to weakly convex or concave sides and notched angles. Laesurae straight, length ¾ of, to almost equal to, spore radius; enclosed within membraneous, elevated (2-3 μ high), sometimes undulating lips. Exine 1-2 μ thick, smooth on contact areas. Distal and equatorial exine with three series of narrow, low (1-2 μ high), occasionally bifurcating, sharply crested muri; each mural series consists of seven to twelve muri which are orientated parallel both to each other and to interradial sides of amb. Distal muri terminate along amb-angle bisectors where they coalesce with corresponding muri of neighbouring series; equatorial muri converge on to proximo-equatorial, radial regions where they coalesce with adjacent muri of the same series. Muri 1·5-2·5 μ wide, mostly wider than intervening lumina (1-2·5 μ wide); four adjacent muri and lumina total 9-12 μ in width.

DIMENSIONS: Equatorial diameter 36 (51) 70 μ; polar diameter (10 specimens) 39 (45) 50 μ.

REMARKS AND COMPARISON: The specimens isolated during the present study broaden the size range of the species. The orientation and size of sculptural elements, the characteristically notched outline of amb angles, and the smooth contact areas distinguish *Cicatricosisporites australiensis* (Cookson) from other concisely defined members of the genus. It resembles *C. goepperti* Groot & Penny and the spores of *Ruffordia goepperti* (Dunk.) (see Couper 1958, p. 109; Pl. 17, fig. 4-6), but differs in having wider and more closely-spaced muri and in the total width of four muri and lumina. *C. mohrioides* Delcourt & Sprumont has wider muri, and *C. dorogensis* (Potonié & Gelletich) is distinct in its shorter laesurae, subcircular amb, and arrangement of muri.

DISTRIBUTION: *C. australienses* is of widespread distribution in the Upper Mesozoic of SE. Australia (see Tables 3-9), and has been recovered previously from both Lower and Upper Cretaceous sediments in this area (Cookson 1953, 1954; Baker and Cookson 1955; Cookson and Dettmann 1958b, 1959a; Dettmann 1959). It is known also from the Lower Cretaceous of Western Australia (Balme 1957) and Queensland and New Guinea (Cookson and Dettmann 1958b), but has not been reported from definite Jurassic strata in Australasia. The extra-Australasian specimens illustrated by Vishnu-Mittre (1955), Lantz (1958b), Bolkhovitina (1961), and Pocock (1962) are from Neocomian (see Arkell 1956, p. 383) of India, uppermost Purbeck of England, Albian of Kazachstan, and Aptian-Lower Albian of Canada respectively.

Cicatricosisporites ludbrooki sp. nov.

(Pl. IX, fig. 17-22)

Diagnosis: Microspores trilete, radially symmetrical, tetrahedral; amb triangular with straight to weakly convex sides and notched angles. Laesurae straight, length ¾ spore radius; lips membraneous, 2-4 μ high. Exine 2 μ thick, with distal and equatorial muri which are arranged in three series; six to nine, occasionally bifurcating, sharply-crested (2·5-3 μ high) muri of each series parallel both each other and interradial margins of triangular amb. Distal muri terminate along amb-angle bisectors where they coalesce with corresponding muri of neighbouring series; equatorial muri converge on to proximo-equatorial, radial regions where they terminate and coalesce with adjacent muri of the same series. Muri 2·5-3·5 μ wide, wider than intervening lumina (1-2 μ); four adjacent muri and lumina total 17-19 μ in width. Contact areas smooth or each with considerably reduced sculpture of four to five, low, narrow (1-2 μ wide), inconspicuous, parallel muri which are disposed at right angles to, and coalesce with, equatorial muri.

Dimensions: Equatorial diameter (20 specimens) 56 (73) 96 μ; polar diameter (1 specimen) 42 μ.

Holotype: Preparation D346/1 40·3 110·9 P22037; Pl. IX, fig. 17, 18. Proximal aspect. Amb triangular, 67 μ in diameter. Laesurae 24 μ long; lips 2 μ high. Distal and equatorial muri 2·5-3 μ high, 2-3 μ wide, and spaced 1-2 μ apart in three series of nine; four adjacent muri and lumina total 17 μ in width. Proximal muri 2 μ wide.

Locus Typicus: South Australia, Penola Bore No. 1 at 2,790-98 ft.

Comparison: The species is similar to *Cicatricosisporites australiensis* (Cookson) in the arrangement of distal and equatorial muri, but differs in its larger size, wider muri (and total width of four adjacent muri and lumina), and proximal sculpture. It may be conspecific with the spores (*Mohria*-Typ.) which Thiergart (1949, p. 22; Pl. 4, fig. 15, 16) described and illustrated, and which Delcourt and Sprumont (1955) included within their species *C. mohrioides*. The latter species is distinct from *C. ludbrooki* sp. nov., however, in its narrower muri (in the holotype four muri and lumina total 14 μ in width), smaller size, and orientation of the muri on the contact areas. The spores assigned to *Anemia tricostata* Bolkhovitina by Markova (in Samoilovitch et al. 1961, p. 70; Pl. 17, fig. 6a-e) resemble *C. ludbrooki* but are smaller in size and have narrower muri which terminate freely in equatorial, radial regions.

Distribution: In certain horizons of the Otway and Great Artesian Basins and E. Victoria (see Tables 4-8). The similar spores figured by Thiergart (1949) are from the Wealden of Germany.

Cicatricosisporites pseudotripartitus (Bolkhovitina) comb. nov.

(Pl. X, fig. 1-5)

1961 *Anemia pseudotripartita* Bolkhovitina, p. 53; Pl. 15, fig. 3a-c.

1961 *Anemia tripartita* Bolkhovitina: Markova in Samoilovitch et al., p. 69; Pl. 17, fig. 4.

Description: Microspores trilete, radially symmetrical, tetrahedral; amb triangular with straight to weakly convex sides and rounded angles. Laesurae straight, extending almost to amb, and with membraneous, elevated (2-3 μ high) lips. Exine 2 μ thick; sculptured distally and equatorially with three series of four to five, weakly sinuous, low (1-2 μ high), broadly rounded muri; muri of each series parallel both each other and interradial sides of triangular amb, and terminate along amb-angle bisectors where they coalesce with alternate muri of neighbouring series. Muri wider (3·5-4·5 μ) than intervening lumina (*c.* 1 μ wide); four adjacent muri and lumina total 21-23 μ in width. Proximal exine has considerably reduced sculpture of two to three, inconspicuous, low, parallel muri on each contact area; muri parallel interradial margin of amb, and coalesce about equatorial termini of laesurae.

DIMENSIONS: Equatorial diameter (19 specimens) 34 (43) 56 μ; polar diameter (3 specimens) 38 (41) 42 μ.

COMPARISON: The Australian specimens conform with Bolkhovitina's (1961, p. 53) diagnosis of the species, and are comparable also to the illustrated specimen which Markova (in Samoilovitch et al. 1961) assigned to *Anemia tripartita* Bolkhovitina. *Cicatricosisporites pseudotripartitus* (Bolkhovitina) is characterized by three series of four to five, weakly sinuous, closely-spaced, wide, rounded, distal muri which coalesce along amb-angle bisectors, and is distinct from *Anemia tripartina* which has more widely-spaced and narrower distal muri which project at equator (see Bolkhovitina loc. cit.; Pl. 15, fig. 2b). *C. pseudotripartitus* is distinguishable from other species of *Cicatricosisporites* recovered in the present study by its smaller size and wider distal muri which are more closely spaced.

DISTRIBUTION: The species has been reported previously from Cenomanian strata of U.S.S.R. only; from Yakutsk (Bolkhovitina 1961) and W. Siberia (Samoilovitch et al. 1961). In SE. Australia it occurs in the Tambo Formation (Albian) only in the Great Artesian Basin, and in certain horizons of the Upper Mesozoic sequence in the Otway Basin (see Tables 5, 6, 7, 9).

Cicatricosisporites hughesi sp. nov.

(Pl. X, fig. 6-16; Fig. 4r)

DIAGNOSIS: Microspores trilete, radially symmetrical, tetrahedral; amb convexly triangular. Laesurae straight, approximating equator, and enclosed within membraneous, elevated (2-3 μ high) lips. Exine one-layered, 2-3 μ thick; smooth over contact areas. Distal and equatorial regions sculptured with three series of six to seven, sinuous, sharply-crested (3-4 μ high) muri; muri of each series are arranged parallel both to each other and to interradial margins of amb, and terminate along amb-angle bisectors where they coalesce with alternate muri of neighbouring series. Muri 2-3 μ wide, narrower than intervening lumina (5-8 μ wide); width of four adjacent lumina and muri totals 30-35 μ.

DIMENSIONS: Equatorial diameter 36 (52) 64 μ; polar diameter (10 specimens) 31 (39) 56 μ.

HOLOTYPE: Preparation D294/1 21·1 110·7 P21965; Pl. X, fig. 6-8. Proximal aspect. Amb convexly triangular, 60 μ in diameter. Laesurae 28 μ long; lips 3 μ high. Sculpture of three series of seven, parallel, sinuous muri each 2 μ wide, 3 μ high, and spaced 5 μ apart; four muri and lumina total 30 μ in width.

LOCUS TYPICUS: South Australia, Penola Bore No. 1 at 1,805-15 ft.

REMARKS: Thin sections show the sculptural elements in transverse and oblique section. The sections depicted (Pl. X, fig. 15, 16) were obtained from a partially corroded specimen, and the one-layered exine shows slight differentiation along its inner margin.

COMPARISON: Conspecificity may exist between *Cicatricosisporites hughesi* sp. nov. and the spores assigned to *Appendicisporites tricornitatus* Weyland & Greifeld by Lantz (1958b; Pl. 3, fig. 25), Groot and Penny (1960; Pl. 1, fig. 4), and Groot et al. (1961; Pl. 24, fig. 6, 7); and those referred to both *Anemia caucasica* Bolkhovitina (1961; Pl. 17, fig. 4b, c) and *Ruffordia aralica* Bolkhovitina loc. cit.; Pl. 1, fig. 9f-h). A similar arrangement of sculptural elements is shown by *Anemia pseudomacrorhyza* Markova, *Appendicisporites punctutatus* Pacltova, and *Cicatricosisporites pseudotripartitus* (Bolkhovitina); *C. hughesi* differs, however, in its narrower, sinuous muri and greater width of four adjacent muri and lumina.

The spores of the modern species, *Anemia jaliscana* Maxon, differ in their larger size and wider muri (see Bolkhovitina 1961, p. 46; Pl. 11, fig. 6).

DISTRIBUTION: Widely distributed in certain horizons of the Upper Mesozoic of SE. Australia (see Tables 4-9). In the Great Artesian Basin it has been recovered from the Roma (Aptian), Tambo (Albian), and Winton (?Cenomanian) Formations. The similar specimens figured by Lantz (1958b), Groot and Penny (1960), Groot et al. (1961), and Bolkhovitina (1961) are from uppermost Wealden of England, Lower Cretaceous and Cenomanian of U.S.A., and Barremian-Albian of U.S.S.R.

Genus **Balmeisporites** Cookson & Dettmann 1958

TYPE SPECIES: *Balmeisporites holodictyus* Cookson & Dettmann 1958.

Balmeisporites holodictyus Cookson & Dettmann 1958

(Pl. XVII, fig. 7-10)

DIMENSIONS: Overall equatorial diameter 110 (145) 220 μ; polar diameter 125 (196) 266 μ.

REMARKS: Transverse sections (Pl. XVII, fig. 9, 10) confirm that the stratified exine forms the surface reticulum and the three, highly elevated, laesurate lips ('neck segments' of Cookson & Dettmann 1958a, p. 42); the lips are developed at the laesurate margins and not in the interlaesurate regions as shown in Cookson and Dettmann's Fig. 3.

DISTRIBUTION: A widely distributed species in E. Australia and Papua (Cookson and Dettmann 1958a, 1958b; present study, Tables 5-9). In the Great Artesian Basin its first occurrence is in uppermost horizons of the Roma Formation (Aptian), and it extends into the basal beds of the Winton Formation (?Cenomanian).

Balmeisporites tridictyus Cookson & Dettmann 1958

(Pl. XVII, fig. 11, 12)

DIMENSIONS: (4 specimens) Overall equatorial diameter 125 (140) 170 μ; polar diameter 170 (180) 196 μ.

DISTRIBUTION: Recovered from samples of the Tambo Formation (Albian) in the Great Artesian Basin, and from certain horizons in the Otway Basin (Cookson and Dettmann 1958a; present study, Tables 5-7, 9).

Balmeisporites glenelgensis Cookson & Dettmann 1958

DISTRIBUTION: This species which was described from Upper Cretaceous strata of the Otway Basin has since been recovered from the Winton Formation (?Cenomanian) of the Great Artesian Basin. Similar, if not identical, specimens have been reported recently from the Turonian of Siberia (Samoilovitch et al. 1961).

Genus **Pyrobolospora** Hughes 1955

TYPE SPECIES: *Pyrobolospora vectis* Hughes 1955.

REMARKS: The type species of this genus is characterized by six, highly elevated laesurate lips and exoexinal 'appendages' which arise from a 'coarse reticulum'

(Hughes 1955, p. 205). Certain other species (e.g., *Pyrobolospora hexapartita* (Dijkstra)) included within the genus do not possess a surface reticulum and conform with Apiculati rather than Murornati. However, no formal subdivision of the genus is proposed here.

Pyrobolospora hexapartita (Dijkstra) Hughes 1955

DISTRIBUTION: Dijkstra (1951) and Hughes (1955) described the species from the English Wealden; Hughes (1958) indicates a Barremian/Aptian occurrence in these sediments. In Australia the species is known from Upper Mesozoic horizons in the Great Artesian and Otway Basins and in E. Victoria (Cookson and Dettmann 1958a; Dettmann 1959; present study, Tables 5-7, 9).

Pyrobolospora reticulata Cookson & Dettmann 1958

(Pl. XVII. fig. 13-16)

DIMENSIONS: (6 specimens) Overall equatorial diameter 230 (272) 343 μ; polar diameter (including 'neck') 430 (530) 693 μ.

REMARKS: The exine stratification is seen clearly in transverse sections (Pl. XVII, fig. 14-16); the exoexine forms the six, elevated, laesurate lips ('neck segments' of Cookson and Dettmann 1958a, p. 41) which surround the laesurae.

DISTRIBUTION: The species shows wide lateral distribution in E. Australia, and is known from the Tambo Formation (Albian) in the Great Artesian Basin (Cookson and Dettmann 1958a, 1958b; Dettmann 1959; present study, Tables 4-9).

Pyrobolospora nuda Cookson & Dettmann 1958

DISTRIBUTION: A rare type known from one Aptian-Albian sample in the Great Artesian Basin (Cookson and Dettmann 1958a; present study, Table 9).

Subturma ZONOTRILETES Waltz 1935

This subturma incorporates acavate, simple or lipped, trilete spores in which the sclerine is equatorially thickened and/or extended; the equatorial thickenings and/or extensions may encroach on to the proximal and/or distal surfaces.

The four infraturma categories of Zonotriletes Waltz are delineated on the basis of the position and character of the equatorial thickenings and/or extensions as follows:

(a) Auriculati Schopf; trilete, acavate spores with thickenings (valvae or appendices) or extensions (auriculae) in the equatorial, radial regions.
(b) Tricrassati infraturma nov.; trilete, acavate spores with thickenings (interradial crassitudes) or extensions (corona etc.) in the equatorial, interradial regions.
(c) Cingulati Potonié & Klaus; trilete, acavate spores with comprehensive equatorial thickening (cingulum) or extension (zona).
(d) Patinati Butterworth & Williams; trilete, acavate spores with comprehensive distal and equatorial thickening (patina).

REMARKS: Zonotriletes as defined above incorporates the acavate forms which Potonié and Kremp (1954, and later) and Potonié (1956, and later) assigned to Zonales Bennie & Kidston sensu Potonié & Kremp (1954) and its subturma categories, Auritotriletes Potonié & Kremp and Zonotriletes Waltz sensu Potonié & Kremp (1954). The zonate, lipped forms (e.g. *Thomsonia* Mädler) of Barbates also conform with Zonotriletes.

The present assignment of Zonotriletes to Triletes is in accordance with Bennie and Kidston's (1886) original allocation of zonate forms to Triletes and not with the grouping proposed by Potonié and Kremp (1954).

Infraturma AURICULATI Schopf emend.

The acavate, trilete spores, which may have simple or lipped laesurae, of this group are characterized by sclerinous thickenings (valvae or appendices) or extensions (auriculae) in the three radial regions at the equator. As such this infraturma incorporates the spores previously attributed to both Auriculati Schopf sensu Potonié & Kremp (1954) and Appendiciferi Potonié.

The following are examples of spores assignable to Auriculati Schopf:

(a) valvate spores; *Matonisporites* Couper, *Trilobosporites* Pant ex Potonié, *Triquitrites* Wilson & Coe.
(b) spores with appendices; *Appendicisporites* Weyland & Krieger, *Elaterites* Wilson.
(c) auriculate spores; *Tripartites* Schemel.

Genus **Matonisporites** Couper emend.

1958 *Matonisporites* Couper (pars), p. 139.
1961 *Boseisporites* Dev, p. 45-46.

EMENDED DIAGNOSIS: Microspores trilete; amb triangular. Laesurae enclosed within membraneous, elevated lips. Exine differentially thickened; thickest in equatorial, radial regions where unsculptured valvae are developed. Exine smooth or almost smooth.

TYPE SPECIES: *Matonisporites phlebopteroides* Couper 1958. Occurrence: Britain; Lias-Aptian.

OTHER SPECIES:

(1) *Matonisporites cooksoni* sp. nov.
(2) *Matonisporites* (al. *Boseisporites*) *praeclarus* (Dev 1961, p. 46; Pl. 2, fig. 15) comb. nov. Occurrence: India; ?Aptian and later (after Arkell 1956, p. 384).
(3) *Matonisporites* (al. *Cyathidites*) *crassiangulatus* (Balme 1957, p. 22; Pl. 3, fig. 39-41) comb. nov. Occurrence: Western Australia; Oxfordian-Aptian.
(4) *Matonisporites* (al. *Phlebopteris*) *conspicuus* (Bolkhovitina 1953, p. 55; Pl. 8, fig. 19) comb. nov. Occurrence: U.S.S.R.; Aptian.
(5) *Matonisporites* (al. *Callispora*) sp. Dev 1961, p. 44; Pl. 1, fig. 4. Occurrence: India; ?Aptian and later (Arkell loc. cit.).

Trilites gigantis Cookson and *Lygodium cavernosum* Ivanova are not entirely conformable with *Matonisporites* Couper; *Dictyophyllidites* (al. *Matonisporites*) *equiexinus* (Couper) is excluded from the genus as emended herein.

REMARKS AND COMPARISON: The genus is here restricted to incorporate only smooth-walled, trilete microspores having exinal thickenings (valvae) in the three, radial regions at the equator, and is transferred to the Infraturma Auriculati (cf. Potonié 1960).

Matonisporites Couper and *Boseisporites* Dev are almost certainly comparable in morphology; the 'infragranulate' spores attributed to *B. praeclarus* Dev are probably corroded examples of a smooth-walled form. *Triquitrites* Wilson & Coe has a valvate exine, but this genus differs from *Matonisporites* in lacking elevated, laesurate lips. *Matonisporites* is distinct also from *Auritulina* Maljavikina ex Potonié which has unthickened radial extensions of the exine at the equator, and *Trilobozonosporites* Pant ex Potonié which is cingulate.

AFFINITY: Couper (1958) discussed the possible affinity of his species, *Matonisporites phlebopteroides*, with three Mesozoic species of *Phlebopteris* Brongn. (*P. muensteri* (Schenk.), *P. hirsuta* Sahni & Sitholey, and *P. indica* Sahni & Sitholey), and Bolkhovitina (1953) noted that *Matonisporites conspicuus* (Bolkhovitina) resembles the spores of *Phlebopteris muensteri*. *Matonisporites* is comparable also to the spores produced by certain living species of *Dicksonia* L'Herit, e.g., *D. sellowiana* (Pr.) (see Bolkhovitina 1956; Pl. 7, fig. 100 c, d) and *D. antarctica* Labill. (see Duigan and Cookson 1956; Pl. 1, fig. 1).

Matonisporites cooksoni sp. nov.

(Pl. XI, fig. 1-8)

Diagnosis: Microspores trilete; biconvex, the distal surface strongly convex. Amb triangular with rounded angles and straight to concave sides. Laesurae sinuous, extending almost to equator; with membraneous, elevated (1-2 μ high) lips and weakly thickened margins. Exine one-layered, 2-3 μ thick; thicker (5-6 μ) in each equatorial, radial region. Proximal exine smooth except for small punctae which are linearly arranged (*c.* 2 μ apart) about the laesurate margins; distal exine smooth or with a faint OL pattern under oil immersion.

Dimensions: Equatorial diameter 59 (65) 78 μ; polar diameter (4 specimens) 39 (43) 48 μ.

Holotype: Preparation D294/1 22·7 112·1 P21965; Pl. XI, fig. 1-2. Proximal aspect. Amb triangular 67 μ in diameter. Laesurae 31 μ long, sinuous; lips membraneous, 1-2 μ high. Exine 2·5 μ thick, thicker (6 μ) in valvate regions; proximal punctae linearly arranged about laesurate margins.

Locus Typicus: South Australia, Penola Bore No. 1 at 1,805-15 ft.

Remarks and Comparison: The proximal punctae may have resulted from corrosion, but they are developed on all seemingly well-preserved specimens. Some specimens (Pl. XI, fig. 5) show a striking resemblance to the holotype of *Matonisporites conspicuus* (Bolkhovitina), the description of which, however, does not mention sinuous laesurae or proximal punctae. *M. cooksoni* sp. nov. differs from *M. phlebopteroides* Couper and *M. crassiangulatus* (Balme) in having sinuous laesurae and pitted laesurate margins. *M. praeclarus* (Dev) is larger and has a thicker exine.

Distribution: The species shows wide lateral distribution in the Upper Mesozoic of SE. Australia (see Tables 3-9); it has not been observed in samples of the Winton Formation in the Great Artesian Basin.

Genus **Trilobosporites** Pant ex Potonié 1956

1954 *Trilobosporites* Pant (nom. nud.), p. 54.
1956 *Trilobosporites* Pant ex Potonié p. 55.
1961 *Lygodium* Swartz: Ivanova (pars) in Samoilovitch et al., p. 90.

Type Species: *Trilobosporites hannonicus* (Delcourt & Sprumont) Potonié 1956.

Remarks and Comparison: Potonié (1956, p. 55) validated the genus and selected the type species which has a valvate, verrucate exine (see Delcourt et al. 1963). The presence of these features distinguishes the genus from the azonate, verrucate forms of *Concavissimisporites* Delcourt & Sprumont and the valvate, laevigate spores of *Matonisporites* Couper.

Potonié (1956), Couper (1958), Pocock (1962), and others have attributed several Mesozoic species to *Trilobosporites*, while some Russian authors have assigned comparable Mesozoic spores to *Lygodium* Swartz. Such an assignment implicitly suggests that the fossil spores have an affinity with *Lygodium*, but little supporting evidence has been brought forward for this relationship.

Trilobosporites trioreticulosus Cookson & Dettmann 1958

(Pl. XII, fig. 1-9)

1958 *Trilobosporites trioreticulosus* Cookson & Dettman, p. 109; Pl. 17, fig. 1-3.
1961 *Lygodium trioreticulosus* (Cookson & Dettman) Bolkhovitina (pars), p. 100; Pl. 35, fig. 5b; Pl. 38, fig. 8.
1961 *Lygodium trioreticulosum* (Cookson & Dettmann) Ivanova (excl. var.) in Samoilovitch et al., p. 111.

Description: Microspores trilete; amb triangular with straight or concave sides and truncated angles; polar outline elliptical. Laesurae straight, length ¾ spore radius, and with narrow (3-4 μ wide), low lips which are composed of coalescent verrucae. Exine valvate; consists of one, sculptured, homogeneous layer which is 3-5 μ thick in valvate regions and thinner (2·5-4 μ) elsewhere. Valvae reticulate; each reticulum comprises weakly sinuous, anastomosing muri (3-5 μ wide, 2-3 μ high) and fourteen to twenty, polygonal to subcircular lumina 7-9 μ in diameter. Remainder of exine with closely-spaced, low, irregular granules and verrucae (1-2 μ in maximum basal diameter).

Dimensions: Equatorial diameter 59 (69) 81 μ; polar diameter (4 specimens) 42 (50) 56 μ.

Remarks: Transverse sections (Pl. XII, fig. 8, 9) show that the one-layered exine is thicker (valvate) and more heavily sculptured in each equatorial, radial region.

Comparison: *Cibotium reticuliangulatum* Maljavikina (1958, p. 53; Pl. 5, fig. 13) and the illustrated specimen assigned by Groot and Penny (1960; Pl. 2, fig. 2) to *Trilobosporites apiverrucatus* Couper may be comparable to *T. trioreticulosus* Cookson & Dettmann. The species is distinct from *T. apiverrucatus* and *T. hannonicus* (Delcourt & Sprumont), both of which have discrete verrucae in their valvate regions. *Cibotiumidites giganteus* Maljavikina is described as cingulate (see Potonié 1960, p. 63).

Distribution: Widely distributed in E. Australia (see Cookson and Dettmann 1958b; present study, Tables 5-7, 9), and apparently restricted to the Tambo (Albian) and uppermost horizons of the Roma (Aptian) Formations in the Great Artesian Basin. Bolkovitina (1961) and Samoilovitch et al. (1961) record the species in Barremian-Cenomanian strata of U.S.S.R., but this stratigraphical range also includes that of *Trilobosporites purverulentus* (Verbitskaya) (= *Lygodium trioreticulosum* var. *senomanicum* Ivanova).

Trilobosporites purverulentus (Verbitskaya) comb. nov.

(Pl. XIII, fig. 1-5)

1958 *Lygodium* sp.: Verbitskaya; Pl. 3, fig. 43.
1961 *Lygodium trioreticulosus* (Cookson & Dettmann) Bolkhovitina (pars), p. 100; Pl. 35, fig. 5a, c, d.
1961 *Lygodium trioreticulosum* (Cookson & Dettmann) var. *senomanicum* Ivanova in Samoilovitch et al., p. 111; Pl. 31, fig. 2a, b.
1962 *Lygodium purverulentus* Verbitskaya, p. 101; Pl. 9, fig. 48a-c.

Description: Microspores trilete, biconvex; amb triangular with straight or concave sides and broadly rounded angles. Laesurae straight, length ⅔-¾ spore radius, and with weakly thickened margins. Exine 2-3·5 μ thick; slightly thicker (3·5-5 μ) in three, equatorial, radial regions (valvate). Valvae reticulate; reticula consist of broadly rounded, sinuous muri (2·5-4 μ wide) and irregularly elongated to subcircular lumina which are 1·5-3 μ in maximum diameter and which number twenty-five to thirty per reticulum. Remainder of exine granulate to subverrucate.

Dimensions: Equatorial diameter (14 specimens) 59 (72) 88 μ; polar diameter (2 specimens) 42 μ, 48 μ.

Comparison: The species is clearly distinct from *Trilobosporites trioreticulosus* Cookson & Dettmann in having smaller and more lumina on its valvae together with a more finely sculptured polar exine.

Distribution: Recorded previously from U.S.S.R. in Albian-?Cenomanian strata (Verbitskaya 1962); the Barremian-Cenomanian age range quoted by Bolkhovitina (1961) and Samoilovitch et al. (1961) includes the ranges of both *T. trioreticulosus* and *T. purverulentus* (Verbitskaya). In the present study the species was recovered from samples of the Blythesdale Group and the Roma (Aptian) and Tambo (Albian) Formations in the Great Artesian Basin (see Tables 4-6).

Trilobosporites tribotrys sp. nov.

(Pl. XII, fig. 10-14)

1961 *Lygodium* sp.: Samoilovitch et al.; Pl. XXXIV, fig. 5-7.

Diagnosis: Microspores trilete; amb triangular with straight or concave sides and rounded angles; polar outline elliptical. Laesurae straight, length ¾ spore radius, and with conspicuous, verrucate lips 5-7 μ wide. Exine 2-3 μ thick, thicker in equatorial, radial regions (valvate). Valvae with low, narrow (2-3 μ wide), anastomosing muri which enclose polygonal lumina (4-5 μ in diameter) and from which arise conspicuous, hemispherical to spherical (4-5 μ high, 4-5 μ in basal diameter) verrucae. Remainder of exine with low, closely-spaced, irregular granules and verrucae (1-3 μ in basal diameter, 1-2 μ high).

Dimensions: (10 specimens) Equatorial diameter 67 (77) 91 μ.

Holotype: Preparation D217/22 34·5 118·9 P22061; Pl. XII, fig. 10, 11. Proximal aspect. Amb triangular with straight sides, 67 μ in diameter. Laesurae 36 μ long; lips 5 μ wide. Exine 2·5 μ thick; valvae with verrucae (4 μ high, 4-5 μ in basal diameter) and narrow (2 μ wide) muri. Exine otherwise subverrucate; verrucae 1-2 μ in basal diameter.

Locus Typicus: South Australia, Robe Bore No. 1 at 1,400 ft.

Comparison: The large, hemispherical to spherical verrucae which are developed on the valvae distinguish the species from *Trilobosporites trioreticulosus* Cookson & Dettmann and *T. purverulentus* (Verbitskaya). *T. apiverrucatus* Couper and *Lygodium multituberculatum* Bolkhovitina resemble *T. tribotrys* sp. nov., but are distinct in having larger verrucae in the polar regions and in the absence of anastomosing muri on the valvae. *Lygodium bellum* Ivanova is smaller and has discrete verrucae on its valvae.

Distribution: A rare type recovered from a few samples of the Great Artesian and Otway Basins (see Tables 5-7). Comparable spores depicted by Samoilovitch et al. (1961) are from Cenomanian strata of W. Siberia.

Genus **Trilites** Erdtman ex Couper emend.

1947 *Trilites* Erdtman (nom. nud.), p. 110.
1947 *Trilites* Erdtman (nom. nud.): Cookson, p. 136.
1951 *Lygodioisporites* Potonié (nom. nud.), p. 144.
1953 *Trilites* Cookson ex Couper, p. 29.
1955 *Lygodioisporites* Potonié ex Delcourt & Sprumont, p. 33.
1956 *Trilites* (Erdtman, Cookson) ex Couper: Potonié, p. 26.

EMENDED DIAGNOSIS: Microspores trilete; amb triangular. Exine differentially thickened in equatorial, radial regions where sculptured valvae are developed. Sculptural elements include distal and equatorial, sometimes anastomosing, elongated verrucae or rugulae which are larger on valvae. Proximal contact areas smooth to scabrate.

TYPE SPECIES: *Trilites tuberculiformis* Cookson 1947, p. 136; Pl. 16, fig. 61, 62 emend. Occurrence: Kerguelen, Lower Tertiary.

The following description of the species is based upon the holotype together with more than 30 examples which have been recovered by the present writer from a sample labelled Cumberland Bay, Kerguelen and lodged in the British Museum of Natural History (No. 75·139(102); see Cookson 1947, p. 143). The type and three other specimens are depicted in Pl. XXVII, fig. 4-8.

EMENDED DIAGNOSIS: Microspores trilete, biconvex to plano-convex, the distal strongly convex. Amb triangular with weakly concave to convex sides. Laesurae straight, approximating equator. Exine 2-3 μ thick, thicker (3-4 μ) in equatorial, radial regions; faintly scabrate on contact areas and rugulate to verrucate elsewhere. Sinuous, closely-spaced, sometimes anastomosing, randomly orientated sculptural elevations 3 μ high, 2-3 μ wide, and 3-10 μ long. Elements larger (3-4 μ wide, 4-5 μ high) on valvae.

DIMENSIONS: Equatorial diameter 42 (51) 59 μ; polar diameter (7 specimens) 31 (37) 39 μ.

HOLOTYPE: P22726. Cookson 1947; Pl. 16, fig. 61: present study; Pl. XXVII, fig. 4, 5. Distal aspect. Amb concavely triangular, 52 μ in diameter. Laesurae 21 μ long. Exine 2 μ thick, thicker (4 μ) in equatorial, radial regions; contact areas smooth, remainder of exine with sculptural elevations 3 μ high, 3 μ wide, and up to 10 μ long.

LOCUS TYPICUS: Kerguelen, Waterfall Gorge (sample 81a).

REMARKS: The majority of the specimens which have been examined are compressed, and some are corroded. The Triassic spores which Klaus (1960) assigned to the species appear to be distinct from the Kerguelen specimens in the absence of valvae and in having shorter laesurae.

OTHER SPECIES OF TRILITES: The Tertiary species, *T. solidus* (Potonié), *T. asolidus* Krutzsch, and *T. parvallatus* Krutzsch are comparable to *Trilites* as emended herein. The majority of the species attributed to the genus by Cookson and subsequent authors are clearly distinct from *Trilites*.

DISCUSSION: The name *Trilites* was first used by Cookson (1947) for several diversely sculptured, trilete forms which she described from Lower Tertiary deposits of Kerguelen. Couper (1953) subsequently allocated generic rank to *Trilites* and designated the type species *T. tuberculiformis* Cookson. Couper's generic diagnosis, however, embraces spores attributable to many well established, pre-existing genera. Potonié (1956) and Klaus (1960) suggested, but did not formally propose, that *Trilites* should be restricted to incorporate trilete microspores having a triangular amb and a uniformly thick, verrucate exine. Meanwhile, Krutzsch (1959) used the genus for 'corrugate-rugulate', trilete microspores, some of which have a differentially thickened exine.

Upon an examination of the type and other specimens attributable to *Trilites tuberculiformis*, the present writer has concluded that the species is characterized by verrucate to rugulate sculpture distally together with a valvate exine. As such, *Trilites* is comparable morphologically to the type species of Potonié's (1951) genus *Lygodioisporites.* Of the two genera *Trilites* has the priority since it was validated prior to the validation by Delcourt and Sprumont (1955) of *Lygodioisporites.*

COMPARISON: The genus is similar to *Trilobosporites* Pant ex Potonié, but is readily distinguishable in having anastomosing, elongated elevations distally together with a smooth exine about the laesurae. *Matonisporites* Couper is distinct in having a smooth exine, while the type species of *Corrugatisporites* Thomson & Pflug ex Weyland & Greifeld is sculptured with three series of more or less parallel muri.

AFFINITY: The spores of *Dicksonia squarrosa* (Forst.) appear to be comparable to *Trilites* (see Harris, W. F. 1955; Couper 1960).

Trilites cf. **T. tuberculiformis** Cookson 1947

(Pl. XI, fig. 16-19)

DESCRIPTION: Microspores trilete, biconvex; amb triangular with weakly convex to straight sides. Laesurae straight, approximating the equator, and with membraneous, elevated lips *c.* 1 μ high. Exine 2 μ thick, thicker (3-4 μ) in equatorial, radial regions; smooth proximally and verrucate to rugulate both distally and equatorially. Sinuous, sometimes anastomosing, closely-spaced elements broadly rounded in optical section. Elements 3 μ high, 3 μ wide, and up to 10 μ long distally; valvae with larger (3-4 μ high, 4-5 μ wide) elements.

DIMENSIONS: Equatorial diameter (15 specimens) 31 (42) 50 μ; polar diameter (2 specimens) 26 μ, 42 μ.

COMPARISON: The SE. Australian specimens are similar to *Trilites tuberculiformis* Cookson, but are smaller in size and have elevated lips. The species is distinct from *T. solidus* (Potonié), *T. asolidus* Krutzsch, and *T. paravallatus* Krutzsch in having larger (higher and wider) sculptural elevations. The spores of *Rugutriletes toratus* Pierce appear to be more coarsely sculptured.

DISTRIBUTION: This form is of infrequent occurrence in the upper horizons of the Blythesdale Group and in the Roma, Tambo, and Winton Formations of the Great Artesian Basin; a few specimens have been recovered from the Murray and Otway Basins (see Tables 4-6, 8, 9).

Genus **Ischyosporites** Balme 1957

TYPE SPECIES: *Ischyosporites crateris* Balme 1957.

Balme (1957, p. 23) instituted the genus, the diagnosis and type species of which incorporate trilete microspores having anastomosing muri distally and exinal thickenings (valvae) in the equatorial, radial regions. Since the presence of valvae is considered to be a diagnostic criterion of the Infraturma Auriculati, *Ischyosporites* Balme is here transferred to this infraturma (cf. Potonié 1960, p. 46).

COMPARISON: *Trilites* Erdtman ex Couper is distinct in having verruco-rugulate sculpture of irregular, freely terminating muri and intercommunicating lumina. *Trilobosporites* Pant ex Potonié is characterized by granulate to verrucate sculpture in the polar regions of its exine, and *Klukisporites* Couper does not possess a valvate exine.

Ischyosporites punctatus Cookson & Dettmann 1958

(Pl. XI, fig. 9-15)

DESCRIPTION: Microspores trilete, biconvex; amb triangular with rounded angles and straight or weakly concave sides. Laesurae straight, extending almost to amb, and with slightly thickened, pitted margins; pits (which are probably due to corrosion) small (*c.* 1 μ), closely spaced. Exine 3-5 μ thick, thicker (4-7 μ) in equatorial, radial regions (valvate); composed of one, homogeneous layer which has distal and equatorial foveo-reticulate sculpture. Lumina circular to elliptical in outline, 4-10 μ in diameter, up to 3 μ deep, and separated by rounded muri 4-6 μ wide; lumina larger, deeper, and more closely spaced on valvae.

DIMENSIONS: Equatorial diameter 42 (56) 57 μ; polar diameter (3 specimens) 42 (44) 48 μ.

COMPARISON: The species is similar to *Ischyosporites crateris* Balme which, however, has larger lumina especially about the distal pole. Small, corroded specimens of *Trilobosporites trioreticulosus* Cookson & Dettmann and *T. purverulentus* (Verbitskaya) occasionally simulate *Ischyosporites punctatus* Cookson & Dettmann, but they are distinguishable in having smaller lumina which are entirely absent about the distal pole.

DISTRIBUTION: Widely distributed in SE. Australia, being more frequent in the lower horizons of the Upper Mesozoic sequence in the Great Artesian Basin (see Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 3-9). It is known also from Upper Jurassic and Aptian deposits of Western Australia (Cookson and Dettmann 1958b).

Infraturma TRICRASSATI infraturma nov.

Tricrassati is here proposed for trilete, acavate spores having simple or lipped laesurae and sclerine thickenings (interradial crassitudes) or extensions (corona) in the three interradial regions at the equator. In polar view, the thickenings or extensions are widest interradially and taper towards the equatorial radial regions where they are lacking.

REMARKS AND COMPARISON: Tricrassati is distinct from Cingulati in having equatorial thickenings or extensions which are confined to the interradial regions. Tricrassati is also distinguishable from Auriculati, which has radially situated, equatorial thickenings, and Patinati which is thickened over the entire distal hemisphere.

Spores attributable to this group include:

(a) spores with interradial crassitudes; *Rotaspora* Schemel, *Camarozonosporites* Pant ex Potonié, *Sestrosporites* gen. nov.

(b) spores with equatorial, interradial extensions (corona etc.); *Zebrasporites* Klaus, *Reinschospora* Schopf, Wilson, & Bentall, *Diatomozonotriletes* Naumova ex Playford.

Genus **Gleicheniidites** Ross ex Delcourt & Sprumont emend.

1949 *Gleicheniidites* Ross (nom. nud.), p. 31.
1955 *Gleicheniidites* Ross ex Delcourt & Sprumont, p. 26.
1957 *Triremisporites* Delcourt & Sprumont, p. 61.
1959 *Gleicheniidites* Ross ex Delcourt & Sprumont emend. Delcourt & Sprumont p. 34.
1959 *Gleicheniidites* Ross emend. Krutzsch (pars) p. 109.
1961 *Gleichenia* J. E. Smith: Grigorjeva (pars) in Samoilovitch et al., p. 44.
1961 non *Gleicheniidites* Grigorjeva in Samoilovitch et al., p. 59 non Ross ex Delcourt & Sprumont 1955.

EMENDED DIAGNOSIS: Microspores trilete; amb triangular. Exine smooth or almost smooth, and with exinal thickenings (crassitudes) in each equatorial, interradial region.

TYPE SPECIES: *Gleicheniidites senonicus* Ross 1949.

Remarks and Comparison: Delcourt and Sprumont (1955) formally allocated generic rank to *Gleicheniidites* Ross, and selected the type species, *G. senonicus* Ross. The illustrated holotype of this species has a smooth, trilete exine which is thickened in the interradial regions at the equator. Similar spores were assigned by Delcourt & Sprumont (1957) to the type species of their genus, *Triremisporites,* and these authors subsequently (1959) recognized that the two genera (*Gleicheniidites* and *Triremisporites*) are synonymous. Krutzsch (1959) redefined *Gleicheniidites* to receive both smooth and spinose, trilete microspores having a thickened exine in the equatorial, interradial regions. Five of the six subgeneric categories proposed by Krutzsch incorporate smooth-walled spores and conform with the above generic diagnosis; Krutzsch's other subgeneric category, *Peregrinisporis,* contains microspores having spinose sculpture, and these spores are excluded from *Gleicheniidites* as emended above.

Attention is drawn to Grigorjeva's (in Samoilovitch et al. 1961) recent assignment of *G. senonicus* to the living genus *Gleichenia* J. E. Smith, and to her proposal (loc. cit. p. 59) to conserve *Gleicheniidites* for dispersed spores morphologically distinct from those of *Gleicheniidites* Ross ex Delcourt & Sprumont. *Gleicheniidites* Grigorjeva is thus a later homonym of *Gleicheniidites* Ross ex Delcourt & Sprumont (International Code of Botanical Nomenclature 1961, Art. 48), and *Gleicheniidites* Grigorjeva cannot be conserved against *Gleicheniidites* Ross ex Delcourt & Sprumont unless Grigorjeva's proposal is approved by the General Committee on Botanical Nomenclature (loc. cit. Art. 14, 15).

The type species of *Fasciatisporites* Sato may be comparable to *Gleicheniidites* Ross ex Delcourt & Sprumont, but Sato's (1961) illustrations do not convincingly show that the species is characterized by interradial crassitudes at the equator.

Affinity: The spores of modern *Gleichenia circinata* Swartz (see Cookson 1953; Pl. 1, fig. 7) and of *G. laevissima* Christ. (see Erdtman 1957; Fig. 114C) are comparable morphologically to *Gleicheniidites.*

Gleicheniidites cf. **G. cercinidites** (Cookson) comb. nov.

(Pl. XIII, fig. 6-10)

Selected Synonymy:

1953 *Gleichenia cercinidites* Cookson, p. 464; Pl. 1, fig. 5-6.
1957 *Gleichenia* cf. *G. cercinidites* Cookson: Balme, p. 23; Pl. 3, fig. 42-44.

Description: Microspores trilete; biconvex, the distal surface strongly arched or with three, arcuate, interradial folds about the pole. Amb triangular with concave or straight sides and acutely rounded angles. Laesurae straight to weakly sinuous, extending to amb, and with narrow, elevated (1-2 μ high) lips. Exine smooth, 1-1·5 μ thick; thicker at equator where three, interradial crassitudes (3-6 μ in maximum width) are developed.

Dimensions: Equatorial diameter 23 (32) 42 μ.

Affinity: Cookson (1953) demonstrated that her species *Gleicheniidites cercinidites* is comparable to the spores, which have equatorial, interradial crassitudes, of *Gleichenia cercinata* Swartz.

Distribution: The species was described from Lower Tertiary deposits of South Australia and Victoria (Cookson 1953). The similar form, *Gleicheniidites* cf. *G. cercinidites,* is of common occurrence both in the Upper Jurassic and Lower Cretaceous of Western Australia (Balme 1957) and in Upper Mesozoic sediments of SE. Australia (see Tables 3-9).

Genus **Sestrosporites** gen. nov.

Diagnosis: Microspores trilete; laesurae simple or lipped. Exine differentially thickened in equatorial, interradial regions where crassitudes are developed. Sculpture foveolate to foveo-reticulate.

Type Species: *Sestrosporites* (al. *Foveotriletes*) *irregulatus* (Couper 1958, p. 143; Pl. 22, fig. 9, 10) comb. nov. Occurrence: Britain; Oxfordian-Kimeridgian.

Holotype: Couper 1958, p. 143; Pl. 22, fig. 9: present study; Pl. XXVII, fig. 1-3. Oblique proximal aspect. Amb triangular with weakly convex sides; 48 μ in diameter. Laesurae straight, extending to equator, and with elevated (1-2 μ high) lips. Exine 2 μ thick but thicker (3-4 μ) in equatorial, interradial regions where narrow crassitudes are developed. Proximal surface smooth; distal surface sculptured with deep foveolae which are circular to irregularly elongated in outline (1-3 μ in maximum diameter) and spaced 1-3 μ apart.

Other Species:

Sestrosporites (al. *Cingulatisporites*) *pseudoalveolatus* (Couper 1958, p. 147; Pl. 25, fig. 5, 6) comb. nov.

Comparison: The foveolate sculptured features distinguish the genus from *Gleicheniidites* Ross ex Delcourt & Sprumont, *Camarozonosporites* Pant ex Potonié, *Camarozonotriletes* Naumova ex Naumova, and *Rotaspora* Schemel. *Foveosporites* Balme lacks equatorial crassitudes.

Affinity: The spores of *Lycopodium manii* (Hillebr.), which are described by Selling (1946, p. 16; Pl. 1, fig. 13-15), and those of *L. laterale* R. Br. (see Harris, W. F. 1955) are comparable to *Sestrosporites* gen. nov.

Sestrosporites pseudoalveolatus (Couper) comb. nov.

(Pl. XIII, fig. 11-16)

1958 *Cingulatisporites pseudoalveolatus* Couper, p. 147; Pl. 25, fig. 5, 6.

Description: Microspores trilete, with a convexly triangular amb; distal surface convex, proximal surface pyramidal. Laesurae straight, extending to equator, and enclosed within membraneous, elevated (2 μ high) lips. Proximal and distal exine 2 μ thick; equatorial exine differentially thickened in interradial regions where crassitudes are developed. Crassitudes cavate, 4-6 μ wide interradially, narrowing to 2 μ in radial regions. Compressed specimens usually with a membraneous equatorial 'zona' (3-5 μ wide) which is formed from the outermost portion of the cavate crassitudes. Exine comprehensively sculptured with deep foveolae that are circular in outline, 0·5-1 μ in diameter, and spaced 2-3 μ apart.

Dimensions: Equatorial diameter (14 specimens) 39 (48) 64 μ.

Remarks: The specimen (Pl. XIII, fig. 14) which shows a membraneous 'zona' is comparable in all respects to *Sestrosporites pseudoalveolatus* (Couper), and the 'azonate' specimens (Pl. XIII, fig. 11-13) are considered to be well-preserved representatives of the same species. It was found that by subjecting spores of the latter type to prolonged maceration and/or compression, the outermost portion of their cavate, interradial crassitudes ruptured and formed a membraneous 'zona' comparable to that seen in the holotype. It is perhaps noteworthy to add that Couper (1958, p. 147) recorded some specimens with 'only traces of the cingulum', and, moreover, that the two specimens figured by Couper (and which have been examined by the present writer) were subjected to prolonged (6 days') treatment with concentrated nitric acid and potassium chlorate.

Thin sections (Pl. XIII, fig. 15, 16) confirm that the interradial crassitudes are cavate.

COMPARISON: *Sestrosporites irregulatus* (Couper) has narrower interradial crassitudes together with more closely-spaced and irregularly shaped foveolae.

DISTRIBUTION: Couper (1958) described the species from Bajocian-Aptian of Britain. In SE. Australia it is of rare occurrence throughout the Upper Mesozoic sequence in the Great Artesian Basin; it has been recovered also from some horizons of the Otway Basin (see Tables 3-8).

Genus **Coronatispora** gen. nov.

DIAGNOSIS: Microspores trilete; laesurae simple or lipped. Exine differentially thickened in equatorial, interradial regions where crassitudes are developed. Distal hemisphere with a circumpolar ridge which concentrically encircles a polar thickening; polar, circumpolar, and equatorial thickenings may be connected by radially arranged elevations. Sculpture foveolate to reticulate.

TYPE SPECIES: *Coronatispora perforata* sp. nov.

OTHER SPECIES:

(1) *Coronatispora* (al. *Microreticulatisporites*) *telata* (Balme 1957, p. 25; Pl. 4, fig. 52, 53) comb. nov.

(2) *Coronatispora* (al. *Cingulatisporites*) *valdensis* (Couper 1958 p. 146; Pl. 24 fig. 6, 7) comb. nov. Occurrence: England; Wealden-Aptian. The specimen figured by Lantz (1958b; Pl. 3, fig. 28) of *Cingulatisporites* cf. *caminus* Balme, and those of *Staplinisporites caminus* (Balme) Pocock (1962; Pl. 5, fig. 87; Pl. 6, fig. 88-90) appear to be conformable with *Coronatispora valdensis*.

COMPARISON: In possessing equatorial thickenings (interradial crassitudes), the genus is distinct from *Staplinisporites* Pocock, *Neochomotriletes* Reinhardt, and *Taurocusporites* Stover all of which show a similar concentric arrangement of distal thickenings (or elevations). These distal features distinguish *Coronatispora* gen. nov. from *Camarozonosporites* Pant ex Potonié, *Rotaspora* Schemel, *Camarozonotriletes* Naumova ex Naumova, *Zebrasporites* Klaus, and *Sestrosporites* gen. nov.

Coronatispora perforata sp. nov.

(Pl. XIII, fig. 17-25)

DIAGNOSIS: Microspores trilete; amb convexly triangular to subcircular; distal surface convex, proximal surface pyramidal. Laesurae straight, extending to equator; with thin (*c.* 1 μ thick), elevated (3 μ high), undulose lips. Exine 1·5-2 μ thick; thicker distally and in each equatorial, interradial region. Equatorial thickenings (interradial crassitudes) cavate; attaining maximum width (4-8 μ) interradially, and narrowing to 2 μ at radii. Distal thickenings include a scabrate, polar crassitude which is circular in outline and 7-10 μ in diameter; and a narrow (2 μ wide), low, scabrate, circumpolar ridge which is situated midway between (and 5-8 μ from) the polar and equatorial crassitudes. Exine, except for distal thickened areas, with circular to elliptical foveolae 1-2 μ in diameter and spaced 2-3 μ apart.

DIMENSIONS: Equatorial diameter (27 specimens) 26 (46) 53 μ.

HOLOTYPE: Preparation D304/2 18·5 109·7 P22070; Pl. XIII, fig. 17-19. Proximal aspect. Amb convexly triangular, 44 μ in diameter. Laesurae 22 μ long. Exine 1·5 μ thick; equatorial interradial crassitudes cavate, 6 μ in maximum width. Distal polar thickening circular in outline, 7 μ in diameter; circumpolar ridge 2 μ wide. Foveolae circular to elliptical, 1-2 μ in diameter.

Locus Typicus: South Australia, Cootabarlow Bore No. 2 at 1,471-72 ft.

Discussion: Optical sections of spores in full polar view (Pl. XIII, fig. 18, 20) show the cavate nature of the equatorial crassitudes. Some 'zonate' specimens have been recovered; the 'zona' consists of the ruptured and unfurled, outermost portion of the cavate, interradial crassitudes. The illustrated 'zonate' specimen (Pl. XIII, fig. 21-23) has been compressed (by means of pressing the coverslip with a needle), and was, before compression, a typical representative of *Coronatispora perforata* sp. nov. (cf. discussion of *Sestrosporites pseudoalveolatus* (Couper)).

Comparison: The species differs from *Coronatispora telata* (Balme) and *C. valdensis* (Couper) in its foveolate sculpture; and from *Sestrosporites pseudoalveolatus* (Couper) in its distal polar thickening and circumpolar ridge.

Distribution: Recovered from the lower intervals only of bores in the Great Artesian and Otway Basins (see Tables 3, 4, 6-8).

Coronatispora telata (Balme) comb. nov.

(Pl. XIV, fig. 1-4)

1957 *Microreticulatisporites telatus* Balme, p. 25; Pl. 4, fig. 52, 53.

Description: Microspores trilete, biconvex; amb convexly triangular to subcircular. Laesurae straight, extending to equator, and with thin (1-2 μ thick), elevated (1-2 μ high) lips. Exine differentially thickened, particularly at the equator where cavate crassitudes (3-6 μ in maximum width) are developed interradially. Distal exine thickened in a circular area (7-10 μ in diameter) about the pole, and with a low, wide (3-4 μ), circumpolar ridge situated approximately midway between pole and equator. Radially disposed, low, narrow (*c.* 2 μ wide) ridges anastomose with the polar, circumpolar, and equatorial thickenings to form a shallow distal reticulum with lumina 3-6 μ in diameter. Proximal exine 1-2 μ thick, smooth or with a few widely-spaced foveolae.

Dimensions: Equatorial diameter (6 specimens) 39 (47) 53 μ.

Remarks and Comparison: The holotype of the species has cavate interradial crassitudes (see Balme 1957, Pl. 4, fig. 52). *Coronatispora telata* (Balme) is distinct from *C. valdensis* (Couper) in having a thicker exine, wider circumpolar ridge, and greater development of thickening at the equator.

Distribution: The species is known from Australian sediments only: in Oxfordian-Aptian strata of Western Australia (Balme 1957), and in a few samples from South Australia (Great Artesian and Otway Basins) and E. Victoria (present study, Tables 4-8).

Infraturma Cingulati Potonié & Klaus emend.

Trilete, avacate spores attributable to this group have simple or lipped laesurae and are characterized by comprehensive equatorial thickening (cingulum), extension (zona), or thickened extension (cingulizona).

Cingulati Potonié & Klaus as circumscribed here includes not only cingulate and zonate forms but also cingulizonate forms (spores having a thickened equatorial extension which is membraneous near its outer margin and thicker at its inner limit). Segregation of these three morphological types into more restricted units (Cingulati Potonié & Klaus sensu Potonié and Kremp 1954 and Zonati Potonié & Kremp) seems undesirable since cingulizonate forms cannot adequately be distinguished from either cingulate or zonate types. Transverse sections of certain cingulizonate and cingulate spores (see Hughes et al. 1962, Dettmann and Playford

1963) indicate that there are no essential morphological differences between cingulizona and cingulum, except that the former tapers more sharply towards the equator.

Examples of spores assignable to Cingulati as defined above include:

(a) cingulate forms; *Murospora* Somers, *Cingutriletes* Pierce
(b) cingulizonate forms; *Cirratriradites elegans* (Waltz), *Densosporites intermedius* Butterworth & Williams
(c) zonate forms; *Kraeuselisporites* Leschik, *Cirratriradites saturni* (Ibrahim).

Genus **Cingutriletes** Pierce emend.

1961 *Cingutriletes* Pierce (pars), p. 20.

EMENDED DIAGNOSIS: Microspores trilete, cinuglate; amb subcircular to circular. Exine smooth or almost smooth.

TYPE SPECIES: *Cingutriletes congruens* Pierce 1961.

REMARKS AND COMPARISON: Pierce (1961) instituted the genus to incorporate cingulate, as well as interradially crassate, smooth-walled, trilete microspores. The interradially crassate forms, which have a concavely triangular amb, are excluded from *Cingutriletes* Pierce as emended above, and conform with *Gleicheniidites* Ross ex Delcourt & Sprumont.

Cingutriletes is similar to *Anulatisporites* Loose ex Potonié & Kremp but, pending reappraisal of the latter genus by the International Commission for the Microflora of the Palaeozoic (I.C.M.P.), *Cingutriletes* is retained for Mesozoic and Tertiary forms that conform with the above diagnosis. The genus may be comparable to *Discisporites* Leschik, the morphology of which, however, is imprecisely known. *Murospora* Somers is distinct in having a concavely triangular amb.

Cingutriletes clavus (Balme) comb. nov.

(Pl. XIV, fig. 5-8)

SELECTED SYNONYMY:

1953 *Sphagnites australis* (Cookson) f. *crassa* Cookson, p. 464; Pl. 1, fig. 2-4.
1953 cf. *Sphagnites australis* (Cookson) f. *crassa* Cookson, p. 469; Pl. 2, fig. 24.
1956 *Sphagnumsporites australis* (Cookson) f. *crassa* Cookson: Potonié, p. 17.
1957 *Sphagnites clavus* Balme, p. 16; Pl. 1, fig. 4-6.
1959 *Stereisporites crassus* (Cookson) Krutzsch, p. 73.
1959 *Sphagnumsporites clavus* (Balme) de Jersey, p. 348; Pl. 1, fig. 2.
1961 *Sphagnum australe* (Cookson) Drozhastchich f. *crassa* Cookson: Drozhastchich in Samoilovitch et al., p. 14; Pl. 1, fig. 2, 3.

DESCRIPTION: Microspores trilete, biconvex; amb subcircular. Laesurae straight, extending to amb of spore cavity, and enclosed within low, membraneous lips. Exine cingulate; cingulum 2·5-5 μ wide, radially striated. Proximal exine *c.* 1 μ thick, smooth. Distal exine thickened in a circular area (14-18 μ in diameter) about the distal pole; in corroded examples the peripheral region of the distal thickening is reduced to verrucae and granules.

DIMENSIONS: Equatorial diameter; overall 25 (34) 45 μ, spore cavity 18 (25) 36 μ.

COMPARISON: The distal features of the species distinguish it from *Cingutriletes congruens* Pierce and *Stereisporites megastereoides* Pflug. *Sphagnum subflavum* Bolkhovitina and Pocock's specimen (1962; Pl. 1, fig. 4) of *Sphagnumsporites psilatus* (Ross) show granules, verrucae, and a polar thickening distally, and may be conspecific with *C. clavus* (Balme).

Drozhastchich (in Samoilovitch et al. 1961) compares the species with the spores of *Sphagnum tenellum* Pers., *S. apiculatum* Lindl., and *S. cuspidatum* Ehrh.

DISTRIBUTION: The species is known from Jurassic, Cretaceous, and Tertiary strata of Australia (Cookson 1953, Balme 1957, de Jersey 1959) and the U.S.S.R. (Samoilovitch et al. 1961). It is an uncommon but widely distributed form in the Upper Mesozoic of SE. Australia (see Tables 3-9).

Genus **Murospora** Somers 1952

TYPE SPECIES: *Murospora kosankei* Somers 1952.

After an examination of the type species and following Staplin's (1960) circumscription of the genus, Pocock (1961) assigned two Upper Mesozoic species, *M. florida* (Balme) and *M. mesozoica* Pocock, to *Murospora*. These Mesozoic forms undoubtedly conform with the genus, but, as evinced herein, Pocock has misinterpreted the morphology of *M. florida*. He contends that the species is characterized by distally thickened exine (patella). However, as revealed by sections of SE. Australian specimens, its exine is cingulate (thickened in equatorial region only). Similar cingulate features have been described by Playford (1962) for several Lower Carboniferous species of *Murospora*, and sections of one of these *M. aurita* (Waltz), show that the cingulum is thickest near the equator (see Hughes et al. 1962).

Cingulate Cretaceous microspores assigned to *Trilibozonosporites rotalis* (Weyland & Krieger) and *Dicksonia paraguadia* Bolkhovitina may be comparable morphologically to *Murospora*.

Murospora florida (Balme) Pocock 1961

(Pl. XIV, fig. 9-14)

1957 *Cingulatisporites floridus* Balme, p. 26; Pl. 5, fig. 60. 61.
1961 *Murospora florida* (Balme) Pocock, p. 1233; Fig. 1, fig. 6, 7.

DESCRIPTION: Cingulate microspores trilete, biconvex; amb subtriangular to irregular. Exine composed of one, homogeneous, almost smooth, differentially thickened layer which is 5-8 μ thick in polar regions and 11-16 μ thick equatorially. Cingulum shows considerable variation in width (10-28 μ) in individual specimens; outer margin irregularly undulate, inner margin conformable with triangular amb of spore cavity. Laesurae straight to weakly sinuous, extending to inner margin of cingulum, and with elevated (3-5 μ high) lips which are 1-2 μ wide at crests.

DIMENSIONS: Equatorial diameter (22 specimens); overall 59 (79) 100 μ, spore cavity 40 (51) 67 μ.

REMARKS: Except for their greater size range, the SE. Australian specimens are identical to those described from Western Australia by Balme (1957) and Pocock (1961). The latter author states (p. 1233) that the species has a distally situated, 'thick laevigate patella 8 to 15 μ thick'; however, transverse sections (present study; Pl. XIV, fig. 13, 14) show that the exine is cingulate, and, moreover, that the proximal exine is as thick as the distal exine. The laesurate lips are composed of proximal extensions of the exine, and have narrow crests.

One of the specimens figured by Balme (1957; Pl. 5, fig. 61) has a pitted exine in the polar regions. Similar features, which are probably due to corrosion, are exhibited by some of the specimens recovered in the present investigation (Pl. XIV, fig. 11, 12). The polar exines of some specimens (see Pl. XIV, fig. 11) are with small, evenly-spaced pits; in more heavily corroded spores (Pl. XIV, fig. 12), the pits are larger and often encroach on to the cingulum where they are radially arranged.

COMPARISON: The larger size and/or wider cingulum of *Murospora florida* (Balme) distinguishes it from *M. mesozoica* Pocock, *Trilobozonosporites rotalis* (Weyland & Krieger), and *Dicksonia paraguadia* Bolkhovitina.

DISTRIBUTION: Balme (1957) indicates a Neocomian-Aptian distribution of the species in Western Australia; Pocock's (1961) Western Australian record is from the probably Neocomian-Aptian Strathalbyn Sandstone (see Balme 1957, p. 44; Table 4). In South Australia it shows restricted vertical distribution in the Great Artesian Basin and has been recovered from the Otway Basin and E. Victoria (see Tables 3, 4, 6-8).

Genus **Foraminisporis** Krutzsch 1959

TYPE SPECIES: *Foraminisporis foraminis* Krutzsch 1959.

REMARKS: The microspores here attributed to *Foraminisporis* possess a narrow, sculptured cingulum, and are not strictly applicable to the genus as diagnosed by Krutzsch (1959, p. 130). However, the Australian spores resemble closely the type species, the illustrated holotype of which appears to be weakly thickened equatorially.

It should be noted that the cingulate nature of the Australian species was recognized only after a critical examination of specimens mounted in 50% glycerine, and situated in off-polar aspects. Almost all of the specimens recorded in glycerine jelly mounts are orientated in full-polar aspect.

AFFINITY: As discussed subsequently, two of the Australian Mesozoic species closely resemble spores found in the living hepatic species *Nothylas breutelii* Gottsche and *Phaeoceros bulbiculosus* (Brotero).

Foraminisporis wonthaggiensis (Cookson & Dettmann) comb. nov.

(Pl. XIV, fig. 19-23; Fig. 4o)

1958 *Apiculatisporis wonthaggiensis* Cookson & Dettmann, p. 100; Pl. 14, fig. 7-10.
1961 *Cirratriradites* cf. *tilchaensis* Cookson & Dettmann; Samoilovitch et al.; Pl. XXXIX, fig. 6.
1962 *Lycospora cretacea* Pocock, p. 34; Pl. 1, fig. 12, 13.

DESCRIPTION: Microspores trilete, biconvex; amb subcircular, subtriangular, or occasionally subquadrangular with convex sides. Laesurae straight to undulose, extending to equator, and with membraneous lips *c.* 1 μ high. Exine spinulose, 1·5-2·5 μ thick but thicker (3-5 μ) equatorially; narrow, tapering cingulum spinulose and with a few irregularly scattered, small foveolae. Distal spinulae 1-1·5 μ in basal diameter, 1-2 μ high, and spaced 1-3 μ apart; proximal spinulae smaller, more closely spaced, and often with confluent bases.

DIMENSIONS: Overall equatorial diameter 36 (49) 61 μ.

COMPARISON: The species may be conspecific with the spore attributed by Chlonova (1961, p. 49; Pl. 4, fig. 29) to *Osmunda granulata* (Maljavikina). It is distinct from *Osmundacidites hirtus* Lantz which has shorter laesurae, and *Alsophila asperata* Bolkhovitina which has more crowded spinulae and is larger in size. *Trilites bifurcatus* Couper and *Foraminisporis foraminis* Krutzsch resemble *F. wonthaggiensis* (Cookson & Dettmann), but differ in possessing branched laesurae and more reduced proximal sculpture.

AFFINITY: Spores morphologically similar to *F. wonthaggiensis* occur in the living hepatic species *Nothylas breutelii* Gottsche, and are described in Appendix I (see also, Pl. XXVII, fig. 12-14).

Distribution: The species shows wide distribution and is of some stratigraphical value in the Upper Mesozoic of SE. Australia (Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 4-9). It is known also from Barremian strata of Canada (Pocock 1962), and in the Turonian of Siberia (Samoilovitch et al. 1961). The similar spore of *Osmunda granulata* which Chlonova (1961) recorded is from Cenomanian-Turonian deposits of Siberia.

Foraminisporis dailyi (Cookson & Dettmann) comb. nov.

(Pl. XIV, fig. 15-18)

1958 *Granulatisporites dailyi* Cookson & Dettmann, p. 99; Pl. 14, fig. 2-4.

Description: Microspores trilete, biconvex; amb subcircular, subtriangular, or subquadrangular with convex sides. Laesurae straight, extending to equator, and with membraneous, inconspicuous lips *c.* 1 μ high. Exine 1-2·5 μ thick, thicker (2-6 μ) at equator; narrow cingulum equatorially tapering and with small, shallow, irregular foveolae. Distal exine sculptured with irregularly disposed, low granules and verrucae (1-5 μ in basal diameter); proximal exine with a cluster of small, clearly defined granules on the central area of each contact face.

Dimensions: Overall equatorial diameter 36 (55) 70 μ.

Comparison: The species is similar in overall construction to *Foraminisporis wonthaggiensis* (Cookson & Dettmann) which differs, however, in possessing spinulose sculpture. The spores illustrated, but not described, by Paeltova (1961; Pl. 13, fig. 1, 2) of *Sporites* sp., and by Samoilovitch et al. (1961; Pl. XXXIX, fig. 7) of *Selaginella* sp. may be comparable to *F. dailyi* (Cookson & Dettmann). The species is distinct from *Trilites lachlanae* Couper and *Trachytriletes mixtus* Bolkhovitina both of which lack proximal sculpture.

Affinity: *F. dailyi* is similar in morphology to microspores, which are described in Appendix I (see also, Pl. XXVII, fig. 15-18), of *Phaeoceros bulbiculosus* (Brotero) and *Nothylas breutelii* Gottsche. The latter species also produces spores which are comparable to *Foraminisporis wonthaggiensis* and this may indicate that *F. dailyi* and *F. wonthaggiensis* originated in closely related plants.

Distribution: A widely dispersed species in the Upper Mesozoic of SE. Australia (Cookson and Dettmann 1958b, 1959a; Dettmann 1959; present study, Tables 4-9).

Foraminisporis asymmetricus (Cookson & Dettmann) comb. nov.

(Pl. XVI, fig. 15-19)

1958 *Apiculatisporis asymmetricus* Cookson & Dettmann, p. 100; Pl. 14, fig. 11, 12.
1958 *Todea gibva* Verbitskaya; Pl. 2, fig. 29.
1962 *Todea gilva* Verbitskaya, p. 94; Pl. 4, fig. 35a-e.
1962 *Verrucosisporites asymmetricus* (Cookson & Dettmann) Pocock, p. 56; Pl. 8, fig. 124-126.

Description: Microspores trilete, biconvex; amb asymmetrically subquadrangular to subtriangular with straight or convex sides. Laesurae inconspicuous, approximating amb, and enclosed within membraneous lips 1-2 μ high. Exine verrucate, 2-3 μ thick; thicker (4-6 μ) equatorially where a narrow, verrucate cingulum is developed. Distal and equatorial verrucae broadly rounded and 2-3 μ high in optical section; with circular to polygonal bases (2-3 μ in diameter), and spaced 1-3 μ apart. Proximal verrucae smaller (1-2 μ in basal diameter) and more sparsely distributed.

Dimensions: Overall equatorial diameter 40 (53) 70 μ.

COMPARISON: The species is readily distinguishable from *Foraminisporis wonthaggiensis* (Cookson & Dettmann) in having verrucate sculpture, and from *F. dailyi* (Cookson & Dettmann) in possessing larger and more evenly developed verrucae. *F. asymmetricus* (Cookson & Dettmann) resembles *Dicksonia bulbacea* Bolkhovitina, but is distinct in lacking verrucate, laesurate lips. *Dicksonia densa* Bolkhovitina has smaller and more crowded verrucae and *D. crocina* Bolkhovitina has larger verrucae which appear to be confined to the distal surface.

DISTRIBUTION: A widely distributed species in E. Australia (Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 4-9) where it appears to be of some stratigraphical importance. In the Great Artesian Basin its first occurrence is in the upper horizons of the Blythesdale Group, and it ranges into the Tambo Formation (Albian). Extra-Australian records include Aptian-Albian of Russia (Verbitskaya 1962) and Barremian-Aptian of Canada (Pocock 1962).

Genus **Contignisporites** gen. nov.

DIAGNOSIS: Microspores trilete, cingulate; symmetrical about a plane that includes the polar axis and which is situated either at right angles to, or parallel to, the length of the distal muri (see Fig. 5). Distal exine shows bilaterally symmetrical sculpture; sculptural elements include a series of more or less parallel, sometimes bifurcating and anastomosing muri which are coalescent with cingulum. Proximal exine radially symmetrical; with one tangentially disposed murus on equatorial region of each contact face; polar exine with or without sculpture.

TYPE SPECIES: *Contignisporites glebulentus* sp. nov.

OTHER SPECIES:

(1) *Contignisporites* (al. *Cicatricosisporites*) *cooksonii* (Balme 1957, p. 19; Pl. 1, fig. 23, 24; Pl. 2, fig. 25, 26) comb. nov.
(2) *Contignisporites fornicatus* sp. nov.
(3) *Contignisporites multimuratus* sp. nov.
(4) *Contignisporites* (al. *Aneimia*) *dorsostriatus* (Bolkhovitina 1956, p. 60; Pl. 7, fig. 95b) comb. nov. Occurrence: U.S.S.R.; Upper Jurassic-Lower Cretaceous (Bolkhovitina 1956, 1961).
(5) *Contignisporites* (al. *Cicatricosisporites*) *dunrobiensis* (Couper 1958, p. 137; Pl. 17, fig. 13-15) comb. nov. Occurrence: Britain; Lower Lias-Bajocian.
(6) *Contignisporites* (al. *Chomozonotriletes*) *mitriforminus* (Korgenevskaja) comb. nov. (see Verbitskaya 1958; Pl. 2, fig. 37, 37a: 1962, p. 100; Pl. 9, fig. 46a-g). Occurrence: U.S.S.R.; Aptian (after Verbitskaya 1962). The validity of this species is in some doubt as a holotype has not been designated in the available literature.
(7) *Contignisporites* (al. *Chomotriletes*) sp. Sah 1953, p. 3; Pl. 1, fig. 7; Pl. 2, fig. 34. Occurrence: Ceylon; Jurassic.

The illustrated specimens of *Anemia sujfunensis* Bolkhovitina (1961, p. 59; Pl. 17, fig. 5a-c) appear to be comparable morphologically to *Contignisporites* gen. nov., but according to the description the distal muri parallel the triangular amb.

DISCUSSION: This interesting group of Upper Mesozoic spores is characterized by equatorially thickened exine (cingulate), bilaterally symmetrical sculpture, and radially symmetrical proximal sculpture. Fig. 5 illustrates the distal, proximal, and overall symmetry of *Contignisporites*, and the two symmetry types recorded for each of the Australian species described below. These types differ only in the orientation (relative to the laesurae) of the distal muri; in the first type (Fig. 5a-c), the distal muri parallel one laesura and bisect the angle formed by the other two; in the second type (Fig. 5d-f), the distal muri are arranged at right angles to a laesura and bisect the angles between it and the other two laesurae. In *Contignisporites glebulentus* sp. nov. and *C. cooksonii* (Balme) both types have been recorded in approximately equivalent proportions, and this may indicate that they were derived from spore tetrads comprising two spores of each type.

The criteria largely used in the delineation of the Australian species include shape of muri, overall width of four adjacent muri and lumina in the distal polar region, proximal polar sculpture, and width of cingulum. The cingulum and sculptural elevations in some examples are cavate; the cavae, which are shown in transverse sections (Pl. XV, fig. 8-10, 17, 18), are considered to have resulted from a partial breakdown (possibly due to corrosion) of the exine. As seen in polar view, cavate specimens have a concentrically striated cingulum.

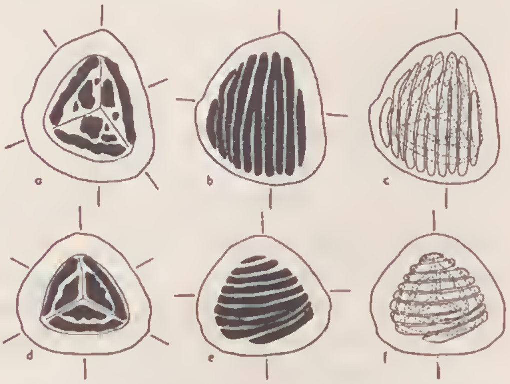

Fig. 5—Drawings from photographs illustrating proximal, distal, and overall symmetry of the two symmetry types recorded in *Contignisporites glebulentus* sp. nov. (a-c) Holotype in which the distal muri parallel one laesura and bisect the angle formed between the other two laesurae (see also Pl. XV, fig. 1-2); Penola Bore No. 1 at 1,805-15 ft, D286/5 34·9 119·6 (P22081); (d-f) Specimen in which the distal muri are arranged at right angles to one laesura and bisect the angle between it and the other two laesurae (see also Pl. XV, fig. 3, 4); Robe Bore No. 1 at 1,400 ft, D217/12 41·7 118·8 (P22082). Magnifications × *c*. 250.

Comparison and Affinity: The cingulate feature coupled with the distal sculpture of one series of parallel muri distinguishes *Contignisporites* from *Cicatricosisporites* Potonié & Gellitich, *Plicatella* Maljavikina ex Potonié, and *Appendicisporites* Weyland & Krieger.

Bolkhovitina (1961) implies that *Contignisporites cooksonii* and *C. dorsostriatus* (Bolkhovitina) bear an affinity with *Anemia* Swartz, but, as far as the author is aware, none of the spores presently known in living and fossil species of the Schizaeaceae is comparable to *Contignisporites.*

Contignisporites glebulentus sp. nov.

(Pl. XV, fig. 1-10; Fig. 5)

Diagnosis: Microspores trilete, symmetrical about one plane that includes the polar axis and which is situated either at right angles to or parallel to the length of the distal muri (Fig. 5c, f); biconvex; amb triangular, usually elongated along one median, and with straight to weakly convex sides. Exine (as seen in transverse sections) weakly differentiated into two layers; intexine *c*. 1 μ thick; sculptured exoexine cingulate, 3-4 μ thick in polar regions (inclusive of sculpture). Cingulum smooth, 9-14 μ wide; concentrically striated in corroded specimens in which it is cavate (Pl. XV, fig. 3-6). Distal exoexine with bilaterally symmetrical, cicatricose sculpture; sculptural elevations include seven to ten, parallel, occasionally bifurcating, rarely anastomosing, closely-spaced, rounded muri which coalesce with cingulum along its inner margin. Muri sometimes cavate, 3-5 μ wide, 2-3 μ high; separated by narrow (1-2 μ wide), elongated lumina; four adjacent muri and lumina total 22 μ in width. Proximal exoexine shows radially symmetrical sculpture; polar interradial regions with low (2-3 μ high), broad-based (2-14 μ in diameter), sometimes elongated verrucae; equatorial region of each contact face with one, tangentially disposed, fusiform murus, 2-3 μ high, 3-5 μ wide, and 36-46 μ long. Laesurae straight, extending to inner margin of cingulum.

Dimensions: Equatorial diameter; overall 59 (68) 78 μ, spore cavity 39 (48) 56 μ. Polar diameter (3 specimens) 35 (41) 45 μ.

Holotype: Preparation D286/5 34·9 119·6 P22081; Pl. XV, fig. 1, 2; Fig. 5a-c. Proximal aspect. Amb triangular, 78 μ in diameter. Cingulum 14 μ wide. Distal surface with ten parallel muri (each 4 μ in width) that are separated by narrow (1·5 μ wide) lumina; muri parallel one laesura. Proximal polar verrucae 3-14 μ in diameter; interradial muri 4 μ wide, 40 μ long. Laesurae 28 μ long.

Locus Typicus: South Australia, Penola Bore No. 1 at 1,805-15 ft.

Discussion: Fig. 5 illustrates the overall symmetry and the two types of distal sculpture patterns shown by the species. The distal muri of 18 of the 33 specimens examined are orientated at right angles to one laesura, whilst in the other 15 examples they parallel one laesura and bisect the angle formed by the other two laesurae. Transverse sections (Pl. XV, fig. 8-10) of the two-layered exine show the cavate nature of the cingulum and sculptural elevations.

Comparison: *Contignisporites glebulentus* sp. nov. is distinguishable from *C. dorsostriatus* (Bolkhovitina) which has wider distal muri and a subcircular amb.

Distribution: The species appears to have restricted vertical distribution in the Otway and Great Artesian Basins. In the Oodnadatta Bore it has been recovered from the uppermost horizons of the Roma (Aptian) Formation and from samples of the Tambo (Albian) Formation (see Tables 5-7, 9).

Contignisporites cooksonii (Balme) comb. nov.

(Pl. XV, fig. 11-16)

1957 *Cicatricosisporites cooksonii* Balme, p. 19; Pl. 1, fig. 23, 24; Pl. 2, fig. 25, 26.
1961 *Anemia cooksonii* (Balme) Bolkhovitina, p. 59; Pl. 17, fig. 6b-e.
1961 non *Anemia mitriformina* Verbitskaya: Bolkhovitina, p. 59.

Description: Microspores trilete, symmetrical about one plane, biconvex; amb roundly triangular, sometimes elongated along one median. Exine one-layered, 3-4 μ thick in polar regions (inclusive of sculpture), thicker equatorially; cingulum 4-7 μ wide, cavate in corroded specimens. Distal exine with bilaterally symmetrical, cicatricose sculpture; sculptural elevations include six to nine, parallel, rarely bifurcating, low (2-3 μ high), rounded muri which coalesce with cingulum towards equator. Muri wider (3·5-4·5 μ) than intervening lumina (1·5-2·5 μ); four adjacent muri and lumina total 20-25 μ in width. Proximal exine shows radial symmetry; smooth about pole, and with one, low, tangentially orientated murus (3·5-4·5 μ in width) on each interradial area near inner margin of cingulum. Laesurae straight, extending to cingulum, and with thin lips *c.* 1 μ high.

Dimensions: Equatorial diameter (23 specimens); overall 39 (50) 59 μ, spore cavity 31 (37) 42 μ.

Discussion and Comparison: The distal muri are disposed either parallel to (in 10 specimens) or at right angles to (in 13 specimens) one laesura (see Pl. XV, fig. 11-14). Sections (Pl. XV, fig. 17, 18) cut obliquely to the distal muri show the cavate nature of the cingulum.

Contignisporites cooksonii (Balme) is distinguishable from *C. glebulentus* sp. nov. in its lack of proximal polar sculpture, narrower cingulum, and smaller size. *C. dorsostriatus* (Bolkhovitina) shows wider distal muri, and *C. mitriforminus* (Korgenevskaja) is larger and has proximal polar sculpture.

Distribution: Balme (1957) described the species from Oxfordian-Aptian strata of Western Australia; the specimens subsequently illustrated by Bolkhovitina (1961) are from Barremian-Aptian of U.S.S.R. In SE. Australia the species has been recovered from the Blythesdale Group and Roma (Aptian) Formation in the Great Artesian Basin and from sediments in the Otway Basin and E. Victoria (Tables 3, 4, 6-8; see also Dettmann 1959).

Contignisporites fornicatus sp. nov.

(Pl. XVI, fig. 1-5)

Diagnosis: Microspores trilete, symmetrical about one plane; spheroidal, the distal surface strongly arched; amb subcircular. Exine 4 μ thick in polar regions (inclusive of sculpture), cingulate; cingulum 5-8 μ wide. Distal surface with bilaterally symmetrical, cicatricose sculpture of five to eight parallel, occasionally bifurcating, low (2-3 μ high), straight-sided, broadly-crested muri which anastomose with inner margin of cingulum. Muri wider (5-6 μ) than intervening lumina which are 2-3 μ wide; four adjacent muri and lumina total 32-35 μ in width. Proximal exine radially symmetrical; equatorial interradial area of each contact face with a tangentially disposed murus, c. 1 μ high and 4-5 μ wide; polar regions with hemispherical verrucae 2-8 μ in diameter. Laesurae straight, extending to inner margin of cingulum.

Dimensions: Equatorial diameter (12 specimens); overall 42 (53) 62 μ, spore cavity 31 (38) 46 μ. Polar diameter (2 specimens) 40, 42 μ.

Holotype: Preparation D222/11 41·5 119·3 P22088; Pl. XVI, fig. 1-3. Distal aspect. Amb subcircular, 62 μ in diameter. Laesurae 26 μ long. Cingulum 7 μ wide; distal exine with seven muri (each 5-6 μ wide) that are arranged at right angles to one laesura. Proximal muri 4·5 μ wide, 33 μ long; verrucae 2-8 μ in diameter.

Locus Typicus: South Australia, Tilcha Bore No. 2 at 460-80 ft.

Discussion and Comparison: In three of the specimens recovered, the distal muri are arranged at right angles to one laesura; in the other nine examples the distal muri parallel a laesura (cf. Fig. 5).

The species differs from *Contignisporites glebulentus* sp. nov. and *C. cooksonii* (Balme) in its subcircular amb and wider distal sculptural elements (total width of four muri and lumina); *C. dorsostriatus* (Bolkhovitina) has wider distal muri (6-9 μ).

Distribution: A rare type, recovered only from sediments of the Great Artesian Basin, South Australia (see Tables 4-6, 9).

Contignisporites multimuratus sp. nov.

(Pl. XVI, fig. 6-13)

Diagnosis: Microspores trilete, symmetrical about one plane; plano-convex, the distal surface strongly arched; amb subtriangular with convex sides. Exine one-layered, 7 μ thick in polar regions (inclusive of sculpture); thicker equatorially. Cingulum 7-10 μ wide, cavate in corroded specimens. Distal exine bilaterally symmetrical; sculpture of eleven to sixteen, more or less parallel, bifurcating and usually anastomosing, straight-sided, roundly-crested muri which coalesce with cingulum near equator. Muri 5-6 μ high, slightly wider than, or as wide as, intervening lumina (2-3 μ); four adjacent muri and lumina total 18-20 μ in width. Proximal exine radially symmetrical; with conspicuous verrucae (2-10 μ in diameter) on polar regions, and three, fusiform, tangentially disposed muri (2-3 μ high, 2-3 μ wide), which parallel interradial margin of contact faces. Laesurae straight, extending to cingulum, and with membraneous lips *c.* 1 μ high.

DIMENSIONS: Equatorial diameter (7 specimens); overall 58 (66) 76 μ, spore cavity 42 (48) 56 μ. Polar diameter (5 specimens) 42 (48) 56 μ.

HOLOTYPE: Preparation D331/1 54·4 114·5 P22057; Pl. XVI, fig. 6-8. Distal aspect. Amb subtriangular, 76 μ in diameter. Laesurae 23 μ long. Cingulum 10 μ wide, irregular in outline. Distal surface shows twelve, more or less parallel, bifurcating muri, each 3 μ in width; muri arranged parallel to one laesura. Proximal verrucae 2-10 μ in diameter.

LOCUS TYPICUS: South Australia, Cootabarlow Bore No. 2 at 1,348-52 ft.

DISCUSSION AND COMPARISON: The specimens incorporated within *Contignisporites multimuratus* sp. nov. bear distal muri which are orientated either at right angles to (in 3 specimens) or parallel to (in 5 specimens) one laesura. The muri, as seen in transverse sections (Pl. XVI, fig. 11-13), are higher and narrower than those of the other three SE. Australian species of *Contignisporites*. *C. dorsostriatus* (Bolkhovitina) has wider muri and is smaller in size. One of the specimens assigned by Verbitskaya (1962; Pl. 9, fig. 46e) to *C. mitriforminus* (Korgenevskaja) resembles *C. multimuratus*.

DISTRIBUTION: A rare type found in sediments of the Great Artesian and Otway Basins (see Tables 4, 6-8).

Genus **Kraeuselisporites** Leschik emend. Jansonius 1962

1955 *Kraeuselisporites* Leschik, p. 36.
1958 *Styxisporites* Cookson & Dettmann, p. 114.
1962 *Kraeuselisporites* Leschik emend. Jansonius, p. 46.

TYPE SPECIES: *Kraeuselisporites dentatus* Leschik 1955.

The genus was originally diagnosed (Leschik 1955) as alete, and thus no reference was made to it when Cookson and Dettmann (1958b) instituted their genus *Styxisporites* to incorporate trilete, zonate microspores with distal spinose sculpture. Jansonius (1962) subsequently recognized that the type species of *Kraeuselisporites* Leschik is trilete, and the features connoted in his emendation of the genus are comparable to those of *Styxisporites*. However, Jansonius (1962) and Balme (1963) suggest that the two genera are distinguishable on the extent and height of their laesurate lips and the density of their zona. The present writer considers that these features provide insufficient basis for the retention of *Styxisporites* as a genus distinct from *Kraeuselisporites*.

In addition to the species described by Leschik (1955), Jansonius (1962), and Balme (1963), the following Mesozoic microspores conform with *Kraeuselisporites*:

(1) *Kraeuselisporites* (al. *Styxisporites*) *linearis* (Cookson & Dettmann 1958, p. 114; Pl. 19, fig. 3, 4, 8, 9) comb. nov.
(2) *Kraeuselisporites* (al. *Styxisporites*) *majus* (Cookson & Dettmann 1958, p. 115; Pl. 19, fig. 10-13) comb. nov.

(3) *Kraeuselisporites* (al. *Selaginella*) *maturus* (Bolkhovitina 1959, p. 85; Pl. 1, fig. 10) comb. nov. Occurrence: U.S.S.R.; Upper Cretaceous.

(4) *Kraeuselisporites* (al. *Styxisporites*) *cooksonae* (Klaus 1960, p. 141; Pl. 31, fig. 29, 31) comb. nov. Occurrence: Europe; Carnian.

Mesozoic microspores assigned to *Cingulatisporites saevus* Balme may be comparable to *Kraeuselisporites.*

Kraeuselisporites linearis (Cookson & Dettmann) comb. nov.

(Pl. XVII, fig. 1-4)

1958 *Styxisporites linearis* Cookson & Dettmann, p. 114; Pl. 19, fig. 3, 4, 8, 9 (non fig. 6, 7).
1960 *Styxisporites linearis* Cookson & Dettmann: Potonié, p. 66; (non Pl. 4, fig. 69).

DIAGNOSIS: As given by Cookson and Dettmann (1958b).

DIMENSIONS: Equatorial diameter (22 specimens); overall 53 (62) 70 μ, spore cavity 42 (47) 53 μ. Width of zona 5-9 μ; maximum height of laesurate lips 5-7 μ.

HOLOTYPE: P17630 Cookson and Dettmann 1958b; Pl. 19, fig. 3, 4: present study; Pl. XVII, fig. 1, 2. Distal aspect. Amb subcircular, 59 μ in diameter. Laesurae straight, extending to inner margin of zona, and enclosed within membraneous, elevated lips; lips 6 μ high at pole, tapering to *c.* 1 μ near equator. Exine 2 μ thick, smooth proximally; with distal coni and setulae which are 7-8 μ high, 2-3 μ in basal diameter, and spaced 5-8 μ apart. Zona membraneous, 7 μ wide, and with a serrated margin.

LOCUS TYPICUS: Victoria, Wonthaggi State Coal Mine Area; Kirrak, floor of coal seam at 103 ft.

REMARKS: The holotype was incorrectly captioned in the accompanying plate explanation of Cookson and Dettmann (1958b). This error was rectified subsequently by these authors (1959d), but it has been perpetuated by Potonié (1960) who illustrates an example of *Aequitriradites spinulosus* (Cookson & Dettmann) under the name *Styxisporites* Cookson & Dettmann.

COMPARISON: The species resembles *Kraeuselisporites apiculatus* Jansonius, but has longer sculptural elements and higher lips. *K. linearis* (Cookson & Dettmann) is distinct from *K. maturus* (Bolkhovitina) and *K. dentatus* Leschik both of which are smaller in size and have smaller sculptural elements; and from *K. ramosus* Leschik which has a thicker exine and smaller coni.

DISTRIBUTION: An uncommon type showing wide lateral and restricted vertical distribution in the Upper Mesozoic of SE. Australia (Cookson and Dettmann 1958a; present study, Tables 3, 4, 6-8). In the Oodnadatta Bore, Great Artesian Basin it has been recovered from samples of the Blythesdale Group and overlying Roma (Aptian) Formation.

Kraeuselisporites majus (Cookson & Dettmann) comb. nov.

(Pl. XVII, fig. 5, 6)

1958 *Styxisporites majus* Cookson & Dettmann, p. 115; Pl. 19, fig. 10-13.

DIAGNOSIS: As given by Cookson and Dettmann (1958b).

DIMENSIONS: Equatorial diameter; overall 56 (69) 83 μ, spore cavity 42 (51) 64 μ. Polar diameter (2 specimens) 25, 36 μ. Width of zona 9-17 μ; maximum height of laesurate lips 7-12 μ.

COMPARISON: *Kraeuselisporites majus* (Cookson & Dettmann) is distinct from other members of the genus in the form and arrangement of its distal sculptural elements. It resembles the spores of *Selaginella pedata* Klotzsch which differ, however, in having proximal sculpture (see Knox 1950, p. 249; Pl. 11, fig. 88a, b).

DISTRIBUTION: The species is widely distributed in Australian Upper Mesozoic sediments where it seems to have stratigraphical importance. It is known from the Albian of Western Australia, Queensland, and the Great Artesian Basin (South Australia and New South Wales); and has been recovered from certain horizons of the Otway Basin (Cookson and Dettmann 1958b; present study, Tables 5-7, 9).

Genus **Minerisporites** Potonié 1956

TYPE SPECIES: *Minerisporites mirabilis* (Miner) Potonié 1956.

Minerisporites marginatus (Dijkstra) Potonié 1956

(Pl. XVI, fig. 14)

DIMENSIONS: Overall equatorial diameter (6 specimens) 240 (310) 375 μ.

DISTRIBUTION: The species was described from the Wealden of the Netherlands (Dijkstra 1951), and subsequently reported from the Ashdown Sands (Valanginian) of England (Hughes 1958) and Upper Mesozoic strata of E. Australia (Cookson and Dettmann 1958a, 1958b; Dettmann 1959; present study, Tables 3-9).

Suprasubturma PERINOTRILITES Erdtman emend.

Perinotrilites Erdtman is emended to incorporate trilete spores which are characterized by a cavate sclerine of uniform or differential thickness. The laesurae may be simple or lipped.

REMARKS AND COMPARISON: As defined above this category includes certain of the trilete spores previously attributed to Monosaccites Chitaley and to Perinotrilites Erdtman sensu Potonié (1956).

The name Perinotrilites was first introduced by Erdtman (1947, p. 111) who stated that 'fossil spores with a distinct perine may be referred to Perinotrilites'. Potonié (1956) subsequently applied the name to a suprageneric category which was diagnosed to incorporate perinate, trilete *sporae dispersae*. The assignment of fossil spores to Perinotrilites Erdtman sensu Potonié is dependent, therefore, upon the presence of a perine, a wall layer that is often difficult to distinguish even in recent spores (Erdtman 1947, 1952; Harris, W. F. 1955). Nevertheless, Perinotrilites was used by several authors for fossil spores of Palaeozoic and Mesozoic age. Few of these spores are certainly perinate, but many possess a membraneous outer wall layer which loosely envelopes the inner wall layer (s). Spores exhibiting these features are here termed 'cavate', and the outermost wall layer of cavate spores is denoted by 'outer layer of sculptine' rather than by 'perine' (see Glossary of Descriptive Terms).

Trilete spores possessing a cavate sclerine have also been attributed to Monosaccites, and these conform with Perinotrilites Erdtman emend. They are readily distinguishable from definite monosaccate forms that exhibit a proximal trilete mark e.g., *Nuskoisporites dulhuntyi* Potonié & Klaus) on the following characters:

(a) the wall layers in saccate forms are attached both proximally and distally; in cavate forms the wall layers are usually only attached either about the proximal laesurae or distally;

(b) the distal polar exine of saccate forms usually is thinner and less conspicuously patterned than the proximal exine; the sclerine of described cavate forms is either uniformly patterned or more strongly patterned on the distal surface;

(c) the equatorial exoexine of saccate forms has small structural elements ('baculoid or endosexinous rods' of Erdtman 1952; 'columellae' of Faegri and Iverson 1950) attached to its undersurface; comparable structural elements are not known in trilete, cavate spores.

It should be noted that the diagnosis of Membraniti Neves conforms with Perinotrilites, but the two genera included within Neves's (1961) category do not convincingly show a cavate sclerine.

The following selected forms are comparable morphologically to Perinotrilites: *Endosporites* Wilson & Coe, *Diaphanospora* Balme & Hassell, *Velosporites* Hughes & Playford, *Spinozonotriletes* Hacquebard, *Densoisporites* Weyland & Krieger, and *Crybelosporites* gen. nov. Some of these genera include spores in which the outer layer of the cavate sclerine is equatorially thickened (e.g., *Densoisporites* and certain species of *Endosporites*), while in other described species (e.g. *Velosporites echinatus* Hughes & Playford, *Diaphanospora* spp.) the sclerine is of uniform thickness. The presence of equatorial thickening provides a basis for subdivision of Perinotrilites, but subdivision is not proposed here since many of the constituent genera are in need of revision.

Genus **Crybelosporites** gen. nov.

DIAGNOSIS: Microspores trilete, spheroidal to ellipsoidal. Sclerine stratified; consisting of a smooth, homogeneous, inner layer enclosed within a two-layered, proximally cavate, structured sculptine. Outer layer of sculptine without a trilete aperture; proximally detached from trilete, inner layers; and with a reticulate, rugulate, or foveolate (OL) surface pattern.

TYPE SPECIES: *Crybelosporites striatus* (Cookson & Dettmann) comb. nov.

COMPARISON: *Crybelosporites* gen. nov. is distinct from *Perotrilites* Erdtman ex Couper in having a proximally cavate, structured sculptine which has a reticulate to foveolate surface pattern. It shows superficial resemblance to *Dictyotosporites* Cookson & Dettmann, but is readily distinguishable by its stratified, proximally cavate sculptine. *Densoisporites* Weyland & Krieger is cingulate and its sclerine layers are attached about the proximal pole.

Mesozoic microspores assigned to *Hymenozonotriletes platychilus* (Maljavkina), *Selaginella asperrima* Bolkhovitina, *Salvinia perpulchra* Bolkhovitina, and *S. sangarensis* Bolkhovitina show some resemblance to *Crybelosporites*. Krutzsch's (1962) Tertiary species, *Hydrosporis*? *tectatus* and *H.*? *sinotectatus*, are almost certainly comparable to *Crybelosporites*.

DISCUSSION AND AFFINITY: Cookson and Dettmann (1958a) have demonstrated that the type species bears a close relationship both to dispersed megaspores included within *Pyrobolospora reticulata* Cookson & Dettmann and to microspores borne by several living species of the Marsiliaceae. The microspores of *Pilularia* L., *Marsilea* L., and *Regnellidium* Lind. are perinate, and their structured perine (which is devoid of a trilete aperture and which has a reticulate, rugulate, or foveolate surface) is proximally detached from the trilete, stratified exine. Similar, if not identical, features are shown by all three species of *Crybelosporites* recovered during the present study. Despite these morphological and structural analogies the term 'perine' is not used herein to definite the outermost, proximally detached layer of the fossil spores; instead, this layer is denoted by 'outer layer of sculptine'.

Crybelosporites striatus (Cookson & Dettmann) comb. nov.

(Pl. XVIII, fig. 1-6)

1958 *Perotrilites striatus* Cookson & Dettmann, p. 43; Pl. 1, fig. 8-12.

Description: Microspores trilete, spheroidal. Sclerine stratified, cavate proximally, 4-5 μ thick (inclusive of sculptural/structural elements); consisting of a smooth, homogeneous, inner layer (1-1·5 μ thick) and a ruffled, proximally cavate, two-layered sculptine, the outer layer of which forms a conical gula-like projection over the proximal pole. Sculptine 3 μ thick in optical section, striated proximally, reticulate distally and equatorially; reticulum composed of membraneous muri (1·5-3 μ high) which enclose circular to polygonal lumina 1-3 μ in diameter. Laesurae developed on two inner wall layers only; straight, length $\frac{3}{4}$ spore radius, and with weakly thickened lips.

Dimensions: Equatorial diameter 28 (37) 45 μ; polar diameter 34 (45) 56 μ; diameter of inner layer 20 (29) 29 μ.

Affinity: Cookson and Dettmann (1958a, b) have discussed fully the possible affinity of *Crybelosporites striatus* (Cookson & Dettmann) both with Cretaceous megaspores, *Pyrobolospora reticulata* Cookson & Dettmann, and with microspores of the living Marsiliaceae (*Pilularia novaezealandiae* T. Kirk, *P. novae-hollandiae* A. Braun, and *Regnellidium diphyllum* Lindley).

Distribution: *C. striatus* is of widespread distribution in E. Australia where it is of undoubted stratigraphical importance. Its northerly occurrences include the Albian of New Guinea and Queensland, and in SE. Australia it has been widely recognized in deposits from New South Wales, South Australia, and Victoria (Cookson and Dettmann 1958a, 1958b, 1959a; Dettmann 1959; present study, Tables 4-9). In the Great Artesian Basin it first appears in the upper horizons of the Roma Formation (Aptian), with a vertical extension into the Winton Formation (?Cenomanian).

Crybelosporites punctatus sp. nov.

(Pl. XVIII, fig. 7-11)

Diagnosis: Microspores trilete, spheroidal. Sclerine 3-4 μ thick, stratified, cavate proximally; consisting of a thin (1 μ thick), homogeneous, inner layer and a thicker (2-3 μ thick), enveloping, two-layered, structural sculptine. Sculptine layers adherent distally and cavate proximally; inner layer composed of randomly arranged granules; outer layer minutely pitted (OL surface pattern) and additionally striated in proximal regions where it forms a gula-like projection over the pole. Laesurae developed on two inner layers only; straight, length $\frac{2}{3}$ spore radius, and with weakly thickened lips.

Dimensions: (12 specimens) Equatorial diameter 36 (51) 64 μ; polar diameter 42 (60) 78 μ; diameter of inner layer 31 (42) 53 μ.

Holotype: Preparation D383/1 37·5 128·5 P22105; Pl. XVIII, fig. 7, 8. Equatorial aspect. Microspore spheroidal; equatorial diameter 36 μ, polar diameter 53 μ. Sclerine 3 μ thick. Sculptine 2 μ thick; with granulate structure and a punctate surface.

Locus Typicus: South Australia, Oodnadatta Bore No. 1 at 248 ft.

Comparison: *Crybelosporites punctatus* sp. nov. is distinguishable from both *C. striatus* (Cookson & Dettmann) and *C. stylosus* sp. nov. by the punctate surface of its sculptine. It resembles the microspores of *Marsilea* L., e.g. those of *M. aegyptiaca* Willd. (see Erdtman 1957, p. 80; Fig. 145).

DISTRIBUTION: The species is of rare occurrence in some samples from the Great Artesian and Otway Basins (see Tables 4-7, 9).

Crybelosporites stylosus sp. nov.

(Pl. XVIII, fig. 12-20)

DIAGNOSIS: Microspores trilete; plano-convex, the distal surface strongly convex. Uncompressed specimens with a circular to subcircular amb; compressed specimens irregular in equatorial outline. Sclerine 5-9 μ thick, stratified, cavate; consisting of an inner, unsculptured, homogeneous layer (1-2·5 μ thick) and a thicker, enveloping, two-layered, structured, proximally cavate sculptine. Inner layer of sculptine 2-4 μ thick, finely spongeous in structure; outer layer 1-3 μ thick, composed of radially arranged fibrous elements that form a surface reticulum composed of narrow muri and polygonal to circular lumina (1-2 μ in diameter). Sculptine layers adherent distally, elsewhere they are separated by a cavity. Laesurae straight, approximating amb of inner layer; not developed on outermost layer.

DIMENSIONS: Equatorial diameter (19 specimens); overall 50 (61) 78 μ, inner layer 36 (43) 56 μ. Polar diameter (6 specimens); overall 47 (53) 57 μ, inner layer 36 (37) 39 μ.

HOLOTYPE: Preparation D302/1 23·8 113·0 P22002; Pl. XVIII, fig. 12, 13. Distal aspect. Amb circular 54 μ in diameter; inner layer 38 μ in diameter. Smooth, homogeneous, inner layer 1·5 μ thick. Inner layer of sculptine 3 μ thick; proximally detached from outermost layer which is 1·5 μ thick. Laesurae 17 μ long.

LOCUS TYPICUS: South Australia, Cootabarlow Bore No. 2 at 1,469-70 ft.

REMARKS AND COMPARISON: Transverse sections (Pl. XVIII, fig. 19, 20) clearly show the stratified and cavate nature of the sclerine. Similar morphological and structural features are exhibited by the microspores of *Pilularia globulifera* L. that are precisely depicted by Erdtman (1957, p. 87; Fig. 162).

Crybelosporites stylosus sp. nov. differs from *C. striatus* (Cookson & Dettmann) in having a thicker sclerine and a larger size. It resembles superficially *Dictyotosporites complex* Cookson & Dettmann but is readily distinguishable by its cavate sclerine, smaller-meshed reticulum, and longer laesurae. *Hymenozonotriletes platychilis* (Maljavikina) and Bolkhovitina's species, *Selaginella asperrima* and *Salvinia sengarensis*, are distinct in having shorter laesurae, whilst *S. perpulchra* Bolkhovitina differs in its radially striated proximal surface.

DISTRIBUTION: Recovered from several samples of the Blythesdale Group in the Great Artesian Basin and in certain horizons of the Otway Basin and E. Victoria (see Tables 3, 6-8).

Genus **Velosporites** Hughes & Playford 1961

TYPE SPECIES: *Velosporites echinatus* Hughes & Playford 1961.

Velosporites triquetrus (Lantz) comb. nov.

(Pl. XIX, fig. 1-3)

1958 *Laricoidites triquetrus* Lantz, p. 926; Pl. 5, fig. 51-54.

DESCRIPTION: Microspores indistinctly trilete, biconvex; amb circular in uncompressed specimens, irregular in compressed specimens. Exine two-layered;

consisting of a thin (*c.* 1 μ thick), finely echinate intexine and a membraneous, punctate exoexine. Intexine loosely enveloped within exoexine, particularly at the equator. Laesurae straight, extending to periphery, and with membranous, elevated lips *c.* 1 μ high.

DIMENSIONS: Equatorial diameter; overall 48 (60) 70 μ, intexine 28 (39) 50 μ.

REMARKS AND COMPARISON: Although *Velosporites* Hughes & Playford has hitherto been recorded only from Carboniferous sediments, there is no morphological basis for the erection of a new genus to accommodate the Mesozoic spores described above. *Laricoidites* Potonié, Thomson, & Thiergart is alete, and its type species possesses a one-layered exine. *Velosporites triquetrus* (Lantz) is distinct from *Perinopollenites elatoides* Couper which has a monoporate, scabrate exine.

DISTRIBUTION: Lantz (1958b) described the species from Bathonian-Kimeridgian strata of England. It is of infrequent occurrence in the majority of the samples examined from the Upper Mesozoic of SE. Australia (see Tables 3-8).

Genus **Densoisporites** Weyland & Krieger emend.

1953 *Densoisporites* Weyland & Krieger, p. 12.
1961 *Selaginella* Spring: Krasnova (pars) in Samoilovitch et al., p. 19.

EMENDED DIAGNOSIS: Microspores trilete. Spore wall (sclerine) two-layered, cavate; consisting of an outer structured layer (sculptine) loosely enveloping, but proximally attached to, a thinner inner layer. Sculptine equatorially thickened, and with a finely patterned surface, the pattern being formed by an arrangement of the structural elements (but not of sculptural elements which are lacking). Inner layer thin, smooth, and with interradial thickenings (papillae) situated near the proximal pole.

TYPE SPECIES: *Densoisporites velatus* Weyland & Krieger 1953, p. 12; Pl. 4, fig. 12-14 emend. Krasnova 1961, p. 35 (=*Densoisporites perinatus* Couper 1958, p. 145; Pl. 23, fig. 6-9). A detailed consideration of this species is given subsequently.

OTHER SPECIES: (1) *Densoisporites triradiatus* Delcourt & Sprumont 1955, p. 42; fig. 11. Occurrence: Belgium; Wealden. Holotype. Delcourt and Sprumont 1955, fig. 11; Delcourt et al. 1963; Pl. 45, fig. 7. Proximal aspect. Microspore biconvex with subcircular amb, 125 μ in diameter. Laesurae straight, extending to periphery, and with membraneous, elevated (3 μ high) lips. Sclerine two-layered, cavate; sculptine with spongeous structure, 8 μ thick but thicker at equator where a tapering cingulum (25 μ wide) is developed. Sculptine loosely envelops smooth, thin (1 μ thick), inner layer which has three, low, interradial, proximal thickenings that are elliptical in outline and 10 μ in maximum diameter. The other specimen depicted by Delcourt et al. (1963; Pl. 45, fig. 8, 9) is smaller (96 μ) than the holotype (which is corroded), but it shows more clearly the sculptine features. (2) *Densoisporites* (al. *Lundbladispora*) *playfordi* Balme 1963, p. 23; Pl. 5, fig. 4-8) comb. nov. Occurrence: Western Australia; Lower Triassic.

DISCUSSION: Weyland and Krieger (1953, p. 12) validly instituted the genus (on the basis of *Densoisporites velatus*) to incorporate trilete microspores in which the cingulum is 'laminated on the inside, irregularly and finely wrinkled on the outside'. Delcourt and Sprumont (1955) added their species, *D. triradiatus*, to the genus but did not elaborate on the generic diagnosis which was later restated by Potonié (1956) and Krutzsch (1959). Couper (1958) made no mention of the cingulate (generic) feature when he described his species, *D. perinatus*, which

Krasnova (in Samoilovitch et al. 1961) subsequently included within the type species. Both Couper and Krasnova recognized that the spores are characterized by a two-layered wall, but Krasnova's description more fully clarifies the morphology of *D. velatus*. She demonstrated that it shows an equatorially thickened outer layer loosely enveloping a smooth inner layer which has proximal interradial thickenings. These morphological features were not incorporated in the generic diagnosis, however, as Krasnova attributed the type species (and the genus) to *Selaginella* Spring, a procedure which has not been adopted by the present writer.

The non-committal term 'sculptine' is used in the above generic emendation to designate the outer, loosely enveloping layer of the spore wall (sclerine) instead of 'perine' which Couper, Krasnova, and others have used in describing the same wall layer. The emendation is based upon an examination of Australian spores referable to the type species, *D. velatus*, and of the type material of *D. perinatus* (= *D. velatus*) and *D. triradiatus*.

Comparison and Affinity: *Densoisporites* Weyland & Krieger resembles *Lundbladispora* Balme (1963), which differs, however, in having distal 'cones, spines or grana'. Perhaps the closest morphological and structural analogies are to be found in certain species of *Endosporites* Wilson & Coe. In both *Endosporites globiformis* (Ibrahim) and *E. papillosus* Jansonius the two-layered, cavate wall consists of a thin, smooth, inner layer (central body) which has proximal, interradial papillae and which is proximally atached to the structured outer layer ('saccus'). In *E. globiformis* the outer layer is equatorially thickened (limbate). *Densoisporites* exhibits these features, but is distinguishable from *Endosporites* in possessing a thicker outer layer (which is more strongly thickened at the equator) together with a considerably smaller cavity between the two wall layers.

It is of considerable interest to note that a lycopodiaceous affinity has been suggested for both *Densoisporites playfordi* and *Endosporites globiformis*. Chaloner (1953, 1958) demonstrated that *E. globiformis* is comparable to the microspores of the lycopod cone *Polysporia mirabilis* Newberry (= *Lepidostrobus zea* Chaloner), and Balme (1963) suggested a lycopodiaceous, possibly selaginellid, affinity for *D. playfordi* after comparing the species with the microspores associated with *Selaginellites polaris* Lundblad.

Densoisporites velatus Weyland & Krieger emend. Krasnova 1961

(Pl. XIX, fig. 4-8)

1953 *Densoisporites velatus* Weyland & Krieger, p. 12; Pl. 4, fig. 12-14.
1958 *Densoisporites perinatus* Couper, p. 145; Pl. 23, fig. 6-9.
1958 *Dictyotosporites complex* Cookson & Dettmann (pars), p. 107; Pl. 18, fig. 1.
1961 *Selaginella velata* (Weyland & Krieger) Krasnova in Samoilovitch et al., p. 35-36; Pl. 7, fig. 5, 6.

Description: Microspores trilete, biconvex; amb roundly triangular to subcircular. Laesurae straight or slightly sinuous, length $\frac{2}{3}$-$\frac{3}{4}$ amb radius; enclosed within membraneous, low lips. Sclerine two-layered, cavate; consisting of a thin, homogeneous, inner layer and a loosely enveloping, but proximally attached, structured sculptine. Sculptine 2-3 μ thick, thicker equatorially; equatorial thickening (cingulum) 3-4 μ wide interradially and up to 6 μ wide radially. Sculptine composed of randomly arranged structural elements which are more widely spaced towards outer surface; surface pattern scabrate overall; low, sinuous, radial folds on proximal surface only. Inner layer smooth, c. 1 μ thick; with three, low, proximally situated, interradial polar thickenings (papillae) which are circular to elliptical in outline and 3-5 μ in maximum diameter.

DIMENSIONS: Equatorial diameter (26 specimens); overall 53 (69) 86 μ, inner layer 42 (53) 68 μ. Polar diameter (2 specimens) 30 μ, 45 μ.

COMPARISON: The Australian specimens are larger than those described by Weyland and Krieger (1953), but are similar in size to those recorded by Couper (1958), Chlonova (1961), and Krasnova (in Samoilovitch et al. 1961). *Densoisporites triradiatus* Delcourt & Sprumont is larger and has a wider cingulum; *D. playfordi* (Balme) posseses a more finely textured sculptine and a narrower cingulum. Bolkhovitina's species *Hymenozontriletes utriger, Selaginella utrigera,* and *Salvinia perpulchra* resemble *D. velatus* Weyland & Krieger but differ in showing an uniformly thick, membraneous, outer wall layer.

Potonié (1956) suggested a comparison of the species with the microspores of *Selaginella hallei* (Lundblad) and *Selaginella scandens* Spring, but *D. velatus* is clearly distinct from these spores. Except for its considerably thicker sculptine, *D. velatus* resembles the microspores associated with *Selaginellites polaris* Lundblad.

DISTRIBUTION: Weyland and Krieger described the species from Senonian strata near Aachen, Germany. It was recorded subsequently from Lower Lias-Aptian of Britain (Couper 1958); from ?Neocomian of U.S.A. (Groot and Penny 1960); and from Valanginian-Danian only of W. Siberia (Samoilovitch et al. 1961; Chlonova 1961). In SE. Australia *D. velatus* is more common in samples from the Great Artesian Basin; it has been recovered also from some horizons in the Otway Basin (see Tables 3-9).

TURMA MONOLETES Ibrahim 1933

The spores of this group are characterized by a proximal monolete aperture which has its centre at the pole; the aperture (laesura) may be simple or lipped, the lips constituting thickened and/or upturned extensions of the proximal sclerine. Monolete spores usually show bilateral symmetry.

Classification of monolete spores, as proposed here (see Table 2), is based, firstly, on the stratification of the sclerine, secondly, on the presence (or absence) of equatorial thickening and/or extension, and thirdly, on sculptural features.

Suprasubturma ACAVATOMONOLETES s.s. turma nov.

Acavatomonoletes is proposed here to incorporate monolete spores possessing an acavate sclerine.

Monolete spores having a cavate sclerine are referred by Potonié (1956) to Perinomonoliti Erdtman, and certain species assigned to Zonomonoletes Luber? appear to possess a cavate sclerine (e.g., *Saturnisporites* Klaus, *Aratrisporites* Leschik).

Subturma AZONOMONOLETES Luber 1935

Monolete spores possessing an acavate sclerine which is of uniform thickness are included within Azonomonoletes Luber.

Potonié (1956) diagnosed Zonomonoletes to incorporate monolete forms having an equatorially thickened and/or extended sclerine, but none of the types assigned to this group is convincingly equatorially thickened or extended.

Infraturma LAEVIGATOMONOLETI Dybová & Jachowicz 1957

Smooth, monolete spores possessing an acavate sclerine are incorporated within this infraturma.

Genus **Laevigatosporites** Ibrahim 1933

TYPE SPECIES: *Laevigatosporites vulgaris* (Ibrahim) Ibrahim 1933.

Laevigatosporites ovatus Wilson & Webster 1946

(Pl. XIX, fig. 9-11)

SELECTED SYNONYMY:

1946 *Laevigatosporites ovatus* Wilson & Webster, p. 273; Fig. 5.
1947 *Monolites minor* Cookson, p. 135; Pl. 15, fig. 57.
1956 *Polypodiaceaesporites minor* (Cookson) Potonié, p. 76.

DIMENSIONS: Equatorial diameter; length 31 (40) 50 μ, breadth 20 (27) 36 μ. Polar diameter 20 (26) 34 μ.

DISTRIBUTION: A widely distributed type in the Upper Mesozoic of SE. Australia (see Tables 4-7, 9); it appears to be confined to the Tambo (Albian) and Winton (?Cenomanian) Formations of the Upper Mesozoic succession in the Great Artesian Basin. Similar, if not identical, spores have been recorded frequently from other parts of the world in sediments ranging from Devonian to Recent.

Infraturma SCULPTATOMONOLETI Dybová & Jachowicz 1957

Monolete, acavate spores with a sculptured sclerine are allocated to this infraturma.

Genus **Reticuloidosporites** Pflug 1953

TYPE SPECIES: *Reticuloidosporites dentatus* (Pflug) Pflug 1953.

Krutzsch (1959) has broadened Pflug's (in Thomson and Pflug 1953) original circumscription of *Reticuloidosporites*, and has proposed three subgeneric categories of the genus. The type species (and the type subgenus *Reticuloidosporites*) is characterized by a sculpture of narrow, elongated elevations which anastomose to form a perfect or imperfect, positive reticulum. On the other hand, the subgenus *Polypodiisporites* Potonié has broadly-based, closely-spaced, low verrucae, the narrow interstices of which connect to form a negative reticulum; and the third subgenus *Accusosporis* Krutzsch shows a sculpture of intercommunicating foveolae. The present writer considers that both *Polypodiisporites* and *Accusosporis* are generically distinct from *Reticuloidosporites* which is used herein in the original sense of Pflug.

Reticuloidosporites arcus (Balme) comb. nov.

(Pl. XIX, fig. 12-14)

1957 *Polypodiidites arcus* Balme, p. 28; Pl. 6, fig. 67.

DESCRIPTION: Microspores monolete, bilateral; concavo-convex in full polar view; amb broadly elliptical to subcircular. Laesura straight, length ⅔ that of major equatorial axis. Exine 2-3 μ thick; with narrow, low, sinuous muri which terminate freely or anastomose to enclose polygonal lumina 1-3 μ in diameter.

DIMENSIONS: (7 specimens) Equatorial diameter; length 42 (44) 48 μ, breadth 39 (40) 42 μ. Polar diameter 31 (32) 34 μ.

COMPARISON: *Reticuloidosporites inflexus* (Bolkhovitina) and *R. dentatus* Pflug differ in having a coarser-meshed reticulum.

DISTRIBUTION: Described by Balme (1957) from Jurassic and Lower Cretaceous strata of Western Australia, and recorded herein in samples from the Great Artesian and Otway Basins (see Tables 4, 6-8).

Genus **Microfoveolatosporis** Krutzsch 1959

TYPE SPECIES: *Microfoveolatosporis pseudodentatus* Krutzsch 1959.

This genus embraces azonate, monolete microspores having foveolate sculpture, and it is morphologically similar to the foveo-reticulate types species of *Reticulosporis* Krutzsch and *Retimonolites* Pierce. Tertiary spores included within the latter two genera are comparable to some spores of *Schizaea* J. E. Smith, whilst the Mesozoic spores here attributed to *Microfoveolatosporis canaliculatus* sp. nov. resemble the deviating spores of *Schizaea pectinata* (L.) that are described by Selling (1944, p. 22; Pl. 1, fig. 5, 6).

Microfoveolatosporis canaliculatus sp. nov.

(Pl. XIX, fig. 15-21)

DIAGNOSIS: Microspores bilateral, monolete; concavo-convex in full equatorial view; amb broadly elliptical. Laesura straight, simple, length ½ that of the major amb axis. Exine 1·5-2 μ thick, foveolate to foveo-reticulate; with circular to irregular, unevenly disposed, intercommunicating foveolae that are 1-3 μ in diameter and 0·5-1 μ deep.

DIMENSIONS: (17 specimens) Equatorial diameter; length 28 (32) 39 μ, breadth 18 (22) 26 μ. Polar diameter 14 (20) 25 μ.

HOLOTYPE: Preparation D386/2 32·1 112·7 P22115; Pl. XIX, fig. 15, 16. Oblique lateral aspect. Equatorial diameter (length) 34 μ; polar diameter 22 μ. Exine 2 μ thick.

LOCUS TYPICUS: South Australia, Cootabarlow Bore No. 2 at 581 ft.

COMPARISON: *Reticulosporis candidus* (Bolkhovitina) has larger and more regularly arranged sculptural elements. The deviating spores that are described by Selling (1944) of *Schizaea pectinata* show a similar sculpture pattern but are larger in size.

DISTRIBUTION: Recognized only in samples from the Tambo Formation (Albian) of the Great Artesian Basin (see Tables 5, 6, 9).

TURMA HILATES turma nov.

Hilates is proposed here for spores with structural and/or sculptural modification at and about the distal or proximal pole where a hilum may be developed as the result of a natural sclerinous breakdown. The proximal sclerine may possess a tetrad mark comprising three radial ridges.

The spores of this group are readily distinguishable from trilete and monolete forms on the form of their polar aperture (hilum). The hilum may be developed either proximally (*Couperisporites tabulatus* sp. nov.) or distally (*Aequitriradites* Delcourt & Sprumont).

Some described forms comprising this group exhibit a cavate sclerine (e.g., *Rouseisporites* Pocock), whilst others are acavate (*Coptospora* gen. nov., *Cooksonites* Pocock). Further, the sclerine may be azonate (*Coptospora*) or zonate (*Aequitriradites, Couperisporites* Pocock). The presence of these features indicates that Hilates may be classified on the same basis as Triletes and Monoletes, but no formal subdivision of the group is proposed here.

Genus **Coptospora** gen. nov.

1962 *Cooksonites* Pocock (pars), p. 54.

DIAGNOSIS: Microspores tetrahedral, inaperturate or hilate. Exine characterized by a modification of structure and/or sculpture at and about one (?distal) pole where a hilum may be formed as a result of a natural exinous breakdown. Sculptural/structural elements various. Membraneous, outer layer of sclerine, if represented, impersistent.

TYPE SPECIES: *Coptospora striata* sp. nov.

OTHER SPECIES:

(1) *Coptospora* (al. *Cingulatisporites*) *paradoxa* (Cookson & Dettmann 1958, p. 100, Pl. 17; fig. 9-13) comb. nov.

(2) *Coptospora* (al. *Cooksonites*) *reticulata* (Pocock 1962, p. 55; Pl. 8, fig. 118-120) comb. nov. Occurrence: Canada; Barremian.

Two other types are described subsequently from the SE. Australian Upper Mesozoic sediments, but insufficient examples have been obtained for the institution of formally named species.

The polar morphology of the Mesozoic forms referred to *Orbipatella scrutinaeformis* Maljavikina, *Chasmatosporites apertus* (Rogalska), and *Tasmanites* cf. *tardus* Eisenack (in Reinhardt 1962) has not been precisely defined; thus, their detailed comparison with *Coptospora* is precluded.

COMPARISON AND AFFINITY: On morphological grounds, the present writer considers it necessary to separate formally 'Groups I and II' of *Cooksonites* Pocock. Thus, *Coptospora* gen. nov. is instituted to incorporate Group II (acingulate species, such as *Cooksonites reticulatus* Pocock); *Cooksonites* is emended subsequently, and thereby restricted to the cingulate but otherwise similar types (Group I). *Aequitriradites* Delcourt & Sprumont differs from both genera in having an equatorially tapering membraneous 'zona'.

Polar features comparable to those of *Coptospora, Cooksonites,* and *Aequitriradites* are shown by certain modern hepatic spores which germinate by means of a rupture in, and after a breakdown of, their polar (distal) exine (see Duthie and Garside 1936, Fulford 1956, Udar 1957). Moreover, many of the modern spores borne by the Sphaerocarpaceae, Ricciaceae, and Riellaceae are hilate, and some of these are morphologically similar to *Coptospora.* In particular, the spores of *Geothallus tuberosus* Campbell resemble the dispersed spores herein assigned to *Coptospora striata* sp. nov., and it is tempting to infer a related origin of the fossil spores.

Coptospora striata sp. nov.

(Pl. XX, fig. 1-5)

DIAGNOSIS: Microspores inaperturate or hilate, biconvex; amb circular to subcircular. Exine 2-5 μ thick; smooth to faintly patterned (LO) on one hemisphere. Exine of other hemisphere (?distal) radially striated near equator; thinner (1-2 μ thick) and radially fractured in a ± circular area (30-40 μ in diameter) at and about the pole. Radially fractured, polar area composed of discrete, minute granules at pole and narrow, sinuous, radially elongated elements towards periphery; occasionally an irregular rupture (hilum) is formed by the breakdown of the exine in this area. A thin, granulate, ruffled, outer sclerinous layer loosely envelops some specimens.

DIMENSIONS: Equatorial diameter 56 (78) 100 μ; polar diameter (3 specimens) 48-78 μ.

Holotype: Preparation D225/10 34·3 117·3 P22117; Pl. XX, fig. 1, 2. Proximal (?) aspect. Amb subcircular, 86 μ in diameter. Exine 4 μ thick at equator; one surface radially fractured, and with an irregular rupture in an elliptical area (45 μ in diameter) about the pole.

Locus Typicus: South Australia, Robe Bore No. 1 at 2,630 ft.

Remarks and Comparison: Specimens (Pl. XX, fig. 5) mounted in equatorial aspect show that the exine is unthickened at the equator. The species differs from *Coptospora reticulata* (Pocock) comb. nov. which has a thicker, reticulate exine.

C. striata sp. nov. resembles the thick-walled spores of *Geothallus tuberosus* Campbell, but these modern spores (which, by kind permission of Professor G. Erdtman, have been examined by the writer) differ in showing a reticulate pattern at and about one pole (see Erdtman 1957, p. 109; Fig. 216).

Distribution: The species is common in a few samples from the Otway Basin, and occasional specimens were found in samples from E. Victoria (see Tables 4, 5, 7, 9).

Coptospora paradoxa (Cookson & Dettmann) comb. nov.

(Pl. XXI, fig. 1-7)

1958 *Cingulatisporites paradoxus* Cookson & Dettmann, p. 100; Pl. 17, fig. 9-13.

Description: Microspores tetrahedral, inaperturate or hilate, biconvex; amb subtriangular to subcircular. Exine 1·5-3 μ thick, scabrate; distal exine only fractured at and about pole. Fractures delimit hexagonal areas, 5-7 μ in diameter and numbering three to nine in any one specimen; in some specimens the distal polar exine is ruptured (hilate). Proximal exine inaperturate and rarely with faint tetrad mark. Exine occasionally enveloped within a thin (1 μ thick), granulate, outer, sclerinous layer.

Dimensions: Equatorial diameter 40 (53) 62 μ.

Remarks: Sections (Pl. XXI, fig. 5-7) show that the one-layered exine is not thickened equatorially, and that it is partially traversed by fractures in the distal polar area. These sections were obtained from a specimen which was not enveloped within an outer sclerinous layer ('cingulum' of Cookson and Dettmann 1958a, p. 100).

Comparison: The species differs from *Coptospora striata* sp. nov. and *C. reticulata* (Pocock) in its smaller size, scabrate exine, and larger hexagonal polar areas.

Distribution: *C. paradoxa* shows wide lateral distribution in SE. Australia where it appears to have undoubted stratigraphical importance (see present study, Tables 5-7, 9; Cookson and Dettmann 1958b; Dettmann 1959). In the Ooodnadatta Bore, South Australia it is confined to the uppermost beds of the Roma (Aptian) Formation and to the Tambo (Albian) Formation; the specimens recorded by Cookson and Dettmann (1958b) from the Aptian sample (Cootabarlow Bore No. 2 at 1,354 ft) are, in fact, small, broken representatives of *Araucariacites australis* Cookson.

Coptospora sp. A

(Pl. XX, fig. 6-8)

Description: Microspores inaperturate or hilate, spheroidal; amb subcircular. Exine 6-7 μ thick; verrucate, except about one pole where it is radially fractured in a circular to elliptical area 50-60 μ in diameter; polar area composed of minute, radially arranged, discrete granules, and may be with an irregular rupture (hilum).

Closely-spaced, sometimes coalescent verrucae broadly rounded in optical section and with irregular to circular bases 3-8 μ in diameter. Inner surface of exine radially striated.

Dimensions: Equatorial diameter (2 specimens) 81, 89 μ.

Comparison: The verrucate sculpture distinguishes this type from other species of *Coptospora*.

Distribution: A rare type found in one sample from the Otway Basin, South Australia (see Table 5).

Coptospora sp. B

(Pl. XX, fig. 9, 10)

Description: Microspores inaperturate or hilate, spheroidal; amb subcircular. Exine 6 μ thick, radially fractured in a subcircular area (25 μ in diameter) about one pole; fractures delimit minute, radially elongated elements; polar area sometimes ruptured (hilate). Remainder of exine with widely-scattered, low (1-2 μ high) spinules and coni which have circular to irregular bases 1-2 μ in diameter. Inner surface of exine radially striated.

Dimensions: Equatorial diameter (2 specimens) 79 μ, 89 μ; polar diameter (1 specimen) 48 μ.

Comparison: Distinct from *Coptospora striata* sp. nov., *C. reticulata* (Pocock), and *C.* sp. A in its spinulose sculpture.

Distribution: Recovered from one sample in the Otway Basin, South Australia (see Table 4).

Genus **Cooksonites** Pocock emend.

1962 *Cooksonites* Pocock (pars), p. 54.

Emended Diagnosis: Microspores tetrahedral, cingulate. Exine inaperturate or hilate; with structural and/or sculptural modification at and about the distal pole where a hilum may be formed as the result of a natural exinous breakdown. Sculptural/structural elements various. Enveloping outer layer of sclerine occasionally present, but not persistent.

Type Species: *Cooksonites variabilis* Pocock 1962.

Remarks and Comparison: The above generic emendation is based upon the SE. Australian cingulate spores which conform with the type species and Pocock's Group I of the genus. In its cingulate feature *Cooksonites* Pocock is distinct from the acingulate spores which Pocock (1962) assigned to his Group II of the genus, and which are here allocated to *Coptospora* gen. nov. *Cooksonites* differs from *Aequitriradites* Delcourt & Sprumont which is characterized by an equatorially tapering, membraneous zona.

As noted previously the polar features of *Cooksonites, Coptospora,* and *Aequitriradites* are comparable to those of certain modern spores found in the Hepaticae.

Cooksonites variabilis Pocock 1962

(Pl. XXI, fig. 8-11)

Description: Microspores inaperturate or hilate, cingulate, spheroidal; amb subcircular to irregular. Exine rarely enveloped within a delicate outer sclerinous layer, and composed of one, structured, cingulate layer; cingulum 7-18 μ wide, smooth to irregular in outline. Proximal exine 3-5 μ thick, almost smooth, inaperturate, and rarely with faint tetrad mark. Distal exine 5 μ thick, patterned at and about the pole where it is radially and tangentially fractured. Fractures narrow; delimit discrete, radially arranged, areas which are subcircular to hexagonal in outline and 3-5 μ in diameter. Sometimes a distinct opening (hilum) with an irregular to circular outline is formed by the partial or complete breakdown of the distal polar exine.

DIMENSIONS: Equatorial diameter; overall 59 (75) 100 μ, spore cavity 45 (56) 75 μ. Polar diameter (7 specimens) 36 (45) 56 μ.

REMARKS: The preservation of the Australian specimens is variable, and their cingula show considerable variation in width, thickness, and outline. Complete sections were difficult to obtain as the exine fractured during cutting and mounting processes. The illustrated section (Pl. XXI, fig. 11) shows that the one-layered exine is thickened equatorially.

DISTRIBUTION: Pocock (1962) described the species from Valanginian-Barremian strata of Canada. In SE. Australia it shows widespread lateral distribution, and appears to be of some stratigraphical significance (see Tables 4, 6-9).

Genus **Aequitriradites** Delcourt & Sprumont emend.
Cookson & Dettmann 1961

1955 *Aequitriradites* Delcourt & Sprumont, p. 44.
1961 *Selaginellidites* Krasnova in Samoilovitch et al., p. 38.
1961 *Aequitriradites* Delcourt & Sprumont emend. Cookson & Dettmann, p. 426.

TYPE SPECIES: *Aequitriradies dubius* Delcourt & Sprumont emend. Delcourt, Dettmann, & Hughes 1963.

OTHER SPECIES:

(1) *Aequitriradites verrucosus* (Cookson & Dettmann) Cookson & Dettmann 1961.
(2) *Aequitriradites tilchaensis* (Cookson & Dettmann) Cookson & Dettmann 1961.
(3) *Aequitriradites spinulosus* (Cookson & Dettmann) Cookson & Dettmann 1961.
(4) *Aequitriradites* (al. *Zonalasporites*) *acusus* (Balme 1957, p. 27; Pl. 5, fig. 64, 65; Pl. 6, fig. 66) comb. nov. Occurrence: Western Australia; Neocomian-Aptian.
(5) *Aequitriradites* (al. *Cirratriradites*) *luminosus* (Chlonova 1961, p. 53; Pl. 5, fig. 34) comb. nov. Occurrence: Siberia; Maastrichtian-Danian.
(6) *Aequitriradites variabilis* Pocock 1962. Occurrence: Canada; Barremian.
(7) *Aequitriradites* sp. A new type subsequently described herein.

The following species require further study for reliable identification with *Aequitriradites*:

(1) *Euryzonotriletes* sp. Sah 1953, p. 6; Pl. 1, fig. 19.
(2) *Aequitriradites salebrosaceus* (Maljavikina 1949, p. 65; Pl. 13, fig. 14) Nilsson 1958, p. 47; Pl. 3, fig. 8.
(3) *Aequitriradites* sp. A. Nilsson 1958, p. 47; Pl. 3, fig. 9.
(4) *Cirratriradites interruptus* Bolkhovitina 1959, p. 128; Pl. 8, fig. 117.
(5) *Selaginellidites densituberculatus* Krasnova in Samoilovitch et al. 1961, p. 39; Pl. 8, fig. 2.

The following specimens are distinct from *Aequitriradites*:

(1) *Aequitriradites infrapunctatus* Lantz 1958a, p. 36; Pl. 1, fig. 20; 1958b, p. 924; Pl. 3, fig. 31.
(2) *Aequitriradites* cf. *dubius* Delcourt & Sprumont: Lantz 1958b, p. 924; Pl. 1, fig. 30.

DISCUSSION: Subsequent to Cookson and Dettmann's (1961) reappraisal of the genus, Delcourt et al. (1963) demonstrated that the type species, *Aequitriradites* *dubius* Delcourt & Sprumont, is conspecific with *A. inconspicuous* Delcourt & Sprumont. Moreover, it is clear that the type species incorporates proximally inaperturate, zonate microspores which are characterized by either 'an opening' (hilum) 'in or modification of sculpture' and/or structure 'of the exine at and around the distal pole' (Cookson and Dettmann 1961, p. 425; see also Delcourt et al. 1963). Identical structural and morphological features are diagnosed for *Selaginellidites* Krasnova, and there is no doubt concerning the synonymy of this genus and *Aequitriradites* Delcourt & Sprumont.

COMPARISON: In possessing a membraneous zona *Aequitriradies* is readily distinguishable from *Cooksonites* Pocock and *Coptospora* gen. nov. *Kraeuselisporites* Leschik is proximally aperturate (trilete) and has membraneous, laesurate lips.

AFFINITY: The distal features of *Aequitriradites* resemble those of some modern hepatic spores (e.g., those of the Sphaerocarpaceae). Krasnova (in Samoilovitch et al. 1961) suggests that the genus has an affinity with *Selaginella* Spring the microspores of which, however, are clearly trilete (see Knox 1950, Selling 1946).

Aequitriradites verrucosus (Cookson & Dettmann)
Cookson & Dettmann 1961

(Pl. XXII, fig. 1-5; Fig. 6b)

1958 *Cirratriradites verrucosus* Cookson & Dettmann, p. 112; Pl. 18, fig. 2-6.
1961 *Selaginellidites verrucosus* (Cookson & Dettmann) Krasnova in Samoilovitch et al. p. 40; Pl. 9, fig. 2, 3 (? fig. 1); Pl. 10, fig. 2-4; Pl. 11, fig. 1.
1961 *Aequitriradites verrucosus* (Cookson & Dettmann) Cookson & Dettmann, p. 427; Pl. 52, fig. 1-6.

DESCRIPTION: Microspores zonate, inaperturate or hilate, biconvex; and subcircular. Exine 2-3·5 μ thick, finely granulate except about the distal pole where it is radially and tangentially fractured in a circular area 14-25 μ in diameter. Distal polar area composed of radially arranged, discrete, low 'verrucate' elements which have hexagonal bases (1·5-3 μ in diameter) and pointed apices; sometimes an irregular to circular opening (hilum) is formed by the breakdown of the exine in this area. Proximal exine inaperturate and usually with a tetrad mark which constitutes narrow (1-2 μ wide), low, usually discontinuous ridges extending from the equator to terminate at varying distances from the pole. Zona membraneous, scabrate, 8-14 μ wide; with a smooth to serrate margin and a small, internal cavity near its inner margin.

DIMENSIONS: Equatorial diameter; overall 56 (71) 89 μ, spore cavity 34 (50) 62 μ.

REMARKS AND COMPARISON: Transverse sections (Pl. XXII, fig. 4, 5; Fig. 6b) show that the distal polar 'verrucate' elements are separated from each other by narrow interstices. The zona, which tapers gradually equatorially, is cavate near its inner margin.

The species is similar to *Aequitriradites dubius* Delcourt & Sprunmont, but differs in its finer overall sculpture, consistently narrower zona, and absence of interradially situated, radially orientated ridges on the zona.

DISTRIBUTION: Widely distributed in E. Australia (Cookson & Dettmann 1958a; present study, Tables 3-9). In U.S.S.R. it is known from Neocomian-Senonian strata (Bolkhovitina 1959; Chlonova 1961; Samoilovitch et al. 1961).

Aequitriradites spinulosus (Cookson & Dettmann) Cookson & Dettmann 1961

(Pl. XXII, fig. 7-13; Fig. 6a)

1958 *Cirratriradites spinulosus* Cookson & Dettmann, p. 113; Pl. 18, fig. 9-13; Pl. 19, fig. 1, 2, 5-7 (non fig. 3, 4).
1961 *Selaginellidites spinulosus* (Cookson & Dettmann) Krasnova in Samoilovitch et al., p. 41; Pl. 11, fig. 2, 3.
1961 *Selaginellidites spinulosus* (Cookson & Dettmann) var. *hebatus* Krasnova in Samoilovitch et al., p. 42; Pl. 11, fig. 4; Pl. 12, fig. 1-4.
1961 *Selaginellidites spinulosus* (Cookson & Dettmann) var. *planus* Krasnova in Samoilovitch et al., p. 43; Pl. 12, fig. 6.
1961 *Aequitriradites spinulosus* (Cookson & Dettmann) Cookson & Dettmann, p. 427; Pl. 52, fig. 7-12.

DIAGNOSIS: As given by Cookson and Dettmann (1958b, p. 113). The term 'fovea' was used by these authors to describe the opening (hilum) in the distal polar exine. In inaperturate specimens, and as seen in transverse sections, the distal polar exine is composed of small, discrete, spinulose elements that are separated from one another by narrow fractures (Pl. XXII, fig. 10-13; Fig. 6a). The sections show also that the membraneous zona tapers equatorially, and that it is cavate near its inner limit.

FIG. 6—Drawings from photographs; all magnifications × 500. (a) *Aequitriradites spinulosus* (Cookson & Dettmann); section showing one-layered exine, cavate zona, and discrete distal spinules (see also Pl. XXII, fig. 12); Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S65d/1-2 44·1 111·6 (P22134); (b) *Aequitriradites verrucosus* (Cookson & Dettmann); section showing one-layered exine, cavate zona, and discrete distal 'verrucae' (see also Pl. XXII, fig. 4); Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S67/3 30·5 119·2 (P22132); (c) *Couperisporites tabulatus* sp. nov.; section showing two-layered sclerine, the outer layer of which is zonate, and hollow proximal verrucae (see also Pl. XXI, fig. 18, 19); Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S64/1 30·3 116·2 (P22130); (d) *Rouseisporites reticulatus* Pocock; section showing two-layered sclerine, the outer layer of which forms the zona and the distal muroid ridges (see also Pl. XXIII, fig. 8); Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S68/2 30·5 126·4 (P22139); (e) *Tsugaepollenites trilobatus* (Balme); section showing equatorially monosaccate, two-layered exine which encloses small vesiculae in the polar regions (see also Pl. XXIV, fig. 9); Cootabarlow Bore No. 2 at 1,469-70 ft, D302/S76b/1-2 23·6 112·6 (P22146); (f) *Tsugaepollenites* cf. *T. segmentatus* (Balme); section showing equatorially monosaccate, two-layered exine which encloses small vesiculae in the polar regions (see also Pl. XXIV, fig. 16); Cootabarlow Bore No. 2 at 1,469-70 ft, D302/S76a/1-2 39·1 116·1 (P22150).

DIMENSIONS: Equatorial diameter; overall 45 (65) 86 μ, spore cavity 34 (47) 65 μ. Polar diameter (2 specimens) 34 μ, 48 μ. Width of zona 5-14 μ; diameter of distal polar area 14-28 μ.

REMARKS: *Aequitriradites spinulosus*, as circumscribed by Cookson and Dettmann (1958b), is a broad type, and neither these authors nor the present writer have found any satisfactory criterion which may be used to subdivide the species into more restricted taxonomic units. Krasnova (in Samoilovitch et al. 1961) has proposed three varieties of the species—var. *spinulosus* (presumably, as it includes the holotype of the species), var. *hebatus*, and var. *planus*—but she has not demonstrated conclusively or defined the distinguishing characters of her three varieties.

It should be noted that of the spores illustrated on Plate 19 of Cookson and Dettmann's publication (1958b), only those depicted in fig. 1, 2, 5, 6, and 7 are representatives of *A. spinulosus*; specimens depicted in fig. 6 and 7 were incorrectly captioned (as *Styxisporites linearis* Cookson & Dettmann) in the accompanying plate explanation, and the one shown in fig. 6 is refigured by Potonié (1960; Pl. 4, fig. 69) under the same generic name. The specimen shown in fig. 3 and 4 is the holotype *Kraeuselisporites* (al. *Styxisporites*) *linearis* (see Cookson and Dettmann 1959d; present study, discussion of *K. linearis*).

COMPARISON: *A. spinulosus* is distinct from *A. variabilis* Pocock in its narrower zona and in having proximal sculpture; and from *A. acusus* (Balme) in having larger sculptural elements.

DISTRIBUTION: The species is widely distributed in E. Australia, but it has not been observed in samples from the lowest horizons of the Upper Mesozoic sequence in the Great Artesian Basin (see Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 4-9). Extra-Australian occurrences include Hauterivian-Danian of U.S.S.R. (Bolkhovitina 1959; Samoilovitch et al. 1961) and Valanginian-Barremian of Canada (Pocock 1962).

Aequitriradites tilchaensis (Cookson & Dettmann) Cookson & Dettmann 1961

(Pl. XXIII, fig. 1-3)

1958 *Cirratriradites tilchaensis* Cookson & Dettmann, p. 113; Pl. 18, fig. 7, 8.
1961 *Aequitriradites tilchaensis* (Cookson & Dettmann) Cookson & Dettmann, p. 427.

DIAGNOSIS: As given by Cookson and Dettmann (1958b, p. 113). The 'laesurae of the tetrad-scar' are the narrow, sometimes disconnected ridges of the tetrad mark, and the distal 'fovea' is the rupture (hilum) which may be developed in the polar, verrucate area.

DIMENSIONS: (8 specimens) Equatorial diameter; overall 42 (50) 58 μ, spore cavity 34 (40) 47 μ. Width of zona 3-7 μ; diameter of distal polar verrucate area 14-17 μ.

REMARKS AND COMPARISON: Proximal and distal foci of the holotype are depicted in Pl. XXIII, fig. 1, 2. *Aequitriradites tilchaensis* (Cookson & Dettmann) differs from *A. verrucosus* (Cookson & Dettmann) and *A. dubius* Delcourt & Sprumont in its almost smooth proximal and equatorial exine, narrower zona, and smaller size.

DISTRIBUTION: Of rare occurrence in the Great Artesian and Otway Basins, South Australia (see Tables 4, 5, 7, 9). It has been recorded also from Albian strata of Queensland and New South Wales (Cookson and Dettmann 1958b).

Aequitriradites sp.

(Pl. XXII, fig. 14, 15)

Description: Microspores zonate, inaperturate or hilate; amb of spore cavity triangular with straight sides. Exine 2·5-3 μ thick; distal polar exine composed of discrete, polygonal-based (2-3 μ diameter), low (2 μ high) coni and may be ruptured (hilate); remainder of exine sculptured with small (1 μ basal diameter, 1-2 μ high), sparsely disposed spinules. Zona membraneous, 14-17 μ wide, irregular in outline. Tetrad mark occasionally present in form of narrow, low ridges which extend from equator to just beyond inner margin of zona.

Dimensions: (5 specimens) Equatorial diameter; overall 77 (86) 100 μ, spore cavity 64 (69) 78 μ. Diameter of distal polar area 13-15 μ.

Comparison: The five specimens referred to *Aequitriradites* sp. are distinct from *A. spinulosus* (Cookson & Dettmann) and *A. variabilis* Pocock in their distinctly triangular amb (of spore cavity), larger size, and more sparsely distributed spinules. Insufficient representatives have been obtained for the institution of a formally named species.

Distribution: Recovered from one sample only of the Blythesdale Group in the Great Artesian Basin, South Australia (see Table 8).

Genus **Couperisporites** Pocock 1962

Type Species: *Couperisporites complexus* (Couper) Pocock 1962.

Couperisporites tabulatus sp. nov.

(Pl. XXI, fig. 12-19; Fig. 6c)

Diagnosis: Microspores inperturate or hilate, biconvex; amb roundly triangular to subcircular. Sclerine two-layered; consisting of a thin (1-2 μ thick), inner layer and an enveloping, 'zonate', outer layer. Outer layer 2-3 μ thick, scabrate; polar areas composed of hexagonal-based verrucae individually separated by narrow, deep channels. Proximal verrucate elements hollow, 2-5 μ in basal diameter, and *c.* 2 μ high; distal verrucae considerably lower (less than 1 μ high). Proximal surface occasionally with an irregular rupture (hilum) at and about the pole. Equatorial 'zona' 5-7 μ wide. Tetrad mark comprises three, low, narrow, radial ridges which extend from equator towards proximal pole. Inner layer bears impression of polar verrucae and tetrad mark.

Dimensions: (21 specimens) Equatorial diameter; overall 48 (64) 83 μ, spore cavity 42 (52) 67 μ.

Holotype: Preparation D289/2 53·1 119·9 P21985; Pl. XXI, fig. 12, 13. Distal aspect. Amb subtriangular, 76 μ in diameter. Sclerine 3 μ thick; 'zona' 6 μ wide. Proximal sclerine with hollow verrucae 2-5 μ in basal diameter. Tetrad mark consists of three, low, narrow, radial ridges 10 μ in length.

Locus Typicus: South Australia, Cootabarlow Bore No. 2 at 1,376-77 ft.

Remarks and Comparison: Transverse sections (Pl. XXI, fig. 17-19; Fig. 6c) show the stratified nature of the sclerine which is sometimes hilate proximally. *Couperisporites complexus* (Couper) possesses a two-layered, zonate, sclerine which may be hilate (see Pocock 1962; Pl. 6, fig. 91), but Couper's species differs from *C. tabulatus* sp. nov. in having spinose elements distally. *C. tabulatus* is distinct from *Selaginella elegans* Krasnova in having hexagonal-based verrucae which are restricted to the polar regions.

AFFINITY: The species shows some resemblance to the spores, which are hilate proximally, of the fossil *Naiadita lanceolata* Buchman (see Harris, T. M. 1938, Fig. 21, 22; present study, Appendix I; Pl. XXVII, fig. 9-11).

DISTRIBUTION: Recovered from a few samples of the Great Artesian Basin (see Tables 4, 6).

Genus **Rouseisporites** Pocock 1962

RESTATED DIAGNOSIS: Microspores inaperturate proximally; amb convexly triangular to circular. Sclerine two-layered; outer layer membraneous, sometimes loosely enveloping, zonate. Zona with a flask-shaped to conical invagination in each radial region. Distal surface with muroid ridges which may anastomose to form a reticulum; proximal surface smooth to reticulate. Tetrad mark which comprises three, radial ridges distinct or faintly represented.

TYPE SPECIES: *Rouseisporites reticulatus* Pocock 1962.

OTHER SPECIES:

(1) *Rouseisporites laevigatus* Pocock 1962. Occurrence: Canada; Barremian.
(2) *Rouseisporites triangularis* Pocock 1962. Occurrence: Canada; Barremian-Lower Aptian.
(3) *Rouseisporitese granospeciosus* (Delcourt & Sprumont) Delcourt, Dettmann, & Hughes 1963. Occurrence: Belgium; Wealden.
(4) *Rouseisporites* (al. *Cingulatisporites*) *simplex* (Cookson & Dettmann 1958, p. 110; Pl. 17, fig. 7, 8) comb. nov.
(5) *Rouseisporites radiatus* sp. nov.

The following forms may be comparable to *Rouseisporites*:

(1) *Divisisporites euskirchenensis* Thomson 1952. Potonié (1956) incorrectly cites this species as the type of *Divisisporites* Pflug.
(2) *Hymenozonotriletes bracteatus* Bolkhovitina 1959.
(3) *Hymenophyllum* aff. *australea* Willd.: Verbitskaya 1962.

REMARKS AND COMPARISON: Pocock (1962) fully recognized that the genus is characterized by a two-layered sclerine, the outer, zonate layer of which has invaginations in each radial region at the equator. *Rouseisporites* Pocock is further characterized by a proximally inaperturate sclerine and hollow muroid ridges distally (see Fig. 6d). The distal muroid ridges of several species now included within the genus were described erroneously by Delcourt and Sprumont (1955) and Cookson and Dettmann (1958b) as proximal laesurae.

At noted by Delcourt et al. (1963) *Rouseisporites* is distinct from *Zlivisporis* Pacltova and *Seductisporites* Chlonova in possessing invaginations in each equatorial, radial region.

AFFINITY: The genus is morphologically comparable to some of the spores found in the Ricciaceae and Clevaceae. In particular, the type species, *R. reticulatus* Pocock, closely resembles the spores of the living *Riccia beyrichiana* Hampe and *R. canaliculata* Hoffm. These modern hepatic spores possess an outer, zonate membrane which has invaginations in the equatorial, radial regions and hollow, muroid ridges distally (see Erdtman 1957, Fig. 241; Ladyzhenskaja 1961, Fig. 1). The distal ridges are considered to serve as potential apertures during spore germination, and it has been demonstrated conclusively that the spores of *Riccia* (Mich.) germinate distally (Duthie and Garside 1936, Udar 1957).

Rouseisporites reticulatus Pocock 1962

(Pl. XXIII, fig. 4-9; Fig. 6d)

1958 *Cingulatisporites euskirchensoides* Delcourt & Sprumont: Cookson & Dettmann (pars), p. 109; Pl. 17, fig. 5.
1962 *Rouseisporites reticulatus* Pocock, p. 53; Pl. 7, fig. 101-105.

DESCRIPTION: Microspores biconvex; amb subcircular to convexly triangular. Sclerine two-layered; consisting of a scabrate, inner layer, 1-1·5 μ thick, and an enveloping, membraneous, zonate, outer layer which is reticulate both distally and proximally. Zona membraneous, 3-6 μ wide, and with a flask-shaped invagination in each radial region at equator. Distal reticulum composed of membraneous, muroid ridges (2-3 μ high) which enclose hexagonal lumina 15-30 μ in maximum diameter; ridges higher and wider about the pole. Proximal reticulum smaller meshed; with low, narrow muri and circular to polygonal lumina 1-4 μ in maximum diameter. Faint tetrad mark comprising three, low, radial ridges, which terminate near the invaginations, is usually developed on the proximal surface.

DIMENSIONS: Equatorial diameter; overall 45 (61) 78 μ, spore cavity 39 (53) 67 μ.

REMARKS: Transverse sections confirm that the membraneous outer wall layer forms the zona and the surface reticula. The muroid ridges of the distal reticulum are hollow, and this feature is depicted both in section (Pl. XXIII, fig. 8, 9; Fig. 6d) and surface view (Pl. XXIII, fig. 5-7).

COMPARISON: The following specimens resemble *Rouseisporites reticulatus* Pocock, but none of them clearly show invaginations in the equatorial, radial regions:

(1) *Divisisporites euskirchenensis* Thomson (Thomson and Pflug 1952, p. 14; Pl. 1, fig. 6 (holotype): Chlonova 1961, p. 51; Pl. 5, fig. 32).
(2) *Hymenozonotriletes bracteatus* Bolkhovitina (Bolkhovitina 1959, p. 106; Pl. 4, fig. 65a, c: Chlonova 1961, p. 52; Pl. 5, fig. 33).

The species is readily distinguishable from *R. granospeciosus* (Delcourt & Sprumont) and *Seductisporites signifer* Chlonova in having a reticulate proximal surface together with a coarse-meshed, distal reticulum.

AFFINITY: The spores of *Riccia beyrichiana* Hampe are similar in overall construction to *Rouseisporites reticulatus*.

DISTRIBUTION: Pocock (1962) described the species from Barremian-Lower Albian strata of Canada, and Samoilovitch et al. (1961; Pl. XXVIII, fig. 15, Pl. XLII, fig. 9, 10) depict comparable specimens from Aptian-Albian and Turonian beds of Siberia. The species is widely distributed in E. Australia (Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 4-9); in the Great Artesian Basin it occurs in the upper horizons of the Blythesdale Group, throughout the Roma (Aptian) and Tambo (Albian) Formations, and in samples examined from the Winton Formation (?Cenomanian).

Rouseisporites simplex (Cookson & Dettmann) comb. nov.

(Pl. XXIII, fig. 10-12)

1958 *Cingulatisporites simplex* Cookson & Dettmann, p. 110; Pl. 17, fig. 7, 8.

DESCRIPTION: Microspores biconvex; amb convexly subtriangular to subcircular. Sclerine two-layered; inner layer 1·5-2·5 μ thick, scabrate. Membraneous outer layer forms a narrow (2-5 μ wide), delicate zona (which invaginates a flask-shaped depression in each radial region at equator) and three, radially orientated, muroid ridges distally. Distal muroid ridges 2-3 μ high; emanating from pole and extending to equator along bisectors of interradial surfaces. Proximal surface smooth or with a faint tetrad mark, the inconspicuous ridges of which terminate near the equatorial invaginations.

DIMENSIONS: Equatorial diameter; overall 42 (57) 77 μ, spore cavity 36 (51) 67 μ.

COMPARISON: *Rouseisporites simplex* (Cookson & Dettmann) resembles *R. triangularis* Pocock and two of the illustrated specimens of *Hymenozonotriletes bracteatus* Bolkhovitina (1959; Pl. 4, fig. 65d, e). However, the Australian species is readily distinguishable from both these forms in having a less conspicuous tetrad mark, shorter distal muroid ridges, and a more delicate outer layer which invaginates smaller depressions in the equatorial, radial regions. Both *R. laevigatus* Pocock and *R. granospeciosus* (Delcourt & Sprumont) differ from *R. simplex* in having more than three distal muroid ridges which usually bifurcate towards the equator. *R. reticulatus* Pocock has a reticulate surface pattern both proximally and distally.

DISTRIBUTION: The species shows wide lateral, and restricted vertical, distribution in the Upper Mesozoic of SE. Australia (Cookson and Dettmann 1958b; Dettmann 1959; present study, Tables 4-9); in the Oodnadatta bore it appears to be restricted to the Roma (Aptian) and Tambo (Albian) Formations.

Rouseisporites radiatus sp. nov.

(Pl. XXIII, fig. 13-17)

1958 *Divisisporites euskirchenensis* Thomson: Cookson & Dettmann, p. 98; Pl. 14, fig. 1.
1958 *Cingulatisporites euskirchensoides* Delcourt & Sprumont: Cookson & Dettmann (pars), p. 109; Pl. 17, fig. 4, 6.

DIAGNOSIS: Microspores biconvex; amb subcircular to convexly subtriangular. Sclerine two-layered; inner layer 2-2·5 μ thick, faintly scabrate. Enveloping outer layer membraneous, zonate; smooth proximally and with four to six, radially disposed, muroid ridges distally. Muroid ridges emanate from pole and bifurcate towards equator where they are reduced in height. Narrow zona with a conical invagination (2-3 μ in diameter) in each radial region at equator.

DIMENSIONS: Equatorial diameter; overall 42 (56) 73 μ, spore cavity 39 (50) 64 μ.

HOLOTYPE: Preparation D272/2 43·2 127·6 P22140; Pl. XXIII, fig. 15, 16. Proximal aspect. Amb convexly subtriangular, 73 μ in diameter. Membraneous outer layer zonate; with an invagination (*c.* 3 μ in diameter) in each radial region at equator and four, radially orientated, muroid ridges (up to 28 μ long) distally. Inner layer faintly scabrate, 2·5 μ thick.

LOCUS TYPICUS: South Australia, Penola Bore No. 1 at 2,380-90 ft.

REMARKS AND COMPARISON: The membraneous outer wall layer of this species is often imperfectly preserved, particularly in the equatorial regions. The species may be comparable to *Seductisporites signifer* Chlonova and the spores which Verbitskaya (1962) assigned to *Hymenophylllum* aff. *australea* Willd., but neither Russian form appears to possess conical invaginations in the radial regions at the equator. *Rouseisporites radiatus* sp. nov. is distinct from *R. granospeciousus* (Delcourt & Sprumont) which has a wider zona, thicker outer wall layer, and a more heavily sculptured inner wall layer; *R. laevigatus* Pocock has more muroid ridges which are considerably lower, and both *R. simplex* (Cookson & Dettmann) and *R. triangularis* Pocock have three only, muroid ridges.

DISTRIBUTION: The species is of common occurrence in certain horizons of the Great Artesian and Otway Basins (see Tables 4-7, 9).

ANTETURMA POLLENITES Potonié 1931

TURMA SACCITES Erdtman 1947

Subturma MONOSACCITES Chitaley emend. Potonié & Kremp 1954

Infraturma SACCIZONATI Bhardwaj 1957

Genus **Tsugaepollenites** Potonié & Venitz emend. Potonié 1958

1934 *Tsugaepollenites* Potonié & Venitz, p. 17.
1937 *Tsugaepollenites* Raatz, p. 15.
1953 *Zonalapollenites* Pflug (nom. nud.) in Thomson & Pflug, p. 66.
1958 *Tsugaepollenites* Potonié & Venitz emend. Potonié, p. 48.
1958 *Cerebropollenites* Nilsson, p. 72.
1961 *Callialasporites* Dev, p. 48.
1961 *Applanopsis* Döring, p. 112.
1961 *Triangulopsis* Döring, p. 113.
1962 *Pflugipollenites* Pocock, p. 72.

RESTATED DIAGNOSIS: Pollen grains monoscaccate equatorially, inaperturate; proximal tetrad mark which comprises three, radial ridges distinct or only faintly represented. Exine smooth to granulate, two-layered; exoexine and intexine attached about the polar regions, but separated from each other at the equator where they enclose one, encircling saccus or several, intercommunicating vesiculae. Exine of polar regions sometimes with considerably reduced vesiculae; distal polar exine usually slightly thinner than proximal polar exine.

TYPE SPECIES: *Tsugaepollenites igniculus* (Potonié) Potonié & Venitz 1934.

MESOZOIC SPECIES NOT PREVIOUSLY INCLUDED WITHIN TSUGAEPOLLENITES:

(1) *Tsugaepollenites* (al. *Zonalapollenites*) *dampieri* (Balme) comb. nov.
(2) *Tsugaepollenites* (al. *Zonalapollenites*) *segmentatus* (Balme) comb. nov.
(3) *Tsugaepollenites* (al. *Zonalapollenites*) *trilobatus* (Balme) comb. nov.
(4) *Tsugaepollenites* (al. *Callialasporites*) *monoalosporus* (Dev 1961, p. 48; Pl. 14, fig. 25) comb. nov. Occurrence: India; ? Aptian (after Arkell 1956).
(5) *Tsugaepollenites* (al. cf. *Callialasporites*) sp. Dev 1961, p. 49; Pl. 4, fig. 30, 31. Occurrence: India; ? Aptian (after Arkell 1956).
(6) *Tsugaepollenites* (al. *Applanopsis*) *lenticularis* (Döring 1961, p. 113; Pl. 16, fig. 9, 10) comb. nov. Occurrence: Germany; Upper Jurassic.
(7) *Tsugaepollenites* (al. *Triangulopsis*) *discoidalis* (Döring 1961, p. 114; Pl. 17, fig. 1-3) comb. nov. Occurrence: Germany; Upper Jurassic.
(8) *Tsugaepollenites* (al. *Pflugipollenites*) *lucidus* (Pocock 1962, p. 72; Pl. 12, fig. 185) comb. nov. Occurrence: Canada; Upper Jurassic.
(9) *Tsugaepollenites* (al. *Noeggerathiopsidozonaletes*) *undatus* (Lantz 1958b, p. 925; Pl. 4, fig. 43-45) comb. nov. Occurrence; Britain; Bathonian-Kimeridgian.
(10) *Tsugaepollenites* (al. *Aequitriradites*) *infrapunctatus* (Lantz 1958a, p. 36; Pl. 1, fig. 20) comb. nov. Occurrence: France; Purbeckian: Britain; Bathonian (after Lantz 1958b).
(11) *Tsugaepollenites* (al. *Cingulatisporites*) *dubius* (Couper 1958, p. 145; Pl. 24, fig. 3-5) comb. nov. Occurrence: Britain; Bajocian-Kimeridgian.
(12) *Tsugaepollenites* (al. *Inaperturopollenites*) *undulatus* (Weyland & Greifeld 1953, p. 44; Pl. 13, fig. 89, 90) comb. nov. Occurrence: Germany; Lower Senonian.

DISCUSSION AND COMPARISON: Potonié's (1931, 1958) and Potonié and Venitz's (1934) illustrations and descriptions of the type species indicate that the genus is characterized by a two-layered exine which is monosaccate equatorially and which encloses small vesiculae ('muri to warts' of Potonié 1958; see also Manum 1962, p. 45) in the polar region. Comparable morphological features are exhibited by the more recently established genera that are cited in the synonymy above.

The equatorial saccus of *Tsugaepollenites* Potonié & Venitz may be ± uniform in width (as in *T. dampieri*), or constricted at the equator and composed of several (for example, in *T. trilobatus*) to many (*T. mesozoicus* Couper), intercommunicating vesiculate protrusions. Small polar vesiculae are exhibited by some species included within the genus, and the proximal exine (which usually is thicker and patterned more conspicuously than the distal exine) sometimes exhibits a tetrad mark.

The genus may be similar in construction to the imprecisely known genera, *Tsugella* Maljavikina, *Zonalasporites* Ibrahim, and *Enzonalasporites* Leschik.

AFFINITY: Potonié (1958) compares the type species with the pollen of *Tsuga* Carr., and both Couper (1958) and Balme (1957) suggest that their Mesozoic species are of coniferous origin. Döring (1961) claims that his forms, *Applanopsis* and *Triangulopsis*, probably have derived from planktonic organisms, but there is no evidence for this relationship.

Tsugaepollenites dampieri (Balme) comb. nov.

(Pl. XXIV, fig. 1-5)

SELECTED SYNONYMY:

1957 *Zonalapollenites dampieri* Balme, p. 32; Pl. 8, fig. 88, 90 (? fig. 89).
1961 *Callialasporites dampieri* (Balme) Dev, p. 48; Pl. 4, fig. 26, 27.
1961 *Applanopsis dampieri* (Balme) Döring, p. 113; Pl. 16, fig. 11-15.
1962 *Pflugipollenites dampieri* (Balme) Pocock, p. 72 (? Pl. 12, fig. 183, 184).

DESCRIPTION: Grains monosaccate, biconvex; amb subcircular, sometimes undulate. Exine two-layered; consisting of a thin (*c.* 1·5 μ thick) intexine which is completely enclosed within a thicker (1·5-2 μ), granulate exoexine. Intexine and exoexine closely adherent in polar regions, but enclose a narrow saccus equatorially; saccus radially folded, slightly constricted in each radial region at equator. Tetrad mark absent or only faintly represented.

DIMENSIONS: Equatorial diameter; overall 53 (67) 80 μ, intexine 40 (53) 68 μ.

COMPARISON: *Tsugaepollenites dampieri* (Balme) is distinguishable from *T. lucidus* (Pocock) in having a narrower saccus which is radially folded. *T. dubius* (Couper) possesses a more prominent tetrad mark and has a thicker exine.

DISTRIBUTION: *T. dampieri* is widely distributed in Australasian sediments, with documented occurrences from the Jurassic, Cretaceous, and Eocene of Western Australia (Balme 1957); Lower Jurassic of Queensland (de Jersey 1959); and Aptian-Albian of Papua (Balme 1957). In SE. Australia the species is of infrequent occurrence in the Upper Mesozoic of the Great Artesian Basin, and rare in samples examined from the Otway and Murray Basins and E. Victoria (see Tables 3-9). Numerous extra-Australasian records indicate that the species is represented in Upper Mesozoic strata of India, Canada, and Europe.

Tsugaepollenites trilobatus (Balme) comb. nov.

(Pl. XXIV, fig. 6-10; Fig. 6e)

SELECTED SYNONYMY:

1957 *Zonalapollenites trilobatus* Balme, p. 33; Pl. 8, fig. 91, 92.
1961 *Callialasporites trilobatus* (Balme) Dev, p. 48; Pl. 4, fig. 28, 29.
1961 *Triangulopsis trilobatus* (Balme) Döring, p. 114; Pl. 17, fig. 4-8.
1962 *Pflugipollenites trilobatus* (Balme) Pocock, p. 73; Pl. 12, fig. 186, 187.

DESCRIPTION: Grains saccate, biconvex. Amb subtriangular; convex interradially and indented radially. Exine two-layered; intexine 1·5-2 μ thick, smooth to faintly patterned, and with a convexly triangular amb. Exoexine 2·5-3 μ thick, granulate; loosely envelops intexine, particularly at the equator where a trilobate, usually radially folded saccus is developed. Polar areas of exoexine inconspicuously vesiculate; low (*c.* 1 μ high) vesiculae polygonal (1-3 μ in diameter) in basal outline; distal polar exoexine thinner than proximal polar exoexine. Tetrad mark inconspicuous; consists of three, low, weakly sinuous ridges (2 μ wide) which extend from pole to equator.

DIMENSIONS: Equatorial diameter; overall 67 (76) 86 μ, intexine 42 (53) 64 μ. Maximum width of saccus 12-17 μ.

REMARKS AND COMPARISON: Transverse sections (Pl. XXIV, fig. 9, 10; Fig. 6e) show that the grains are saccate equatorially, and that the exoexine encloses small vesiculae in the polar regions. The species is clearly distinguishable from *Tsugaepollenites discoidalis* (Döring) in having a trilobate, radially folded saccus and low polar vesiculae. *T. trilobatus* (Balme) differs from *T. dampieri* (Balme) and *T. segmentatus* (Balme), the entexines of which are distinctly circular in equatorial outline.

DISTRIBUTION: Apparently widespread in Upper Mesozoic strata, with previous records from Upper Jurassic and Lower Cretaceous of Britain (Lantz 1958b, Hughes and Couper 1958), Germany (Döring 1961), and Western Australia (Balme 1957); from Middle and Upper Jurassic of Canada (Pocock 1962), and from Lower Cretaceous of India (Dev 1961). The species is of sporadic occurrence in the Upper Mesozoic samples from SE. Australia (see Tables 3-8).

Tsugaepollenites cf. **T. segmentatus** (Balme) comb. nov.

(Pl. XXIV, fig. 11-16; Fig. 6f)

1957 *Zonalapollenites segmentatus* Balme, p. 33; Pl. 8, fig. 91, 92.

DESCRIPTION: Grains biconvex; saccate equatorially, vesiculate in polar regions. Amb subcircular to broadly elliptical, usually irregularly indented. Exine two-layered; thin (*c.* 1 μ thick) intexine completely enclosed within a thicker (2-3 μ thick), proximally and distally attached, granulate exoexine; distal polar exoexine thinner than proximal exoexine. Equatorial saccus 5-14 μ wide and usually with intense, radially directed folds; polar vesiculae low (*c.* 1-2 μ high), circular to elongated in basal outline. Tetrad mark comprises three, radially orientated, sinuous ridges (2 μ wide) which extend from pole to equator.

DIMENSIONS: Equatorial diameter; overall 50 (64) 78 μ, intexine 40 (49) 59 μ.

REMARKS AND COMPARISON: Transverse sections (Pl. XXIV, fig. 15, 16; Fig. 6f) show that the exine is vesiculate both proximally and distally and saccate equatorially. The SE. Australian specimens are similar to *Tsugaepollenites segmentatus* (Balme) except that they possess a tetrad mark and are larger in size. The species may be comparable to *T. lenticularis* (Döring) the illustrated holotype of which, however, has a thicker intexine. *T. segmentatus* is distinct from *T. dampieri* (Balme) in having polar vesiculae and a thicker exoexine which forms the more strongly folded and narrower equatorial saccus.

DISTRIBUTION: The species was described from Lower Jurassic strata, and doubtfully recorded in Upper Jurassic sediments of Western Australia (Balme 1957). It was recorded subsequently by de Jersey (1959) from Lower Jurassic coals of Queensland. The similar grains described above are of infrequent occurrence in samples from the Great Artesian and Otway Basins and E. Victoria (see Tables 3-8).

Subturma DISACCITES Cookson 1947

REMARKS: Four bisaccate species are recorded herein with little taxonomic comment. The dimensional terminology of Zauer (1954), Bolkhovitina (1956), and Pocock (1962) has been adopted (see Fig. 3).

It should be noted that the present writer has followed Pocock (1962) in using *Alisporites* Daugherty and *Podocarpidites* Cookson ex Couper which may or may not be comparable to *Pityosporites* Seward. The type specimen of the latter genus is preserved in equatorial aspect, and its distal polar features (including the nature, shape, and extent of the tenuitas or aperture) and the equatorial outline of the corpus and sacci are not precisely determinable. Manum (1960) recently redefined *Pityosporites*, and supported his generic emendation with new illustrations and descriptions of the type specimen; optical sections (loc. cit.; Pl. 1, fig. 1,2) of this specimen resemble polar sections of tenuate grains referred herein to *Podocarpidites* cf. *P. multesimus* (Bolkhovitina) (see Pl. XXV, fig. 16).

Genus **Alisporites** Daugherty 1941

TYPE SPECIES: *Alisporites opii* Daugherty 1941.

Alisporites grandis (Cookson) comb. nov.

(Pl. XXV, fig. 1-4)

SELECTED SYNONYMY:

1953 *Dissaccites grandis* Cookson, p. 471; Pl. 2, fig. 41.
1957 *Pityosporites grandis* (Cookson) Balme, p. 36; Pl. 10, fig. 110, 111.
1959 *Alisporites rotundus* Rouse, p. 316; Pl. 1, fig. 15, 16.

DIMENSIONS: Breadth; overall 78 (102) 136 μ, corpus 36 (53) 70 μ, saccus 31 (45) 62 μ. Length; corpus 56 (73) 97 μ, saccus 56 (71) 94 μ. Depth of corpus 39 (41) 45 μ.

REMARKS: In the light of Pocock's (1962) descriptions and illustrations there is now little doubt concerning the synonymy of *Alisporites rotundus* Rouse and *A. grandis* (Cookson).

DISTRIBUTION: The species is fairly common in almost all the samples examined (see Tables 3-9). It has been reported previously from the Upper Jurassic and Lower Cretaceous of Western Australia (Balme 1957) and Canada (Rouse 1959, Pocock 1962).

Alisporites similis (Balme) comb. nov.

(Pl. XXV, fig. 5-7)

1957 *Pityosporites similis* Balme, p. 36; Pl. 10, fig. 108, 109.

DIMENSIONS: Breadth; overall 45 (56) 67 μ, corpus 28 (34) 42 μ, saccus 17 (21) 25 μ. Length; corpus 31 (38) 45 μ, saccus 31 (38) 45 μ. Depth of corpus not determined.

DISTRIBUTION: The species occurs in the Upper Jurassic and Lower Cretaceous of Western Australia (Balme 1957), and shows wide distribution in SE. Australia (see Tables 3-9); it has not been observed in any samples examined from the Winton Formation (?Cenomanian) in the Great Artesian Basin.

Genus **Podocarpidites** Cookson ex Couper 1953

TYPE SPECIES: *Podocarpidites ellipticus* Cookson 1947.

Podocarpidites cf. **P. ellipticus** Cookson 1947

(Pl. XXV, fig. 8-12)

DIMENSIONS: Breadth; overall 50 (59) 75 μ, corpus 31 (38) 45 μ, saccus 17 (22) 28 μ. Length; corpus 28 (36) 50 μ, saccus 28 (37) 45 μ. Depth of corpus 25 (30) 38 μ.

REMARKS: Sections of a representative grain are shown on Pl. XXV, fig. 11, 12; these were cut parallel to the polar axis and obliquely both to the greatest breadth and the distal tenuitas of the grain.

DISTRIBUTION: Grains similar to Cookson's Kerguelen species, *Podocarpidites ellipticus*, are reported as usually abundant in Jurassic and Lower Cretaceous strata of Western Australia (Balme 1957), and are common in the Upper Mesozoic of SE. Australia (see Tables 3-9).

Podocarpidites cf. **P. multesimus** (Bolkhovitina) Pocock 1962

(Pl. XXV, fig. 13-16)

DIMENSIONS: Breadth; overall 64 (82) 117 μ, corpus 36 (46) 62 μ, saccus 28 (39) 59 μ. Length; corpus 30 (45) 67 μ, saccus 45 (60) 83 μ. Depth of corpus 28 (31) 36 μ.

REMARKS: The SE. Australian grains are similar to those described by Pocock (1962) but show a considerably greater size range. A section which has been cut parallel to both the polar axis and the greatest breadth of the grain is shown in Pl. XXV, fig. 16.

DISTRIBUTION: The species is known from the Lower Cretaceous of Russia (Bolkhovitina 1956), and from Lower and Upper Cretaceous strata of Canada (Rouse 1957, Pocock 1962). The similar grains recorded herein are of infrequent occurrence in the Upper Mesozoic of SE. Australia (see Tables 3-9).

Subturma POLYSACCITES Cookson 1947

Genus **Microcachyridites** Cookson ex Couper 1953

TYPE SPECIES: *Microcachyridites antarcticus* Cookson 1947.

Microcachyridites antarcticus Cookson 1947

(Pl. XXVI, fig. 1-5)

DIMENSIONS: Breadth; overall 28 (44) 56 μ, corpus 26 (37) 45 μ, saccus 11 (15) 20 μ. Length; corpus 26 (37) 45 μ, saccus 14 (24) 28 μ. Depth of corpus 20 (25) 31 μ.

REMARKS: Sections cut parallel to the polar axis of a grain are shown on Pl. XXVI, fig. 4, 5.

DISTRIBUTION: A widely distributed species in Australasian strata. Couper (1953, 1960) records it as ranging from Lower Cretaceous to Oligocene in New Zealand, and in Western Australia it ranges from Middle Bajocian to Eocene. In E. Australia the species is common in Upper Mesozoic strata (see Tables 3-9), and extends into the Oligocene (Cookson and Pike 1954).

Genus **Podosporites** Rao 1943

TYPE SPECIES: *Podosporites tripakshi* Rao 1943.

Podosporites microsaccatus (Couper) comb. nov.

(Pl. XXVI, fig. 6, 7)

1953 *Dacrydium microsaccatum* Couper, p. 35; Pl. 4, fig. 38.
1953 *Trichotomosulcites subgranulatus* Couper, p. 64; Pl. 8, fig. 127, 128.
1954 *Trisaccites micropterus* Cookson & Pike, p. 64; Pl. 2, fig. 21-29.
1957 *Podosporites micropterus* (Cookson & Pike) Balme, p. 34; Pl. 9, fig. 101-103.
1960 *Trisaccites microsaccatum* (Couper) Couper, p. 46; Pl. 4, fig. 12, 13.

Dimensions: Corpus diameter 25 (34) 45 μ. Saccus; breadth 5 (7) 11 μ, length 11 (20) 28 μ.

Distribution: In E. Australia the species is known from Upper Mesozoic (see Tables 3-9) and early Tertiary strata (Cookson and Pike 1954). Other recorded occurrences include Bajocian-Aptian of Western Australia (Balme 1957) and Albian-Maastrichtian of New Zealand (Couper 1953, 1960).

Turma PLICATES Naumova 1939

Subturma Monocolpates Iversen & Troels-Smith 1950

Genus **Ginkgocycadophytus** Samoilovitch 1953

Type Species: *Ginkgocycadophytus caperatus* (Luber) Samoilovitch 1953.

Ginkgocycadophytus nitidus (Balme) de Jersey 1962

(Pl. XXVI, fig. 8, 9)

1957 *Entylissa nitidus* Balme, p. 30; Pl. 6, fig. 78-80.
1962 *Ginkgocycadophytus nitidus* (Balme) de Jersey, p. 12; Pl. 5, fig. 1-3.

Description: Grains tenuate distally; amb elliptical. Tenuitas extending full length of grain; broader at equator than at pole. Exine 1 μ thick, smooth to faintly scabrate.

Dimensions: Equatorial diameter; length 34 (44) 56 μ, breadth 14 (26) 36 μ.

Remarks: The SE. Australian specimens are identical to the type and other specimens which are illustrated by Balme (1957) and which are 33-46 μ in length and 19-26 μ in breadth (cf. the size range quoted by Balme 1957, p. 30). The species is similar to many of the Mesozoic grains that have been attributed to *Monosulcites minimus* Cookson; the holotype of Cookson's species (1947; Pl. 15, fig. 48) has a convexly elliptical tenuitas, and is distinct from *Ginkgocycadophytus nitidus* (Balme).

Distribution: Apparently widespread in Australian Jurassic and Cretaceous sediments, with previous records from Lower Jurassic-Lower Cretaceous of Western Australia (Balme 1957) and Lower Mesozoic of Queensland (de Jersey 1959, 1962). The species is represented in almost all the Upper Mesozoic samples examined from SE. Australia (see Tables 3-9).

Turma POROSES Naumova emend. Potonié 1960

Subturma Monoporines Naumova 1939

Genus **Classopollis** Pflug emend. Pocock & Jansonius 1961

Type Species: *Classopollis classoides* Pflug emend. Pocock & Jansonius 1961.

Discussion: Following a review of the literature, and after an examination of European and Canadian specimens attributable to *Classopollis classoides* Pflug, Pocock and Jansonius (1961) emended the diagnosis of *Classopollis* Pflug. Furthermore, these authors concluded that the type species is specifically distinct from previously described species assignable to *Classopollis*. However, they note in an addendum to their paper that *Corollina* Maljavikina has priority over *Classopollis* if the two genera are proven identical.

The genus shows world-wide distribution in Mesozoic sediments with earliest known occurrences in Rhaetic strata (Chaloner and Clarke 1962); the Permian species, *C. belloyensis* Pocock & Jansonius, is considered by Chaloner and Clarke (1962) to be closely allied to *Vittatina* Luber.

AFFINITY: Couper (1953, 1958) demonstrated that *Classopollis* and the pollen grains associated with *Pagiophyllum connivens* Kendall are similar in morphology. Pocock and Jansonius (1961, p. 448) suggest that species of *Cheirolepis* Schimper, *Brachyphyllum* Brongn., and *Pagiophyllum* Heer may have 'produced *Classopollis*-type pollen'.

Classopollis cf. **C. classoides** Pflug emend.
Pocock & Jansonius 1961

(Pl. XXVI, fig. 10-14)

DIMENSIONS: Equatorial diameter 31 (39) 50 μ; polar diameter 25 (31) 39 μ.

REMARKS: Except for their larger size the SE. Australian specimens conform with Pocock and Jansonius' (1961, p. 443) definition of *Classopollis classoides* Pflug. The surface pattern of the 'belt averaging 9 microns in width surrounding the equator' comprises a series of narrow channels which parallel the equator and which are connected by short, transverse channels (see Chaloner and Clarke 1962; Pl. 80, fig. 2-4: present study, Pl. XXVI, fig. 13). Well preserved specimens recovered in the present investigation show that the proximal pole is enclosed within a cone composed of minute, petal-like, exinal elements (se Pl. XXVI, fig. 11, 12, 14).

DISTRIBUTION: This form is widly dispersed in Upper Mesozoic sediments of SE. Australia (see Tables 3-9).

TURMA ALETES Ibrahim 1933

Subturma AZONALETES Luber emend. Potonié & Kremp 1954

Genus **Araucariacites** Cookson ex Couper 1953

TYPE SPECIES: *Araucariacites australis* Cookson 1947.

Araucariacites australis Cookson 1947

(Pl. XXVI, fig. 15)

DIMENSIONS: 50 (68) 91 μ in maximum diameter.

AFFINITY: Cookson (1947) and Cookson and Duigan (1951) compared Kerguelen and Australian Tertiary *Araucariacites australis* Cookson with pollen from fossil and modern araucariacian species. Couper (1958) has shown that British Mesozoic specimens of the species are comparable to grains of the Jurassic *Brachyphyllum mamillare* Brongn.

DISTRIBUTION: Described from Lower Tertiary lignites of Kerguelen (Cookson 1947), and widely reported in Mesozoic and Tertiary strata from other parts of the world. The species is widely distributed in the Upper Mesozoic of SE. Australia (see Tables 3-9).

Genus **Spheripollenites** Couper 1958

TYPE SPECIES: *Spheripollenites scabratus* Couper 1958.

Spheripollenites psilatus Couper 1958

(Pl. XXVI, fig. 16, 17)

DIMENSIONS: Diameter 20 (28) 36 μ.

DISTRIBUTION: Described from Wealden and Aptian sediments of Britain (Couper 1958), and recorded herein from the Upper Mesozoic of SE. Australia (see Tables 3-9).

INCERTAE SEDIS

Genus **Schizosporis** Cookson & Dettmann 1959

TYPE SPECIES: *Schizosporis reticulatus* Cookson & Dettmann 1959.

REMARKS: There is now little doubt that both *Ovoidites* Potonié ex Krutzsch and *Schizosporis* Cookson & Dettmann incorporate spheroidal to ellipsoidal spores which separate into two approximately equal parts along a line of weakness at the equator. *Ovoidites* was introduced by Potonié in 1951, but the genus remained invalid until April 1959 (Krutzsch 1959, p. 249) when Cookson and Dettmann validly instituted *Schizosporis*. The latter name is retained by the present writer for the Mesozoic spores described below.

Cookson and Dettmann (1959b) noted that *Schizosporis* resembles certain Mesozoic species which Bolkhovitina (1956; see also 1959) attributed to *Psophosphaera* Naumova, and similar Mesozoic spores have been described under the name *Planorbina* Maljavikina (1949). Alete spores which split equatorially are known also from the Carboniferous, and these spores have been assigned to *Retialetes* Staplin.

Schizosporis reticulatus Cookson & Dettmann 1959

(Pl. XXVI, fig. 20, 21)

DIMENSIONS: Equatorial diameter 94 (132) 172 μ.

DISTRIBUTION: Widely distributed in the Upper Mesozoic of E. Australia (Cookson and Dettmann 1959b; present study, Tables 4-9). The species is known also from Upper Neocomian beds of Canada (Pocock 1962).

Schizosporis rugulatus Cookson & Dettmann 1959

(Pl. XXVI, fig. 22, 23)

1959 *Schizosporis rugulatus* Cookson & Dettmann, p. 216; Pl. 1, fig. 5-9.
1962 non *Schizosporis rugulatus* Cookson & Dettmann: Pocock, p. 76; Pl. 13, fig. 203, 204.

DIMENSIONS: (8 specimens) Equatorial diameter 86 (96) 108 μ.

TABLE 3

Distribution of spore and pollen species in samples from the lowermost parts of the Mesozoic sequences intersected in Cootabarlow Bore No. 2 and Penola Bore No. 1. In the core samples that yielded sufficiently well-preserved microfloras, constituent species are recorded as percentages which are based on individual counts of 250 specimens. 'X' indicates observed presence in a particular sample, but not in actual count; 'cf' indicates presence of specimens similar to, but not identical with, a particular species.

OTWAY BASIN	GREAT ARTESIAN BASIN						
PENOLA BORE No.1	COOTABARLOW BORE No.2						
4766-76 ft	1471-72 ft	1469-70 ft	1465-68 ft	1447-64 ft	1447 ft		
5.3	0.6	3.3	3.3	X	X	Cyathidites australis	LAEVIGATI
5.3	6.0	3.3	6.6		0.6	C. minor	
	X	X			X	C. asper	
	0.6	0.6	X			C. concavus	
	8.0	3.3	3.3	X	2.0	Stereisporites antiquasporites	
X						Biretisporites cf. B. potoniaei	
	X	X	X			B. spectabilis	
0.6	X	2.0	2.0	X	X	Dictyophyllidites crenatus	
2.0			0.6	X		Leptolepidites verrucatus	APICULATI
11.3	2.6	2.0	3.3	X	0.6	Osmundacidites wellmanii	
8.0	3.3	8.0	12.6	X	4.6	Baculatisporites comaumensis	
X	0.6	X	1.3	X	1.3	Neoraistrickia truncatus	
2.0	2.0	2.0	3.3	X	X	Ceratosporites equalis	
	X	X	0.6	X		Lycopodiacidites asperatus	MURORNATI
		X	X	X		Tripartina cf. T. variabilis	
	X	X	X	X	X	Cyclosporites hughesi	
X	X	X	X	X	X	Foveotriletes parviretus	
	X	0.6	X		X	Foveosporites canalis	
1.3	4.0	2.0	6.6	X	X	Lycopodiumsporites austroclavatidites	
X	X	X	X	X	X	L. circolumenus	
1.3	2.6	2.0	6.0	X	1.3	L. reticulumsporites	
X	2.0	X	2.6	X	0.6	L. eminulus	
X	X	X	X	X	X	L. nodosus	
		X				L. facetus	
	X	0.6	1.3	X		Reticulatisporites pudens	
			X			Klukisporites scaberis	
	X		X	X	X	Dictyotosporites complex	
	X					Cicatricosisporites australiensis	
		X			0.6	Matonisporites cooksoni	AURICULATI
	X	X	X	X		Ischyosporites punctatus	
0.6	6.0	3.3	8.0	X	2.0	Gleicheniidites cf. G. cercinidites	TRICRASSATI
	X			X		Sestrosporites pseudoalveolatus	
X	X	X	0.6	X	X	Coronatispora perforata	
	0.6	0.6	0.6		0.6	Cingutriletes clavus	CINGULATI
		X	X	X	X	Murospora florida	
		X	X		X	Contignisporites cooksonii	
		X				Kraeuselisporites linearis	
	cf	cf	cf	cf		Minerisporites marginatus	
X	0.6	0.6	X	X	X	Crybelosporites stylosus	PERINOTRILITES
X	X	X	X	X	X	Velosporites triquetrus	
		X	X	X	X	Densoisporites velatus	
X			X			Aequitriradites verrucosus	HILATES
		X				Reticuloidosporites arcus	MONOLETES
0.6	0.6	X	X	X		Tsugaepollenites dampieri	SACCITES
	X	X	X			T. trilobatus	
		X	X		X	T. cf. T. segmentatus	
6.6	3.3	4.6	10.6	X	6.0	Alisporites grandis	
X	2.6	1.3	1.3	X	1.3	A. similis	
5.3	16.0	14.0	6.6	X	11.3	Podocarpidites cf. P. ellipticus	
X	1.3	1.3	X			P. cf. P. multesimus	
	0.6	1.3	X	X	1.3	Podosporites microsaccatus	
4.6	22.0	30.6	10.0	X	18.6	Microcachyridites antarcticus	
6.6	2.6	1.3	2.6		0.6	Ginkgocycadophytus nitidus	PLICATES
X	4.0	7.3	2.6	X	4.6	Classopollis cf. C. classoides	POROSES
6.0	4.0	X	2.6	X	1.3	Araucariacites australis	ALETES
11.3	8.0	3.3	2.0	X	3.3	Spheripollenites psilatus	

COMPARISON: *Schizosporis rugulatus* Cookson & Dettmann shows finer sculpture and is larger in size than the Canadian spores which Pocock (1962) assigned to the species.

DISTRIBUTION: Recovered from the uppermost horizons of the Upper Mesozoic succession in the Great Artesian and Otway Basins (Cookson and Dettmann 1959b; present study, Tables 5-7, 9).

Schizosporis spriggi Cookson & Dettmann 1959

(Pl. XXVI, fig. 24)

DIMENSIONS: Equatorial diameter 67 (90) 111 μ.

COMPARISON: *Schizosporis grandis* Pocock is larger and ellipsoidal in shape.

DISTRIBUTION: The species is of infrequent occurrence, and shows wide distribution in the Upper Mesozoic of SE. Australia (Cookson and Dettmann 1959b; present study, Tables 4-9). It has been reported from Neocomian-Albian strata of Canada (Pocock 1962).

Schizosporis parvus Cookson & Dettmann 1959

(Pl. XXVI, fig. 18, 19)

DIMENSIONS: (10 specimens) Equatorial diameter; length 67 (77) 89 μ, breadth 37 (52) 45 μ. Polar diameter 31 (40) 53 μ.

COMPARISON: This species is characteristically ellipsoidal in shape and is distinct from the larger spheroidal spores of *Schizosporis spriggi* Cookson & Dettmann. *S. parvus* Cookson & Dettmann is distinct also from *S. cooksoni* Pocock which is smaller and has a thinner exine.

DISTRIBUTION: Reported from the upper horizons of the Upper Mesozoic sequences in the Otway and Great Artesian Basins (Cookson and Dettmann 1959b; present study, Tables 5-9), and from Upper Neocomian strata of Canada (Pocock 1962).

Microfloral Assemblages and Stratigraphical Applications

One of the purposes of the present investigation was to evaluate the stratigraphical value of the dispersed-spore species, described herein. and to utilize the spores in the correlation of SE. Australian Upper Mesozoic strata. As outlined below, three, successive, distinct microfloral assemblages are distinguishable in the partly marine sequence of the Great Artesian Basin and in deposits examined from elsewhere in SE. Australia. Each of the microfloral assemblages is characterized by distinctive species of restricted stratigraphical ranges and thus of considerable correlative value both within and without SE. Australia. Concomitant evidence for the ages of the microfloras is assessed.

In addition, quantitative analyses of the spore assemblages studied from cores and cuttings of the more comprehensively sampled bore sequences are presented. Although these analyses probably provide some information concerning the general composition of the contamporaneous flora, collecting has been insufficiently detailed to permit refined correlations on the basis of changes in abundance of constituent species (cf. Couper 1958).

THE MICROFLORAL SUCCESSION

The most comprehensive collections that have been available for study are from marine and non-marine strata intersected by Oodnadatta (Santos) Bore No. 1 and

				LAEVIGATI									APICULATI										MURORNATI									
			Cyathidites australis	C. minor	C. punctatus	C. asper	C. concavus	Stereisporites antiquasporites	Biretisporites cf. B. potoniaei	B. spectabilis	Dictyophyllidites crenatus	Leptolepidites verrucatus	L. major	Osmundacidites wellmanii	O. mollis	Baculatisporites comaumensis	Neoraistrickia truncatus	Ceratosporites equalis	Pilosisporites notensis	P. parvispinosus	Kuylisporites lunaris	Lycopodiacidites asperatus	Tripartina cf. T. variabilis	Cyclosporites hughesi	Foveotriletes parviretus	Foveosporites canalis	Lycopodiumsporites austroclavatidites	L. circolumenus	L. reticulumsporites	L. eminulus	L. nodosus	L. facetus
GREAT ARTESIAN BASIN	OODNADATTA BORE N°1	642 ft	1.3	4.6	X	X		24.6				X	X	X		3.3	1.3	3.3	X	X							0.6		1.3		X	X
		743 ft	1.3	4.0	1.3			21.3				X	X	2.0		6.6	X	8.6	X	X		X		0.6				X	2.6	X	2.0	X
		842 ft	8.0	9.3	0.6	X		14.0		X		2.6		X		4.6	X	4.3	X					1.3		0.6	4.6	X	3.6	0.6	X	X
		862 ft	3.3	6.6	X			24.0			1.3	1.3		1.3		3.3	X	2.6	X					X			2.0	X	0.6	2.0	X	X
		914 ft	2.6	6.6	X	X	X	14.0			1.3			0.6		2.0	1.3	2.0								X	4.6	X	1.3	1.3	X	0.6
		964 ft	0.6	6.6	X	X	X	6.0		X	0.6			X		2.6	0.6	3.3	X		X	0.6			X		3.6	X		2.0		X
		1052-61 ft.	X	X	X	X	X	X			X			X		X	X	X	X					X		X	X	X	X	X	X	X
		1087-92 ft	X	X	X		X	X			X	X	X	X		X	X	X	X						X	X		X	X	X	X	
		1147-52 ft	X	X	X	X	X									X		X	X								X	X	X	X		
		1213 ft	1.3	11.3				7.3			X	X				4.0	2.0	2.6	X			X	1.3		X	X	6.6	X	2.0			
		1227-32 ft	X	X			X	X				X	X	X	X	X	X	X	X				X	X			X	X	X	X	X	X
		1287-92 ft.	X	X				X			X		X										X	X			X			X	X	X
	COOTABARLOW BORE N°2	1330-48 ft	X	X	X	X	X	X			X	X		X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	
		1340 ft	0.6	4.6	X	X		4.6		X	X			X		8.0	0.6	2.6			X	X			X		2.0	X	0.6	2.6		
		1348-52 ft	X	X	X	X	X				X	X	X	X		X	X	X	X	X	X	X		X			X	X	X		X	
		1354 ft	4.6	5.3	0.6	1.3		2.0				X	X				3.3	0.6	1.3	X							X	0.6	X	X	X		
		1376-77 ft	7.3		X	X		4.6	0.6	X	0.6	X	X	1.3		12.0	2.0	4.0			X	X	X	X	2.0	0.6	3.3	X	3.3	0.6	0.6	
		1391-92 ft	8.0	2.0				9.3			0.6	2.0		0.6		9.3	0.6	2.0						X	X		3.3	X	2.6	0.6	0.6	
		1401-02 ft	5.3	4.0	0.6	X	2.0	4.0		X	X	X		2.6		14.0	0.6	2.0			X	X		X	X	X	4.0	0.6	3.3	0.6	X	
		1403-04 ft	X	X				X								X	X	X									X	X	X			X
OTWAY BASIN	PENOLA BORE N°1	2990-3000 ft	4.6	6.0	0.6	0.6		16.6	X		X	X		X		4.0		2.0	X	X							2.0	X	1.3	X	X	
		3180-90 ft	X	X				X				X				X		X	X		X						X		X			
		3363-73 ft.	12.0	14.0	X		0.6	12.0			0.6	0.6	X			1.3	2.6	X	X				0.6	X		X	2.0	X	4.0	4.6	0.6	X
		3614-24 ft	24.0	8.0	2.0		0.6	10.3	X		1.3	0.6	0.6			1.3	1.3	X	X	X			2.0	0.6	X		3.3	X	2.0	X	X	
		3715-21 ft	10.3	16.0			1.3	6.6			2.0	0.6	0.6			4.0	X	4.6	X	X	0.6			X	X		X		0.6	0.6		0.6
		3850-55 ft	20.3	7.3				30.3			1.0	X	X			3.0	2.0	1.6					0.6	X			2.3	X	3.0	2.0	0.3	
		4392 ft	2.6	10.0				6.6	0.6	X	0.6	3.3	0.6	0.6		20.0	3.3	4.6				X		X			4.0	0.6	3.3	1.3	0.6	X
		4618 ft	1.3	10.6				5.3	0.6	X	1.3	2.0	X	8.6		18.6	2.0	5.3						X	X		3.3	X	4.0	2.6	X	X
	ROBE BORE N°1	3325 ft.	12.0	13.6	X	X		9.6	X		X	0.6	X	2.3		6.0	0.3	1.0	X	X			1.0			X	2.6			0.3	0.3	X
		3500 ft	5.0	14.5	X	X		22.0	0.5		X	0.5	X	2.0	X	4.5	X	3.0	X				0.5				1.5			0.5	X	X
		3860 ft	15.0	5.0	X	X		5.6	X	X	1.6	1.6	X	0.3	X	6.3	X	3.0	0.3	X	0.3		0.6	X	0.3		4.6	X	3.0	0.6	0.6	X
		4300 ft	10.3	6.3		X		15.3	X		6.6	0.3	X	X		5.3	X	2.3	0.3	X	X		0.6	0.3			2.3	X	1.3	0.3	X	X

			MURORNATI											AURICULATI				TRICRASSATI				CINGULATI										PERINOTRILITES
			Reticulatisporites pudens	Klukisporites scaberis	Dictyotosporites speciosus	D. complex	D. filosus	Januasporites spinulosus	Staplinisporites caminus	Cicatricosisporites australiensis	C. ludbrooki	C. hughesi	Pyrobolospora reticulata	Matonisporites cooksoni	Trilobosporites purverulentus	Trilites cf. T. tuberculiformis	Ischyosporites punctatus	Gleicheniidites cf. G. circinidites	Sestrosporites pseudoalveolatus	Coronatispora perforata	T. telata	Cingutriletes clavus	Murospora florida	Foraminisporis wonthaggiensis	F. dailyi	F. asymmetricus	Contignisporites cooksonii	C. fornicatus	C. multimuratus	Kraeuselisporites linearis	Minerisporites marginatus	Crybelosporites striatus
GREAT ARTESIAN BASIN	OODNADATTA BORE N°1	642 ft	X			X				X							X	7.3				2.0		X		X						X
		743 ft	1.3	X	X	X	X			X				X				3.3	X						X	X	X			X			
		842 ft	1.3	X	0.6	X				0.6				X			X	2.6				X		X		X					
		862 ft	1.3		X					X								4.6				0.6			X						
		914 ft	3.3		X					X	X			0.6				4.6	X							X					
		964 ft			X	X				X				X	X	X	X	7.0							0.6		X			X		
		1052-61 ft.			X	X			X	X				X				X	X	X		X		X	X	X	X				
		1087-92 ft	X	X						X						X	X	X								X				X		
		1147-52 ft				X									X			X	X	X												
		1213 ft	1.3		X	X				X	X			0.6			X	12.6	X	X				X		?	X					
		1227-32 ft	X	X	X					X							X	X					X	X	?		X		X	X		
		1287-92 ft.	X			X											X	X		X											
	COOTABARLOW BORE N°2	1330-48 ft	X		X	X		X		X				X	X		X	X				X		X	X	X	X	X			cf	
		1340 ft	X		X					X				0.6	0.6	X	X	4.0				X		X	X	X	X				cf	
		1348-52 ft	X		X					X	X	X		X	X	X	X	X			X			X	X	X	X	X	X			
		1354 ft	X	X	X	X				0.6		X		X	X		X	8.0		X		X		0.6	X	1.3	X					
		1376-77 ft	X	X	0.6	X		0.6		X	0.6			X			1.3	1.3		X			X	X	1.3	X	X			X	cf	
		1391-92 ft	X							X								1.3						2.0	0.6		X				cf	
		1401-02 ft		0.6	X	X				X	0.6			X		0.6	0.6	2.0	X				X	X	X		X	X		X		
		1403-04 ft															X						X	X	X		X					
OTWAY BASIN	PENOLA BORE N°1	2990-3000 ft	X	X	X	X				2.6				X			X	0.6		X		3.3		X	X	0.6						0.6
		3180-90 ft		X	X					X			X											X		X					
		3363-73 ft.	X	0.6	0.6	X	X			0.6				X											0.6	X						
		3614-24 ft	0.6	X	1.3					X								0.6						X	X						
		3715-21 ft		X	X	X				1.3	0.6			X			X	2.0						0.6	X						
		3850-55 ft	0.3		1.6														6.0							X						
		4392 ft	0.6	1.3	X	X								X			X						0.6		X						
		4618 ft	1.3	X	X	X								X				0.6	X				X	X			X		X	X		
	ROBE BORE N°1	3325 ft.	0.3	X	X			X		1.0			X	X			X	X				X		X	0.3	0.3					cf	X
		3500 ft	X	0.5	X					1.0			X	X				0.5				0.5		X	X	X						1.0
		3860 ft	X	X	0.3	X			X	1.3	X			X			X	X		X			?	0.3	1.0					X	cf	
		4300 ft	1.3	1.6	X	X				0.3				X				X	X					0.3	0.3					X		

			PERINOTRILITES			HILATES										MONOLETES		SACCITES										PLICATES	POROSES	ALETES		INCERTAE SEDIS	
			C. punctatus	Velosporites triquetrus	Densoisporites velatus	Coptospora striata	C. sp. B	Cooksonites variabilis	Aequitriradites verrucosus	A. spinulosus	A. tilchaensis	Rouseisporites reticulatus	R. simplex	R. radiatus	Couperisporites tabulatus	Laevigatosporites ovatus	Reticuloidosporites arcus	Tsugaepollenites dampieri	T. trilobatus	T. cf. T. segmentatus	Alisporites grandis	A. similis	Podocarpidites cf. P. ellipticus	P. cf. P. multesimus	Podosporites microsaccatus	Microcachryidites antarcticus	Ginkgocycadophytus nitidus	Classopollis cf. C. classoides	Araucariacites australis	Spheripollenites psilatus	Schizosporis reticulatus	S. spriggi
GREAT ARTESIAN BASIN	OODNADATTA BORE N°1	642 ft			X							0.6						0.6			2.0	0.6	3.3		1.3	4.6	1.3	1.3	14.0	10.0		
		743 ft		X								X						X	X		10.0	0.6	6.0		X	4.3	2.6	1.3	3.3	5.3	X	X
		842 ft		X				X														8.0	0.6	6.6		X	3.6	1.3	X	7.3	4.6	X	X
		862 ft		X														0.6			5.3	1.3	10.6		X	6.0	3.3	0.6	6.6	4.0		
		914 ft		X														0.6	X		5.3		11.3		1.3	6.0	1.0	0.6	2.0	13.3		
		964 ft	0.6	X	X			X		X		X						X			4.6	2.0	7.3	X		5.3	0.6	6.0	1.3	16.6		X
		1052-61 ft.			X			X	X			X						X	X		X	X	X		X	X		X	X	X	X	
		1087-92 ft								X		X						X			X	X	X			X	X	X	X	X		
		1147-52 ft																														
		1213 ft		X	X					X									0.6	X	X	2.6	2.0	3.3	X		0.6	0.3	12.0	2.0	10.0	X	
		1227-32 ft			X					X		X						X	X		X	X	X	X	X	X	X	X	X	X		
		1287-92 ft.																X		X	X	X	X			X	X	X	X			
	COOTABARLOW BORE N°2	1330-48 ft			X				X	X		X	X					X	X	X	X	X	X	X		X	X	X	X	X	X	
		1340 ft										X	X							X	10.6	2.0	10.0	1.3	1.3	12.0	3.3	3.3	12.0	10.0		
		1348-52 ft		X	X				X	X		X						X			X	X	X	X	X	X		X	X	X		
		1354 ft	X	X	X				X	X		3.3					X	X	X	X	8.6	X	7.3		0.6	16.0	2.0	5.3	7.3	16.6		
		1376-77 ft		X	X			X	X	X		0.6	X		X					X	11.3	0.6	6.0		0.6	12.0	4.6	4.6	4.6	7.3	X	
		1391-92 ft			X				X			X	X		X			X	X		4.6	1.3	12.6	0.6	2.0	3.3	4.0	6.0	8.0	11.3		
		1401-02 ft		X	X						X		X	X					X		X	10.0	1.3	6.6			6.6	1.3	4.0	4.6	17.3		
		1403-04 ft										X										X	X			X		X		X		
OTWAY BASIN	PENOLA BORE N°1	2990-3000 ft		X		X	X		X	X		2.0	X	X							6.0	1.3	8.6	X	2.0	11.3	2.6	0.6	10.0	9.3		X
		3180-90 ft	X		X														X				X		X			X	X	X		
		3363-73 ft.			X							X									3.3	X	3.3	X	2.0	3.3	6.6	X		22.6		
		3614-24 ft		X					X			0.6						X			2.0	X	4.0		2.6	6.0	1.3	1.3	X	20.0		
		3715-21 ft						0.6	X	X	X	X				cf			X		5.3		10.3		0.6	10.3	2.6	1.3	3.3	8.6	X	X
		3850-55 ft		X												cf					6.6		3.3	X	2.0	3.6	0.3	0.6				
		4392 ft								X									X	X	5.3	1.3	9.3	X		4.6	4.6	0.6	4.0	6.6		
		4618 ft		X						X									X	X	4.0	2.0	7.3	0.6	0.6	2.0	6.0	2.0	6.0			
	ROBE BORE N°1	3325 ft.								X		0.6					X				2.3	X	9.3	X	2.3	9.6	1.6	0.3	1.6	11.3	X	
		3500 ft		X								0.5	X	X		cf					2.0	0.5	9.0	X	4.5	14.0	4.5	0.5	2.5	3.5	X	X
		3860 ft		X				X		X	X	X									2.0	0.3	11.0	X	0.6	7.3	3.3	1.3	X	19.6	X	X
		4300 ft		X					X												5.6	X	8.6	X	1.0	5.3	1.0	2.3	1.0	16.6	X	

TABLE 4

Distribution of spore and pollen species in Mesozoic samples (succeeding those documented in Table 3) from Cootabarlow Bore No. 2 and Penola Bore No. 1, and in samples from the lower parts of the Mesozoic sequences in Oodnadatta Bore No. 1 and Robe Bore No. 1. In the core and cutting samples that yielded sufficiently well-preserved microfloras, constituent species are recorded as percentages which are based on individual counts of 250 specimens. 'X' indicates observed presence in a particular sample, but not in actual count; 'cf' indicates presence of specimens similar to, but not identical with, a particular species; '?' denotes that only doubtful representatives of a species have been observed.

Corrigendum: In the list of species *T. telata* should read *C. telata*.

			LAEVIGATI								APICULATI										
			Cyathidites australis*	C. minor*	C. punctatus	C. asper*	Stereisporites antiquasporites*	Biretisporites cf. B. potoniaei	Dictyophyllidites crenatus	D. pectinataeformis	Leptolepidites verrucatus	L. major	Concavissimisporites penolaensis	Osmundacidites wellmanii*	Baculatisporites comaumensis*	Neoraistrickia truncatus	Ceratosporites equalis*	Pilosisporites notensis	P. parvispinosus	P. grandis	Kuylisporites lunaris
GREAT ARTESIAN BASIN	OODNADATTA BORE Nº1	87 ft	2.6	14.0		X	13.3								1.3		X				
		127 ft	X	X			X								X						
		167 ft	3.3	9.3		X	24.6				X			0.6	4.6	0.6	4.6				
		248 ft		9.3	1.3		18.0							X	1.3		X				
		327 ft	1.3	10.6	X	X	16.0								2.0		1.3			X	
		407 ft	2.0	5.3	0.6	X	22.0							0.6	X		X				
		447 ft	3.3	4.0	0.6	2.0	24.0				0.6			X	3.3	X	1.3		X	X	
		557 ft	2.0	2.0	X		25.3				X	X		0.6	8.0	X	2.0	X	X		
	COOTABARLOW BORE Nº2	581 ft	X	13.2	X	0.6	3.3							X	0.6		1.3		X	X	
		581-603 ft	X	X	X	X	X				X	X			X		X			X	
		660-80 ft	X	X	X	X	X								X		X			X	
		770-880 ft	X	X	X	X	X		X					X	X	X	X			X	X
		810-20 ft	X	X	X		X								X		X		X		
		1040-50 ft	X	X	X		X		X		X			X	X		X				
OTWAY BASIN	PENOLA BORE Nº1	1200-1210 ft	0.5	14.0		X	19.0								3.0						
		1400-1418 ft	4.0	21.5			10.5							1.0	18.0	1.0	1.5			X	
		1610-20 ft	3.3	12.3	X	1.3	7.3	X					X	2.6			X				
		1805-15 ft	4.3	21.0	0.6	X	2.6			X			X	1.0	6.3	X	0.3			X	
		2010-20 ft	4.0	15.5	X	1.0	12.5								6.0	X	1.5				X
		2200-2210 ft	X	X			X									X					
		2380-90 ft	2.0	9.0	4.3	X	6.6								2.3						
		2586-96 ft	2.0	5.3	0.6	8.6	12.6						X		X			X		0.6	
		2790-98 ft	0.6	8.0	0.6	1.3	30.6					X	X	X	5.3		0.6	X	X		
	ROBE BORE Nº1	1400 ft	3.8	17.0	X	3.6	X	1.3		X			X							0.3	
		1780 ft	2.6	7.3	X	0.6	5.6	5.3			X			1.3	5.0	X	X			X	
		2325 ft	4.5	9.0	X	X	4.5	3.0			X			0.5	0.5		X				
		2630 ft	3.5	7.5	0.5	X	7.0				X			1.5	5.5	X	1.0		X		

			MURORNATI																							
			Lycopodiacidites asperatus	Tripartina cf. T. variabilis*	Foveotriletes parviretus	Foveosporites canalis	Lycopodiumsporites austroclavatidites*	L. circolumenus	L. reticulumsporites	L. eminulus	L. nodosus*	L. facetus	Reticulatisporites pudens	Klukisporites scaberis	Dictyotosporites speciosus	D. complex	D. filosus	Januasporites spinulosus	Cicatricosisporites australiensis*	C. ludbrooki	C. pseudotripartitus	C. hughesi*	Balmeisporites holodictyus*	B. tridictyus	Pyrobolospora hexapartita	P. reticulata
GREAT ARTESIAN BASIN	OODNADATTA BORE Nº1	87 ft					1.3		1.3										X			X				
		127 ft					X				X		X													
		167 ft	X				1.3			0.6		X		X		X							X			X
		248 ft					1.3												0.6			X				
		327 ft					1.3	0.6	X		X	X	1.3			X			X		X	X				
		407 ft					2.6		1.3										2.0			0.6	X			
		447 ft					2.0				X		1.3						2.0			0.6	X			
		557 ft					2.0		0.6	0.6	0.6	X	1.3	X					2.6			0.6				
	COOTABARLOW BORE Nº2	581 ft	0.6				0.6		0.6		X								X			0.6	X			X
		581-603 ft					X		X										X		X	X	X	X		
		660-80 ft					X		X			X							X		X	X	X			
		770-880 ft			X		X		X	X	X		X						X			X				
		810-20 ft					X	X	X		X		X						X			X		X		
		1040-50 ft	X	X	X		X		X		X		X	X					X		X	X			X	X
OTWAY BASIN	PENOLA BORE Nº1	1200-1210 ft		X			2.0		X										X							
		1400-1418 ft					9.0		2.5										3.5			X				
		1610-20 ft		0.3			0.3		X										1.3		X	51.6	X			
		1805-15 ft		X			1.0		X			X							19.3		X	22.0	X	X		X
		2010-20 ft				X	2.0		1.5	X									2.0				X			X
		2200-2210 ft					X												X							
		2380-90 ft					X						X					0.6	6.6				0.3			
		2586-96 ft							0.6										10.0				2.0			
		2790-98 ft		X			0.6		0.6	0.6	X		0.6		X		X		10.0	1.3		X	X		X	X
	ROBE BORE Nº1	1400 ft	X	X			0.3												3.0			X	0.6	X	X	X
		1780 ft				X	3.0		2.3			X							1.0			X	X	X	X	X
		2325 ft		0.5		0.5	1.0		X										2.0							
		2630 ft	X				1.0		1.5	X			X	X		X			14.0				X			

			AURICULATI						TRI-CRASSATI			CINGULATI								PERINO-TRILITES			
			Matonisporites cooksoni	Trilobosporites trioreticulosus	T. purverulentus	T. tribotrys	Trilites cf. T. tuberculiformis*	Ischyosporites punctatus	Gleicheniidites cf. G. circinidites*	Sestrosporites pseudoalveolatus	Coronatispora telata	Cingutriletes clavus	Foraminisporis wonthaggiensis*	F. dailyi*	F. asymmetricus	Contignisporites glebulentus	C. fornicatus	Kraeuselisporites majus	Minerisporites marginatus	Crybelosporites striatus*	C. punctatus	Velosporites triquetrus*	Densoisporites velatus
GREAT ARTESIAN BASIN	OODNADATTA BORE Nº1	87 ft							21.3			2.0	X	X	X		X			X		X	
		127 ft							X														
		167 ft							11.3			0.6			X								
		248 ft		X			X		21.3			X			X					1.3	X		
		327 ft		X					22.0			0.6	X	X	X			X		X			
		407 ft		X					14.6				0.6		0.6			X					
		447 ft		X			X		10.6			1.3	X	X	X	X				X			
		557 ft							2.6				1.3		X	X				1.3			
	COOTABARLOW BORE Nº2	581 ft	X	X			X		20.0			X	X	X	X			X		0.6		X	X
		581-603 ft	X	X			X	X	X			X		X	X	X				X			
		660-80 ft	X	X	X	X	X	X	X			X	X	X	X	X	X	X		X			X
		770-880 ft	X	X			X	X	X			X	X	X	X			X		X	X		
		810-20 ft					X	X	X			X	X	X	X			X		X			
		1040-50 ft							X			X	X	X	X			X		X	X		
OTWAY BASIN	PENOLA BORE Nº1	1200-1210 ft							0.5	0.5		0.5	X		0.5			X		X			
		1400-1418 ft										2.5	0.5		X			0.5		1.5			
		1610-20 ft							3.3									X		0.3			
		1805-15 ft	4.0	X		X			0.6					X	1.3	X		X		1.0			
		2010-20 ft	0.5						1.5			X	0.5	0.5	1.0			X		0.3			
		2200-2210 ft	X						X														
		2380-90 ft				X			0.5				1.3		1.0					0.3			
		2586-96 ft	0.6	X		X		1.3	2.0		X			0.6	2.0					X			
		2790-98 ft	X	X				0.6	1.3			12.0	0.6	0.6	X					0.6			
	ROBE BORE Nº1	1400 ft	1.6	X		X			3.3						X	X		X	X	8.3			
		1780 ft	X	X		X			2.0			0.3	X	X	5.0			0.6	X	2.3		X	
		2325 ft							1.5				X		X					X			
		2630 ft	0.5									X			X					0.5		X	

			HILATES									MONOLETES		SACCITES									PLICATES	POROSES	ALETES		INCERTAE SEDIS			
			Coptospora striata	C. paradoxa	C. sp. A	Aequitriradites verrucosus	A. spinulosus	A. tilchaensis	Rouseisporites reticulatus*	R. simplex	R. radiatus*	Laevigatosporites ovatus*	Microfoveolatosporis canaliculatus	Tsugaepollenites dampieri	T. trilobatus	T. cf. T. segmentatus	Alisporites grandis*	A. similis	Podocarpidites cf. P. ellipticus*	P. cf. P. multesimus	Podosporites microsaccatus*	Microcachryidites antarcticus*	Ginkgocycadophytus nitidus	Classopollis cf. C. classoides*	Araucariacites australis*	Spheripollenites psilatus	Schizosporis reticulatus*	S. rugulatus*	S. spriggi*	S. parvus*
GREAT ARTESIAN BASIN	OODNADATTA BORE Nº1	87 ft		0.6					X			1.3					1.3		7.3		0.6	11.3	4.0	0.6	2.0	4.0	X		X	X
		127 ft															X	X	X		X	X	X		X	X				
		167 ft								X				X			8.6	1.3	10.0			5.3	2.0		2.0	1.3	X			
		248 ft		X					X								3.3	X	5.3		3.3	4.0		0.6	4.6	10.0				
		327 ft		X					X	X								2.0	5.3			6.6		0.6	2.6	12.6	X			
		407 ft		1.3		X	X		X	X				X			2.0		10.0		0.6	12.0		X	1.3	7.3				
		447 ft		X		X	X		X	X							X	1.3	3.3	X	0.6	13.3	0.6	X	3.3	6.0				
		557 ft													X		8.6	3.3	11.3		0.6	9.3	0.6	X	4.6	3.3				
	COOTABARLOW BORE Nº2	581 ft		0.6		X	X		X	1.3	0.6		X				2.6	1.3	15.3		6.0	9.3		X	8.0	9.3	X	X	X	
		581-603 ft		X		X	X		X	X							X		X		X	X	X	X	X	X	X			X
		660-80 ft		X		X	X		X	X	X						X		X		X	X		X	X	X				X
		770-880 ft		X			X		X	X	X					X	X	X	X			X	X	X	X	X				
		810-20 ft		X					X					X			X	X	X		X	X	X	X	X	X	X			
		1040-50 ft		X		X	X		X			X	X				X	X	X		X	X	X	X	X	X				
OTWAY BASIN	PENOLA BORE Nº1	1200-1210 ft		0.5		X	X		X	0.5	0.5	X					1.5	1.5	13.5		1.5	12.0	4.0	0.5	4.0	13.5				
		1400-1418 ft					X					0.5					7.5	1.5	2.0			1.5	1.5	0.5	2.5	4.5	X			
		1610-20 ft		1.3		X			X	1.0	0.6	5.0					X		0.6			1.0			1.0	2.6				X
		1805-15 ft		X		X	1.0		X	0.3	0.6	0.6					X		2.6		0.3	0.6	X	X	2.0	4.6	X		X	X
		2010-20 ft		X		X	0.5		0.5	X	2.5	X					3.0	0.3	12.0	X	1.5	13.5	1.5	2.5	7.5	X				X
		2200-2210 ft										X							X							X				
		2380-90 ft	0.3	0.6		0.3	X		9.0	21.3	[illegible]						0.3		4.3		[illegible]	[illegible]	X	X		1.6				
		2586-96 ft		4.0		2.0			X	5.3	X								5.3		4.6	18.6		X	1.3	6.6				
		2790-98 ft		X		X	X		0.6	0.6	X						6.0	X	3.3		1.3	5.3		0.6	0.6	4.6				
	ROBE BORE Nº1	1400 ft		0.3		X	X	X	X	5.3	3.0	6.3						0.3	11.3		2.6	20.6	X	X		1.0		X	X	X
		1780 ft		X		X	X		1.0	0.3		X				X	2.6	X	8.6	X	2.6	17.0	0.3	2.3	7.0	6.0				X
		2325 ft		X		1.5	X		1.0	1.0	X						2.0	0.5	1.5	X	0.5	X	[illegible]	1.5	X	[illegible]				
		2630 ft	1.0	1.5	X		X		6.5	2.0	2.0	0.5				X	3.0	X	7.5	X	1.0	9.0	1.0	2.0	12.5	3.0				X

TABLE 5

*Distribution of spore and pollen species in samples (succeeding those documented in Table 4) from the upper parts of the Mesozoic sequences in Cootabarlow Bore No. 2, Oodnadatta Bore No. 1, Penola Bore No. 1, and Robe Bore No. 1. In the core and cutting samples that yielded sufficiently well-preserved microfloras, constituent species are recorded as percentages which are based on individual counts of 250 specimens. 'X' denotes observed presence in a particular sample, but not in actual count. Species marked * have been observed in samples (Haddon Downs Bore No. 5 between 452 ft 7 in. and 1,406 ft) of the Winton Formation in the Great Artesian Basin.*

Cootabarlow Bore No. 2 in the Great Artesian Basin and from two non-marine bore sequences (Penola Bore No. 1 and Robe Bore No. 1) in the Otway Basin. Tables 3, 4, and 5 list all the spore species present in samples from each of these bore sequences; wherever practicable, quantitative analyses based on counts of 250 specimens per sample are included. Tables 6 and 7, in which the species are arranged approximately in stratigraphical order of appearance, illustrate the microfloral succession in the bore sequences of the Great Artesian Basin and Otway Basin respectively. From these tables it will be seen that, although some of the species are ubiquitous, others possess restricted vertical distribution in each sedimentary basin. Certain of the distinctive species possessing restricted vertical distribution are diagnostic of the three microfloral categories here delineated. For convenience, these microfloral categories are named from their most consistently occurring diagnostic species. A detailed account of the three microfloral assemblages, and of their stratigraphical occurrence in the four bore sections is presented below.

THE STYLOSUS ASSEMBLAGE

This assemblage (see Tables 3 and 6) was identified in non-marine samples from the 1,447-72 ft interval in Cootabarlow Bore No. 2 and at 4,766-76 ft in Penola Bore No. 1. The Cootabarlow deposits are probable equivalents of the Blythesdale Group (Condon et al. 1960, Ludbrook 1963a) and underlie beds (at 1,354 ft) which have yielded Aptian foraminifera (N. H. Ludbrook, South Australian Department of Mines Palaeontological Report 14/56, 1956 unpublished). The sample from Penola Bore No. 1 was taken from the Mocamboro Member (Ludbrook 1963b).

The Stylosus Assemblage is characterized diagnostically by the consistently occurring species *Crybelosporites stylosus* sp. nov. in association with the following species that possess limited vertical distribution but which are not exclusive to the assemblage: *Cyclosporites hughesi* (Cookson & Dettmann), *Coronatispora perforata* sp. nov., *Murospora florida* (Balme), *Contignisporites cooksonii* (Balme), *Kraeuselisporites linearis* (Cookson & Dettmann), and *Biretisporites spectabilis* sp. nov.

The most abundant forms present in the assemblage are *Microcachyridites antarcticus* Cookson and *Podocarpidites* cf. *P. ellipticus* Cookson, while the following species occur commonly: *Classopollis* cf. *C. classoides* Pflug, *Spheripollenites psilatus* Couper, *Araucariacites australis* Cookson, *Ginkgocycadophytus nitidus* (Balme), *Alisporites grandis* (Cookson), *Gleicheniidites* cf. *G. cercinidites* (Cookson), *Lycopodiumsporites austroclavatidites* (Cookson), *L. reticulumsporites* (Rouse), *Baculatisporites comaumensis* (Cookson), *Osmundacidites wellmanii* Couper, *Stereisporites antiquasporites* (Wilson & Webster), *Cyathidites australis* Couper, and *C. minor* Couper.

Species which are of rarer occurrence include: *Cyathidites asper* (Bolkhovitina), *C. concavus* (Bolkhovitina), *Foveosporites canalis* Balme, *Foveotriletes parviretus* (Balme), *Reticulatisporites pudens* Balme, *Cicatricosisporites australiensis* (Cookson), *Cingutriletes clavus* (Balme), *Aequitriradites verrucosus* (Cookson & Dettmann), *Tsugaepollenites dampieri* (Balme), and *T. trilobatus* (Balme).

The Stylosus Assemblage is closely comparable to Western Australian Lower Cretaceous microspore assemblages (Mircoflora IIB of Balme 1957). Although the precise age limits of Microflora IIB have not been determined, it was recorded only in Neocomian-Aptian strata. The Western Australian Neocomian-Aptian microflora is characterized diagnostically, and distinguishable from Oxfordian-Kimeridgian assemblages, by an abundance of *Microcuchyridites antarcticus* and rarity of

Tsugaepollenites dampieri, together with species such as *Reticulatisporites pudens, Cicatricosisporites australiensis, Foveotriletes parviretus*, and *Murospora florida*. The Stylosus Assemblage possesses all these characteristics and, further, lacks all the diagnostic components of Western Australian Oxfordian-Kimeridgian assemblages.

One of the constituent species, *Cicatricosisporites autraliensis*, occurs in Lower Cretaceous strata of Queensland and Papua and has not been reported in definite Jurassic strata in Australasia. It is known also from Lower Cretaceous only of India (Vishnu-Mittre 1955, and cf. Arkell 1956, p. 383), Russia (Bolkhovitina 1961), and Canada (Pocock 1962), and in England it occurs in uppermost horizons of the Purbeck (Lantz 1958b).

Cyathidites asper is reported from Berriasian-Aptian deposits of Canada (Pocock 1962), and in the U.S.S.R. it appears to be typically represented in Lower Cretaceous strata (see Bolkhovitina 1961, p. 87).

Aequitriradites verrucosus occurs exclusively in the Cretaceous of Siberia (Bolkhovitina 1959, Samoilovitch et al. 1961, Chlonova 1961).

Horizons immediately succeeding those from which the Stylosus Assemblage has been recovered contain several species which, in other parts of the world, first appear in Valanginian or younger strata.

Thus, from the available evidence it appears that the Stylosus Assemblage is post-Kimeridgian and Valanginian or older in age; the presence of *Cicatriocosisporites australiensis* and *Aequitriradites verrucosus* supports a Lower Cretaceous rather than an Upper Jurassic age.

THE SPECIOSUS ASSEMBLAGE

This assemblage (see Tables 4, 6, and 7) has been identified in samples which immediately succeed those containing the Stylosus Assemblage in Cootabarlow Bore No. 2 and Penola Bore No. 1 and in the lower intervals of Oodnadatta Bore No. 1 and Robe Bore No. 1 as follows: Oodnadatta Bore No. 1 between 642 ft and 1,292 ft; Cootabarlow Bore No. 2 between 1,330 ft and 1,404 ft; Penola Bore No. 1 between 2,990 ft and 4,618 ft; and Robe Bore No. 1 between 3,325 ft and 4,300 ft.

The interval in the Oodnadatta Bore includes horizons of the Blythesdale Group (1,007-1,292 ft) and the Roma Formation (642-1,007 ft) which is Aptian in age (Sprigg in Glaessner and Parkin 1958); more precise age determinations based on the evolutionary series of *Maccoyella* have not yet been published. In Cootabarlow Bore No. 2 the strata intersected between 1,390 ft and 1,404 ft are believed to be within the Blythesdale Group (Condon et al. 1960, Ludbrook 1963a) and the sample from 1,354 ft is dated as Aptian on the basis of foraminifera (N. H. Ludbrook, unpublished). Microplankton assemblages have been reported from 1,052-61 ft in the Oodnadatta Bore and at 1,354 ft in Cootabarlow Bore No. 2 (Cookson and Eisenack 1960b; Eisenack and Cookson 1960); the age evidence presented by these authors is in agreement with the palaeontological findings cited above.

The Penola Bore sediments include probable equivalents of the Mocamboro Member (4,200-4,618 ft) and the Runnymede Formation (2,990-4,200 ft) and the

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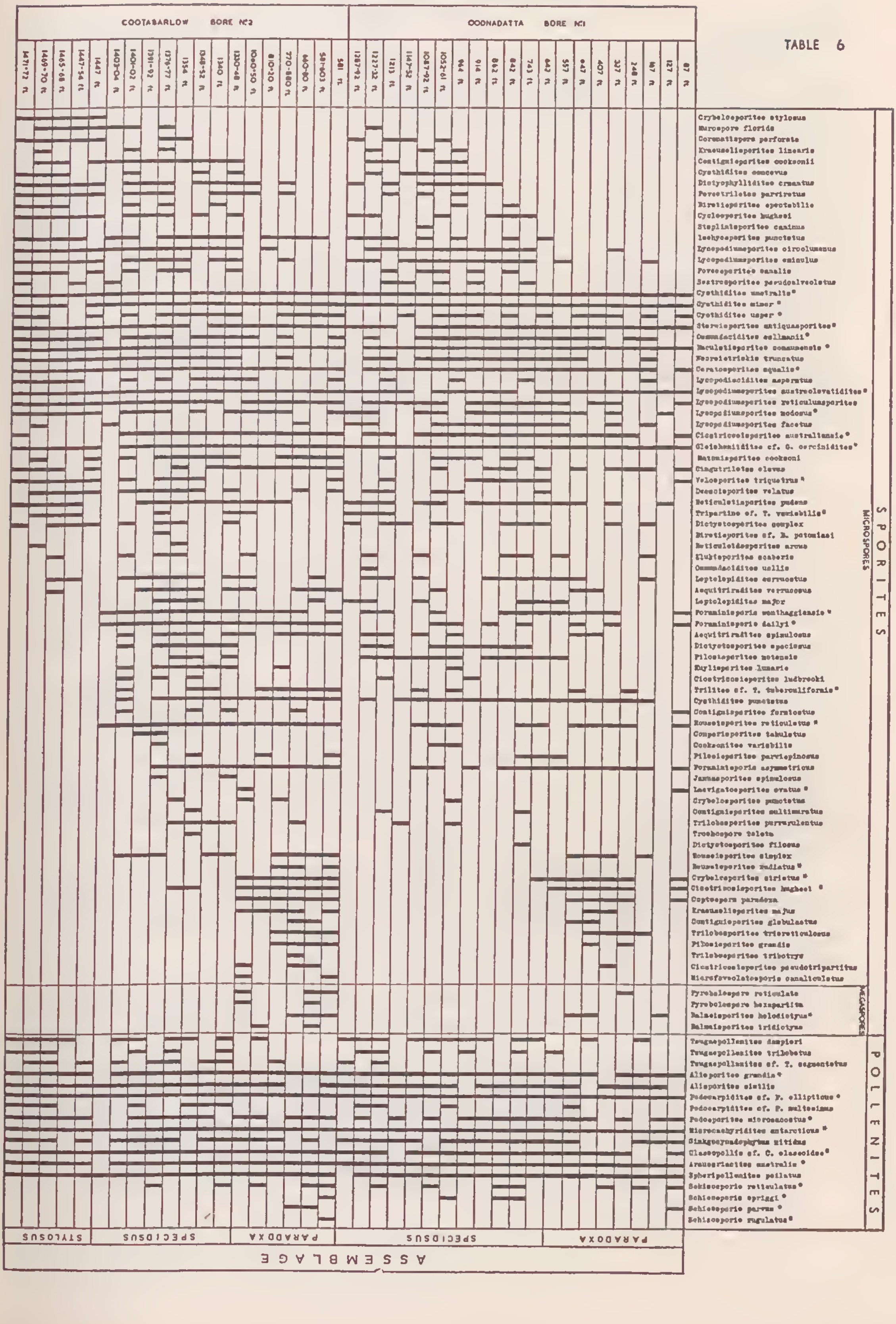
TABLE 6

*Vertical ranges of spore and pollen species in the Mesozoic sequences in Oodnadatta Bore No. 1 and Cootabarlow Bore No. 2 in the Great Artesian Basin. The species are arranged approximately in stratigraphical order of appearance. Species marked * have been observed in samples (Haddon Downs Bore No. 5 between 452 ft 7 in. and 1,406 ft) of the Winton Formation in the Great Artesian Basin.*

Corrigendum: In the list of species *Trochospora telata* should read *Coronatispora telata.*

TABLE 6


COOTABARLOW BORE No.2
1471-72 ft
1469-70 ft
1465-68 ft
1447-54 ft
1447 ft
1403-04 ft
1401-02 ft
1391-92 ft
1376-77 ft
1354 ft
1348-52 ft
1340 ft
1330-48 ft
1060-50 ft
810-20 ft
770-880 ft
660-80 ft
597-603 ft
581 ft
OODNADATTA BORE No.1
1287-92 ft
1227-32 ft
1213 ft
1147-52 ft
1087-92 ft
1052-61 ft
964 ft
914 ft
862 ft
842 ft
743 ft
643 ft
557 ft
447 ft
407 ft
327 ft
248 ft
167 ft
127 ft
87 ft
Crybelosporites stylosus
Murospora florida
Coronatispora perforata
Krauselisporites linearis
Contignisporites cooksonii
Cyathidites concavus
Dictyophyllidites crenatus
Foveotriletes parviretus
Biretisporites spectabilis
Cyclosporites hughesi
Staplinisporites caminus
Ischyosporites punctatus
Lycopodiumsporites circolumenus
Lycopodiumsporites eminulus
Foveosporites canalis
Sestrosporites pseudoalveolatus
Cyathidites australis*
Cyathidites minor *
Cyathidites asper *
Stereisporites antiquasporites*
Osmundacidites wellmanii*
Baculatisporites comaumensis *
Neoraistrickia truncatus
Ceratosporites equalis*
Lycopodiacidites asperatus
Lycopodiumsporites austroclavatidites*
Lycopodiumsporites reticulumsporites
Lycopodiumsporites nodosus*
Lycopodiumsporites facetus
Cicatricosisporites australiensis*
Gleicheniidites cf. G. cercinidites*
Matonisporites cooksoni
Cingutriletes clavus
Velosporites triquetrus*
Densoisporites velatus
Reticulatisporites pudens
Tripartina cf. T. variabilis*
Dictyotosporites complex
Biretisporites cf. B. potoniaei
Reticuloidosporites arcus
Klukisporites scaberis
Osmundacidites mollis
Leptolepidites verrucatus
Aequitriradites verrucosus
Leptolepidites major
Foraminisporis wonthaggiensis*
Foraminisporis dailyi*
Aequitriradites spinulosus
Dictyotosporites speciosus
Pilosisporites notensis
Kuylisporites lunaris
Cicatricosisporites ludbrooki
Trilites cf. T. tuberculiformis*
Cyathidites punctatus
Contignisporites fornicatus
Rouseisporites reticulatus*
Conperisporites tabulatus
Cooksonites variabilis
Pilosisporites parvispinosus
Foraminisporis asymmetricus
Januasporites spinulosus
Laevigatosporites ovatus*
Crybelosporites punctatus
Contignisporites multimuratus
Trilobosporites purverulentus
Trochospora telata
Dictyotosporites filosus
Rouseisporites simplex
Rouseisporites radiatus*
Crybelosporites striatus*
Cicatricosisporites hughesi*
Coptospora paradoxa
Krauselisporites majus
Contignisporites glebulentus
Trilobosporites trioreticulosus
Pilosisporites grandis
Trilobosporites tribotrys
Cicatricosisporites pseudotripartitus
Microfoveolatosporis canaliculatus
MICROSPORES
Pyrobolospora reticulata
Pyrobolospora hexapartita
Balmeisporites holodictyus*
Balmeisporites tridictyus
MEGASPORES
SPORITES
Tsugaepollenites dampieri
Tsugaepollenites trilobatus
Tsugaepollenites cf. T. segmentatus
Alisporites grandis*
Alisporites similis
Podocarpidites cf. P. ellipticus*
Podocarpidites cf. P. multesimus
Podosporites microsaccatus*
Microcachryidites antarcticus*
Ginkgocycadophytus nitidus
Classopollis cf. C. classoides*
Araucariacites australis*
Spheripollenites psilatus
Schizosporis reticulatus*
Schizosporis spriggi*
Schizosporis parvus*
Schizosporis rugulatus*
POLLENITES
STYLOSUS
SPECIOSUS
PARADOXA
SPECIOSUS
PARADOXA
ASSEMBLAGE

Robe Bore interval includes horizons of the Runnymede Formation (see Ludbrook 1961b, 1963b).

The Speciosus Assemblage is characterized by the presence of *Dictyotosporites speciosus* Cookson & Dettmann and lacks the 'index' species, *Crybelosporites stylosus*, of the Stylosus Assemblage. Also significant is the occurrence of the following species which have not been identified in the older assemblage: *Cicatricosisporites ludbrooki* sp. nov., *C. hughesi* sp. nov., *Pilosisporites notensis* Cookson & Dettmann, *P. parvispinosus* sp. nov., *Kuylisporites lunaris* Cookson & Dettmann, *Foraminisporis wonthaggiensis* (Cookson & Dettmann), *F. asymmetricus* (Cookson & Dettmann), *Rouseisporites reticulatus* Pocock, *R. simplex* (Cookson & Dettmann), *R. radiatus* sp. nov., *Cyathidites punctatus* (Delcourt & Sprumont), *Aequitriradites spinlosus* (Cookson & Dettmann), *Cooksonites variabilis* Pocock, *Schizosporis reticulatus* Cookson & Dettmann, and *Crybelosporites striatus* (Cookson & Dettmann).

Furthermore, the following rare components, some of which occur in the Great Artesian Basin only, are unknown in the Stylosus Assemblage: *Dictyotosporites filosus* sp. nov., *Trilobosporites purverulentus* (Verbitskaya), *Trilites* cf. *T. tuberculiformis* Cookson, *Januasporites spinlosus* sp. nov., *Couperisporites tabulatus* sp. nov., *Contignisporites fornicatus* sp. nov., *C. multimuratus* sp. nov., and *Crybelosporites punctatus* sp. nov.

Species present in significant proportions in both the Stylosus and Speciosus Assemblages include: *Microcachyridites antarcticus, Podocarpidites* spp., *Alisporites* spp., *Classopollis* cf. *C. classoides, Cyathidites australis, C. minor, Stereisporites antiquasporites, Lycopodiumsporites* spp., and *Gleicheniidites* cf. *G. cercinidites.*

The Speciosus Assemblage contains many exclusively Cretaceous species reported previously from Western Australia, Canada, Siberia, Russia, and Europe. These include: *Murospora florida, Reticulatisporites pudens*, and *Foveotriletes parviretus* which, as outlined above, occur in the Lower Cretaceous of Western Australia; and *Cyathidites punctatus* which is unknown from pre-Cretaceous strata in England, Belgium, U.S.S.R., and Canada.

Two species, *Foraminisporis wonthaggiensis* and *Rouseisporites reticulatus,* which first appear in the stratigraphically lower horizons containing the Speciosus Assemblage, have been reported hitherto from Barremian or younger strata of Siberia (Samoilovitch et al. 1961) and Canada (Pocock 1962).

Aequitriradites spinuosus which also occurs in the lower horizons containing the Speciosus Assemblage is known from Hauterivian-Danian only of U.S.S.R. (Bolkhovitina 1959, Samoilovitch et al. 1961) and in Canada first appears in Valanginian strata (Pocock 1962).

Cooksonites variabilis, Schizosporis reticulatus, and *Trilobosporites purverulentus* are known only from Valanginian or younger deposits; the former two species first occur in the Valanginian and Barremian respectively of Canada (Pocock 1962), and the latter species has been reported from Barremian or younger strata of Russia and Siberia (Verbitskaya 1962, Samoilovitch et al. 1961).

Another significant species is *Foraminisporis asymmetricus* which first appears in horizons stratigraphically higher than those containing *F. wonthaggiensis* and

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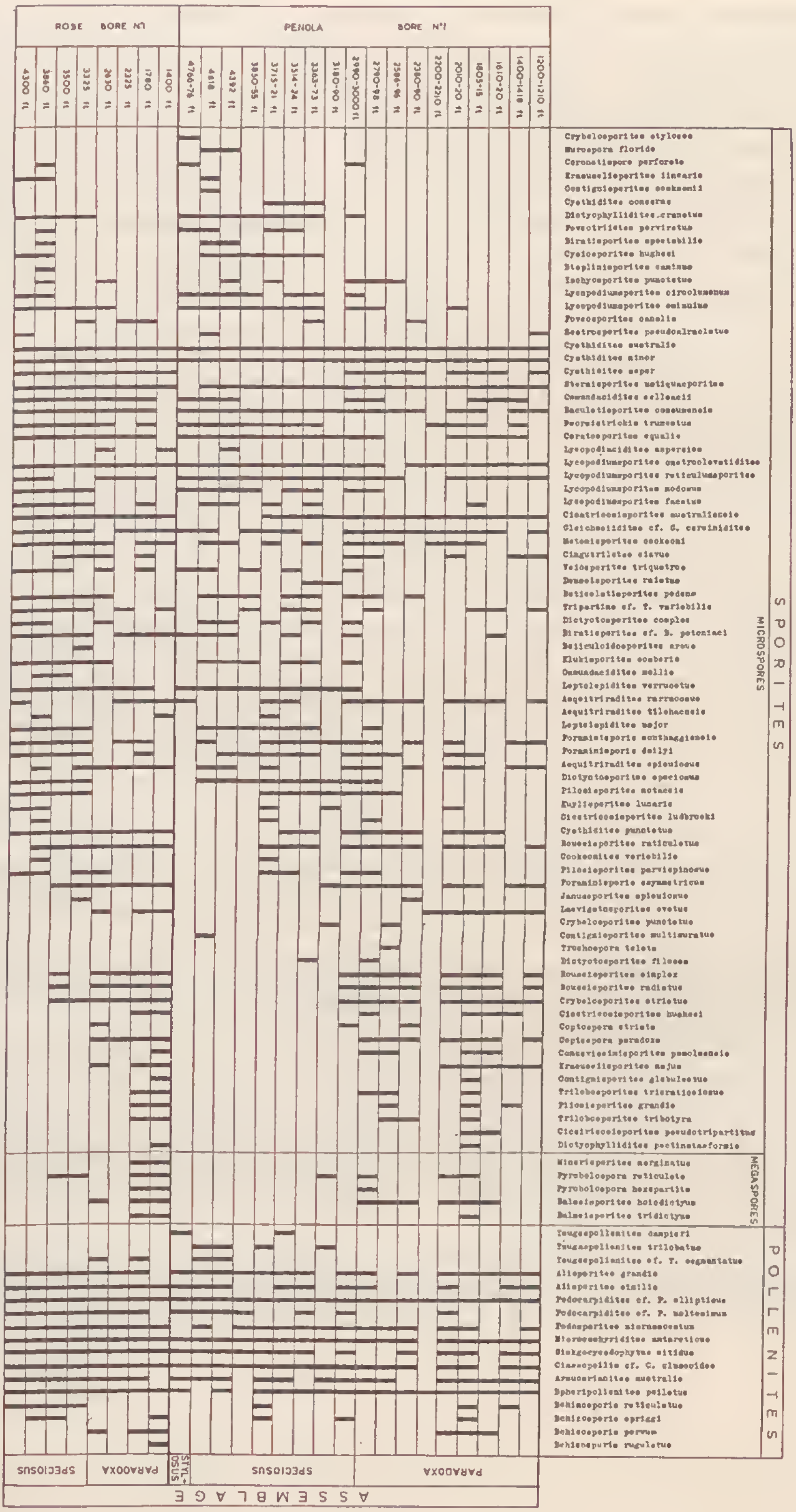
TABLE 7

Vertical ranges of spore and pollen species in the Mesozoic sequences in Penola Bore No. 1 and Robe Bore No. 1 in the Otway Basin. The species are arranged approximately in stratigraphical order of appearance.

Corrigendum: In the list of species *Trochospora telata* should read *Coronatispora telata.*


ROSE BORE Nº1
4300 ft
3860 ft
3500 ft
3325 ft
2630 ft
2325 ft
1780 ft
1400 ft
PENOLA BORE Nº1
4766-76 ft
4618 ft
4392 ft
3850-55 ft
3715-21 ft
3514-24 ft
3363-73 ft
3180-90 ft
2990-3000 ft
2790-98 ft
2586-96 ft
2380-90 ft
2200-2210 ft
2010-20 ft
1805-15 ft
1610-20 ft
1400-1418 ft
1200-1210 ft
Crybelosporites stylosus
Murospora florida
Coronatispora perforata
Kraeuselisporites linearis
Contignisporites cooksonii
Cyathidites concavus
Dictyophyllidites crenatus
Foveotriletes parviretus
Biretisporites spectabilis
Cyclosporites hughesi
Staplinisporites caminus
Ischyosporites punctatus
Lycopodiumsporites circolumenus
Lycopodiumsporites eminulus
Foveosporites canalis
Sestrosporites pseudoalveolatus
Cyathidites australis
Cyathidites minor
Cyathidites asper
Stereisporites antiquasporites
Osmundacidites wellmanii
Baculatisporites comaumensis
Neoraistrickia truncatus
Ceratosporites equalis
Lycopodiacidites asperatus
Lycopodiumsporites austroclavatidites
Lycopodiumsporites reticulumsporites
Lycopodiumsporites nodosus
Lycopodiumsporites facetus
Cicatricosisporites australiensis
Gleicheniidites cf. G. cercinidites
Matonisporites cooksoni
Cingutriletes clavus
Velosporites triquetrus
Densoisporites velatus
Reticulatisporites pudens
Tripartina cf. T. variabilis
Dictyotosporites complex
Biretisporites cf. B. potoniaei
Reticuloidosporites arcus
Klukisporites scaberis
Osmundacidites mollis
Leptolepidites verrucatus
Aequitriradites verrucosus
Aequitriradites tilchaensis
Leptolepidites major
Foraminisporis wonthaggiensis
Foraminisporis dailyi
Aequitriradites spinulosus
Dictyotosporites speciosus
Pilosisporites notensis
Kuylisporites lunaris
Cicatricosisporites ludbrooki
Cyathidites punctatus
Rouseisporites reticulatus
Cooksonites variabilis
Pilosisporites parvispinosus
Foraminisporis asymmetricus
Januasporites spinulosus
Laevigatosporites ovatus
Crybelosporites punctatus
Contignisporites multimuratus
Trochospora telata
Dictyotosporites filosus
Rouseisporites simplex
Rouseisporites radiatus
Crybelosporites striatus
Cicatricosisporites hughesi
Coptospora striata
Coptospora paradoxa
Concavissimisporites penolaensis
Kraeuselisporites majus
Contignisporites glebulentus
Trilobosporites trioreticulosus
Pilosisporites grandis
Trilobosporites tribotrys
Cicatricosisporites pseudotripartitus
Dictyophyllidites pectinataeformis
MICROSPORES
Minerisporites marginatus
Pyrobolospora reticulata
Pyrobolospora hexapartita
Balmeisporites holodictyus
Balmeisporites tridictyus
MEGASPORES
SPORITES
Tsugaepollenites dampieri
Tsugaepollenites trilobatus
Tsugaepollenites cf. T. segmentatus
Alisporites grandis
Alisporites similis
Podocarpidites cf. P. ellipticus
Podocarpidites cf. P. multesimus
Podosporites microsaccatus
Microcachryidites antarcticus
Ginkgocycadophytus nitidus
Classopollis cf. C. classoides
Araucariacites australis
Spheripollenites psilatus
Schizosporis reticulatus
Schizosporis spriggi
Schizosporis parvus
Schizosporis rugulatus
POLLENITES
SPECIOSUS
PARADOXA
STYLOSUS
SPECIOSUS
PARADOXA
ASSEMBLAGE

Rouseisporites reticulatus and which occurs in Aptian-Albian strata of Russia (Verbitskaya 1962). However, in Canada *F. asymmetricus* apparently enters the Manville formation in the basal (Berriasian) beds of the Deville member (Pocock 1962, p. 22; but see p. 56 and Table 1 where the age range is quoted as 'Barremian to Aptian'). It should be mentioned that the Canadian Deville member and overlying Quartz Sand member have been dated as Berriasian-Valanginian and Barremian respectively on the basis of microfloral correlations with the English Wealden. Pocock (1962, p. 25) considers that 'the junction between the Deville and Quartz Sand members is unconformable' and that the Hauterivian stage is 'completely unrepresented' in the Manville formation.

From the above evidence it is concluded that the Speciosus Assemblage is of a Lower Cretaceous age, certainly no younger than Aptian (on faunal evidence) and probably no older than Valanginian. However, a possible extension into the uppermost Berriasian is not precluded; more detailed accounts of the microfloral succession within Canadian and Siberian Lower Cretaceous strata may provide further evidence for the lower age limit of the Speciosus Assemblage.

Further Remarks: There is some evidence in all four bore sequences that the Speciosus Assemblage may be subdivided into two microfloral categories. The stratigraphically lower horizons that contain *Dictyotosporites speciosus* have also yielded one or more of the following species, the first four of which occur also in the Stylosus Assemblage: *Murospora florida, Cyclosporites hughesi, Contignisporites cooksonii, Krauselisporites linearis*, and *Cooksonites variabilis*. None of these species is found in the stratigraphically higher beds that contain *Dictyotsporites speciosus* in association with one or more of *Crybelosporites striatus, Rouseisporites radiatus, Coptospora striata* sp. nov., and *Pyrobolspora reticulata* Cookson & Dettmann.

The former assemblage, in containing *D. speciosus* together with *Cyclosporites hughesi*, is equivalent to the 'pre-Albian' spore association which Cookson and Dettmann (1958b, p. 123) identified in the lower horizons (3,860-4,300 ft) in Robe Bore No. 1. This assemblage occurs also in Oodnadatta Bore No. 1 at 743-1,292 ft, Cootabarlow Bore No. 2 at 1,330-1,402 ft, and Penola Bore No. 1 at 3,363-4,618 ft. On faunal and microfloral evidence assemblages containing *D. speciosus* and *C. hughesi* range in age from Valanginian to Aptian.

The younger assemblage which is characterized by *D. speciosus* together with *Crybelosporites striatus* occurs in beds (Penola Bore No. 1 at 2,990-3,000 ft and Robe Bore No. 1 at 3,325-3,500 ft) in which *Pilosisporites notensis* is also present. In the Oodnadatta Bore *C. striatus* first appears (at 642 ft) within the Roma Formation (Aptian), whilst *D. speciosus* and *P. notensis* are unknown from horizons succeeding the Roma Formation. This evidence indicates that assemblages containing *C. striatus, D. speciosus*, and/or *P. notensis* are Aptian in age.

It is important to note, however, that an admixture of the two microfloras occurs in strata from elsewhere in SE. Australia; Cookson and Dettmann (1958b, p. 125) and Dettmann (1959) recorded an 'intermediate' association characterized by the presence of *D. speciosus, Cyclosporites hughesi*, and *Crybelosporites striatus* in Comaum Bore at 708 ft and Woodside Well No. 2 at 6,892 ft. From the evidence cited above, assemblages containing these three species are of an Aptian age.

THE PARADOXA ASSEMBLAGE

This assemblage (see Tables 5, 6 and 7) has been recovered from samples which immedaitely succeed those containing the Speciosus Assemblage as follows: Oodnadatta Bore No. 1 between 87 ft and 557 ft; Cootabarlow Bore No. 2 between 581 ft and 1,050 ft; Penola Bore No. 1 between 1,200 ft and 2,790 ft; and Robe Bore No. 1 between 1,400 ft and 2,630 ft.

The sediments in the Oodnadatta bore interval include horizons of the Roma Formation (435-557 ft) which is Aptian in age and the Tambo Formation (87-435 ft) of Lower-Upper Albian age (Sprigg in Glaessner and Parkin 1958); more precise age determinations based on palaeonotological analyses are not yet available. Eisenack and Cookson (1960) and Cookson and Eisenack (1962) have reported microplankton assemblages from the 307-612 ft interval in the Oodnadatta bore. A similar assemblage was reported earlier (Cookson and Eisenack 1958) from 581-600 ft in Cootabarlow Bore No. 2, and it was correlated with Albian assemblages from the lower part of the Gearle Siltstone, Western Australia (see McWhae et al. 1958). The strata from the Penola and Robe bores are considered to be from the Runnymede Formation (Ludbrook 1961b, 1963b).

This assemblage, which is named from its most consistently occurring diagnostic species, contains the following forms not observed in the older assemblages: *Coptospora paradoxa* (Cookson & Dettmann), *Pilosisporites grandis* sp. nov., *Cicatricosisporites pseudotripartitus* (Bolkhovitina), *Trilobosporites trioreticulosus* Cookson & Dettmann, *T. tribotrys* sp. nov., *Contignisporites glebulentus* sp. nov., *Kraeuselisporites majus* (Cookson & Dettmann), and both *Concavissimisporites penolaensis* sp. nov. and *Dictyophyllidites pectinataeformis* (Bolkhovitina) which were recovered only from the Otway Basin sections.

None of the above species has been observed in samples from the Winton Formation, Great Artesian Basin (see Tables 5 and 6). Moreover, samples containing the Paradoxa Assemblage, with the exception of that from 2,790-98 ft in Penola Bore No. 1, have not yielded the 'index' species of the Speciosus Assemblage.

Several species, which are also components of the Speciosus Assemblage, are often present in significant proportions: *Cicatricosisporites australiensis, C. hughesi, Balmeisporites holodictyus* Cookson & Dettmann, *Crybelosporites striatus, Rouseisporites reticulatus, R. simplex, R. radiatus, Aequitriradites spinulosus, Cyathidites punctatus*, and *Foraminisporis asymmetricus*.

Species usually abundant, as in both the older assemblages, include: *Cyathidites australis, C. minor, Stereisporites antiquasporites, Baculatisporites comaumensis, Gleicheniidites* cf. *G. cerninidites, Alisporites grandis, Podocarpidites* cf. *P. ellipticus, Microcachyridites antarcticus, Araucariacites australis*, and *Spheripollenites psilatus*.

On faunal evidence the Paradoxa Assemblage is Aptian (in part) and Lower-Upper Albian in age, but a possible extension into the Cenomanian is not precluded on the following grounds: the upper levels (87-167 ft) in Oodnadatta Bore No. 1 contain an undescribed angiospermous (tricolpate) species which occurs in the Winton Formation and which first appears in Upper Cretaceous deposits of W. Victoria (unpublished information); two trilete species (*Cicatricosisporites pseudotripartitus* and *Trilobosporites triobotrys*), apparently restricted to the Paradoxa Assemblage, are known only from Cenomanian or younger strata in Siberia (Bolkhovitina 1961, Samoilovitch et al. 1961); and *Dictyophyllidites pectinataeformis* shows a similar vertical restriction in the Moscow Basin, Russia (Bolkhovitina 1953). However, definite pronouncement on the upper age limit of the Paradoxa Assemblage must necessarily await more conclusive palaeontological evidence together with a more detailed palynological investigation of the upper part of the Tambo Formation and the Winton Formation.

DISCUSSION

As outlined above, the Stylosus, Speciosus, and Paradoxa Assemblages are of probable lowermost Cretaceous (Valanginian or older), Valanginian-Aptian, and Aptian-Albian ages respectively. It is relevant to add that the age limits of the Paradoxa Assemblage and the upper age limit of the Speciosus Assemblage shall be known more precisely when details of the faunal succession in the Oodnadatta Bore become available. On microfloral evidence, the lower non-marine horizons of this sequence are probably no older than Valanginian in age. Thus, Oodnadatta Bore No. 1 incorporates Mesozoic strata (of the Blythesdale Group and Roma and Tambo Formations) ranging in age from Valanginian to at least Upper Albian.

All three microfloral assemblages are represented successively in the partly marine Mesozoic section intersected by Cootabarlow Bore No. 2 in the Great Artesian Basin. This bore sequence includes horizons of the Blythesdale Group and Roma and Tambo Formations, and ranges in age from lowermost Cretaceous (Valanginian or older) to Albian.

The three assemblages also occur in non-marine Mesozoic horizons of the Otway Basin. Strata from Penola Bore No. 1, which penetrated the Runnymede Formation and entered the Mocamboro Member, contain all three assemblages and range in age from lowermost Cretaceous (Valanginian or older) to at least Albian. The two younger microfloral assemblages are represented successively in Robe Bore No. 1, indicating that the Runnymede Formation intersected at this locality incorporates horizons ranging in age from Valanginian to at least Albian.

CORRELATION WITHIN SOUTH-EASTERN AUSTRALIA

The microfloras assemblages delineated above have been identified in samples from various other localities in the Great Artesian Basin and the Otway Basin as well as in the Murray Basin, E. Victoria, and central New South Wales. The sediments from these localities may thus be correlated with the reference sequences in the Great Artesian and Otway Basins. The spore and pollen species recorded from localities other than the four reference sections are listed in Tables 8 and 9. Table 8 incorporates samples containing either the Stylosus Assemblage or the Speciosus Assemblage, and Table 9 includes samples in which the Paradoxa Assemblage has been identified. Stratigraphical and precise locality details are listed in Appendix II (see also Fig. 1); the microfloral content of the majority of the samples is briefly considered below.

GREAT ARTESIAN BASIN

1. Oodnadatta Bore No. 2 at 47 ft.

This horizon contains a microflora representative of the Paradoxa Assemblage and in which angiospermous grains have been identified. As such the microflora corresponds to those extracted from the 87-167 ft interval in Oodnadatta Bore No. 1.

TABLE 8

Check list of spore and pollen species, representative of the Stylosus Assemblage and the Speciosus Assemblage, present in samples additional to those documented in Tables 3 and 4. 'cf' indicates presence of specimens similar to, but not identical with, a particular species.

Corrigendum: In the list of species *T. telata* should read *C. telata.*

NEW SOUTH WALES	EASTERN VICTORIA																										OTWAY BASIN				MURRAY BASIN		GREAT ARTESIAN BASIN	EASTERN VICTORIA		
WARREN BORE No 10520	PARADISE CREEK	MINTOUL'S CREEK	WHITELAW	BENGWORDEN SOUTH BORE No 1	JUMBUNNA BORE No 57					OUTTRIM			C. PATERSON		WONTHAGGI STATE COAL MINE AREA										KILCUNDA	SAN REMO	BARRABOOL HILLS	FORREST	COMAUM BORE No 2		LOXTON BORE		KOPPERAMANNA	KIRRAK		
															WESTERN AREA				No 20 SHAFT		No 18 SHAFT															
580 ft	P22723	P22602	P12805	3937 ft	1107 ft	1065 ft	1022 ft	252 ft	230 ft	BORE No 8 3259 ft	BORE No 7 2690 ft	BORE No 6 2256 ft	P22601	P22600	P22597	P22596	P22595	P22594	P22593	P22592	P22591	P22590	P22589	KIRRAK P22598	MUGD 2513	P22588	P22587	P16770	708 ft	651 ft	1465-70 ft	1410-15 ft	2970 ft	P22599		
x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	Cyathidites australis	LAEVIGATI
x	x		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	C. minor	
x																												x			x	x			C. punctatus	
x				x				x	x				x	x									x		x	x			x						C. asper	
x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	Stereisporites antiquasporites	
		x				x	x							x							x		x											x	Biretisporites cf. B. potoniaei	
	x																																x		B. spectabilis	
	x	x		x		x	x	x					x	x		x	x	x	x	x	x	x	x	x	x	x		x	x				x	x	Dictyophyllidites crenatus	
			x	x	x	x			x	x			x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	Leptolepidites verrucatus	APICULATI
x	x	x	x	x							x		x	x		x		x	x				x			x		x	x	x			x	x	L. major	
	x	x		x																			x						x			x	x		Osmundacidites wellmanii	
																			x				x				x						x	x	O. mollis	
	x		x	x			x	x	x		x	x	x	x	x	x	x			x	x	x	x		x	x	x	x	x	x	x	x	x		Baculatisporites comaumensis	
x	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x	Neoraistrickia truncatus	
x		x		x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	Ceratosporites equalis	
				x	x								x	x									x			x	x	x							Pilosisporites notensis	
			x	x																									x		x	x			P. parvispinosus	
																							x			x			x		x				Kuylisporites lunaris	
		x			x									x									x				x				x	x	x		Lycopodiacidites asperatus	MURORNATI
		x																								x			x					x	Tripartina cf. T. variabilis	
			x										x	x		x			x	x			x	x		x			x				x	x	Cyclosporites hughesi	
																																	x		Foveotriletes parviretus	
													x	x									x			x							x		Foveosporites canalis	
x	x		x	x			x		x	x			x	x	x	x			x	x		x	x	x		x	x	x	x	x	x	x	x		Lycopodiumsporites austroclavatidites	
		x	x		x				x			x	x	x					x		x		x			x	x						x		L. circolumenus	
x	x	x	x		x	x			x	x	x	x	x	x		x	x	x	x	x	x	x	x			x	x		x	x	x	x	x	x	L. reticulumsporites	
x		x		x	x	x		x					x	x	x	x	x	x	x	x	x		x	x	x	x	x		x	x			x	x	L. eminulus	
x		x	x	x	x		x			x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x	x	L. nodosus	
x					x						x	x	x	x									x		x	x	x		x		x		x	x	L. facetus	
x	x		x		x			x		x		x				x	x	x	x	x	x	x	x			x	x		x	x	x	x		x	Reticulatisporites pudens	
		x	x	x	x			x	x			x	x	x	x	x	x	x	x	x		x	x		x	x	x	x	x		x	x	x	x	Klukisporites scaberis	
x	x		x	x	x			x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x			Dictyotosporites speciosus	
x														x					x				x	x		x	x		x		x		x	x	D. complex	
																										x			x		x				D. filosus	
			x	x		x			x				x	x			x						x			x	x	x	x	x	x	x	x		Cicatricosisporites australiensis	
	x																																x		C. ludbrooki	
				x																											x	x			C. hughesi	
																											x					x			Balmeisporites holodictyus	
																																x			Pyrobolospora reticulata	
	x													x													x	x	x	x	x	x	x		Matonisporites cooksoni	AURICULATI
																																x			Trilites cf. T. tuberculiformis	
																											x		x	x		x	x		Ischyosporites punctatus	
x																x	x	x	x	x							x		x	x	x	x	x		Gleicheniidites cf. G. circinidites	TRI-CRASSATI
																																	x		Sestrosporites pseudoalveolatus	
																																	x		Coronatispora perforata	
														x																			x		C. telata	
																											x		x			x	x		Cingutriletes clavus	CINGULATI
	x																																x		Murospora florida	
			x	x					x				x	x									x			x	x	x	x		x	x			Foraminisporis wonthaggiensis	
x	x		x	x	x				x				x	x					x		x	x	x		x	x	x	x	x	x	x	x	x		F. dailyi	
																											x	x	x		x	x			F. asymmetricus	
	x	x																															x		Contignisporites cooksonii	
																																	x		C. multimuratus	
								x											x				x												Kraeuselisporites linearis	
	cf																						cf						x			x	cf		Kimerisporites marginatus	
																																	x	x	Crybelosporites stylosus	PERINO-TRILITES
																											x	x	x		x	x			C. striatus	
														x					x	x	x		x			x			x				x	x	Velosporites triquetrus	
																																	x		Densoisporites velatus	
				x																			x										x		Cooksonites variabilis	HILATES
														x																	x		x		Aequitriradites verrucosus	
				x									x										x		x		x	x	x			x	x		A. spinulosus	
																																	x		A. sp.	
																											x	x	x		x	x			Rouseisporites reticulatus	
																											x				x	x			R. simplex	
	x		x																													x	x		Tsugaepollenites dampieri	SACCITES
		x		x																									x				x		T. trilobatus	
																										x							x		T. cf. T. segmentatus	
x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x	Alisporites grandis	
	x		x						x				x		x				x	x	x	x	x			x	x		x		x	x	x	x	A. similis	
x	x	x	x	x	x	x	x	x	x	x		x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		Podocarpidites cf. P. ellipticus	
													x	x	x	x	x		x	x	x	x	x	x					x					x	P. cf. P. multesimus	
x			x	x	x	x		x	x	x	x		x	x					x	x	x	x	x	x	x	x		x	x	x	x		x	x	Podosporites microsaccatus	
x	x		x		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	Microcachryidites antarcticus	
	x		x	x	x	x		x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						x		Ginkgocycadophytus nitidus	PLICATES
x	x	x	x	x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	Classopollis cf. C. classoides	POROSES
	x	x	x	x				x					x	x	x	x							x			x	x			x	x	x	x		Araucariacites australis	ALETES
			x						x											x			x				x	x	x						Spheripollenites psilatus	
																			x				x			x			x		x	x			Schizosporis reticulatus	INCERTAE SEDIS
	x																														x				S. spriggi	
																													x						S. parvus	
SPECIOSUS ASSEMBLAGE																																	STYLOSUS ASSEMBLAGE			

OTWAY BASIN				GREAT ARTESIAN BASIN				
BELLARINE PENINSULA P22586	DEVIL'S KITCHEN P22584	BARONGAROOK CREEK P22585	DERGHOLM BORE No.1 532 ft	TILCHA BORE No.2 1040-50 ft	TILCHA BORE No.2 460-80 ft	OODNADATTA BORE No.2 47 ft		
X	X	X	X	X	X	X	Cyathidites australis	LAEVIGATI
X	X	X	X	X	X	X	C. minor	
X			X	X			C. punctatus	
X		X		X	X	X	C. asper	
X	X	X	X	X	X	X	Stereisporites antiquasporites	
			X				Dictyophyllidites crenatus	
X			X				Leptolepidites verrucatus	APICULATI
		X		X	X	X	Osmundacidites wellmanii	
X							O. mollis	
X		X	X	X	X	X	Baculatisporites comaumensis	
X		X	X		X	X	Neoraistrickia truncatus	
X	X	X	X	X	X	X	Ceratosporites equalis	
			X				Pilosisporites notensis	
			X	X			P. parvispinosus	
					X		P. grandis	
			X				Kuylisporites lunaris	
		X			X		Lycopodiacidites asperatus	MURORNATI
			X		X		Tripartina cf. T. variabilis	
			X				Foveotriletes parviretus	
X		X	X		X		Foveosporites canalis	
X	X	X	X	X	X	X	Lycopodiumsporites austroclavatidites	
X			X	X	X	X	L. reticulumsporites	
X				X			L. eminulus	
X			X	X			L. nodosus	
X			X				Reticulatisporites pudens	
	X		X				Klukisporites scaberis	
			X				Januasporites spinulosus	
X	X	X	X	X	X	X	Cicatricosisporites australiensis	
X				X			C. pseudotripartitus	
		X		X	X		C. hughesi	
			X	X	X	X	Balmeisporites holodictyus	
				X	X		B. tridictyus	
					X		Pyrobolospora hexapartita	
			X	X			P. reticulata	
					X		P. nuda	
X	X	X	X		X		Matonisporites cooksoni	AURICULATI
	X	X		X	X	X	Trilobosporites trioreticulosus	
X							Trilites cf. T. tuberculiformis	
			X				Ischyosporites punctatus	
X	X	X	X	X	X	X	Gleicheniidites cf. G. circinidites	TRICRASSATI
		X		X	X	X	Cingutriletes clavus	CINGULATI
		X	X			X	Foraminisporis wonthaggiensis	
X		X	X	X	X	X	F. dailyi	
X	X	X	X	X	X	X	F. asymmetricus	
					X		Contignisporites glebulentus	
					X		C. fornicatus	
				X	X		Kraeuselisporites majus	
			X		X		Minerisporites marginatus	
X	X	X	X	X	X	X	Crybelosporites striatus	PERINO-TRILITES
			X		X		C. punctatus	
				X	X	X	Densoisporites velatus	
			X				Coptospora striata	HILATES
X	X	X	X	X	X	X	C. paradoxa	
			?				Cooksonites variabilis	
			X		X		Aequitriradites verrucosus	
	X		X	X	X		A. spinulosus	
					X		A. tilchaensis	
X	X	X	X	X	X	X	Rouseisporites reticulatus	
X		X	X	X	X		R. simplex	
X		X	X	X			R. radiatus	
X			X	X	X	X	Laevigatosporites ovatus	MONOLETES
					X	X	Microfoveolatosporis canaliculatus	
						X	Tsugaepollenites dampieri	SACCITES
X	X	X	X	X	X	X	Alisporites grandis	
X		X	X	X	X	X	A. similis	
X		X	X	X	X	X	Podocarpidites cf. P. ellipticus	
X			X		X		P. cf. P. multesimus	
X		X	X		X	X	Podosporites microsaccatus	
X		X	X	X	X	X	Microcachryidites antarcticus	
X		X	X		X		Ginkgocycadophytus nitidus	PLICATES
		X	X	X	X	X	Classopollis cf. C. classoides	POROSES
X		X	X	X	X	X	Araucariacites australis	ALETES
X	X	X	X			X	Spheripollenites psilatus	
			X	X	X	X	Schizosporis reticulatus	INCERTAE SEDIS
					X		S. rugulatus	
			X		X		S. spriggi	
					X		S. parvus	

Age: Albian.

2. Kopperamanna Bore at 2,970 ft.

This sample yielded a diverse microflora containing *Crybelosporites stylosus* together with three species, *Cooksonites variabilis, Aequitriradites spinulosus*, and *Cicatricosisporites ludbrooki*, which have not been observed in the Stylosus Assemblage recovered from Cootabarlow Bore No. 2. Other stratigraphically significant species include *Biretisporites spectabilis, Cyclosporites hughesi, Cicatricosisporites australiensis, Contignisporites cooksonii, Murospora florida*, and *Coronatispora perforata*. This association comprises diagnostic elements of both the Speciosus and Stylosus Assemblages, but *Dictyotosporites speciosus* has not been observed in any of the preparations studied by the present writer (cf. Cookson and Dettmann 1958, p. 116). Age: lowermost Cretaceous (Valanginian or older).

3. Tilcha Bore No. 2 at 460-80 ft and 1,040-50 ft.

Both samples, which were studied by Cookson and Dettmann (1958a, b), contain diverse microfloras typical of the Paradoxa Assemblage. Age: Aptian-Albian.

MURRAY BASIN

1. Loxton (Australian Oil and Gas Co. Ltd) bore at 1,410-15 ft and 1,465-70 ft.

Both samples contain *Crybelosporites striatus*, and the stratigraphically higher deposit also contains *Dictyotosporites speciosus*. The presence of these two species together with *Pyrobolspora reticulata, Balmeisporites holodictyus, Cicatricosisporites hughesi* and *Pilosisporites parvispinosus* is indicative of an age older than Albian (cf. Ludbrook 1961b; Cookson and Dettmann 1958a, b) and almost certainly Aptian. The microflora is similar to that obtained from Robe Bore No. 1 at 3,325 ft.

OTWAY BASIN

1. Comaum Bore No. 2 at 651 ft and 708 ft.

The two samples contain well-preserved microfloras in which several diagnostic species of the Speciosus Assemblage have been observed. The sample from 651 ft has yielded both *Dictyotosporites speciosus* and *Crybelosporites striatus*, the presence of which suggests a horizon similar to the 3,325-3,500 ft interval in the Robe Bore and the 2,990-3,000 ft interval in Penola Bore No. 1. The lower horizon at 708 ft also contains *Cyclosporites hughesi*; this association comprises the 'intermediate' microflora of Cookson and Dettmann (1958b). Age: Aptian.

2. Dergholm Bore No. 1 at 532 ft.

A well-preserved microflora representative of the Paradoxa Assemblage is contained in this sample. However, a corroded specimen of *Cooksonites variabilis* was also recovered. Age: Aptian-Albian.

3. Barongarook Creek, sample P22585.

This sample yielded a well-preserved microflora typical of the Paradoxa Assemblage and similar to that contained in the sample studied by Cookson and Dettmann (1958b). Age: Aptian-Albian.

TABLE 9

Check list of spore and pollen species, representative of the Paradoxa Assemblage, present in samples additional to those documented in Table 5. '?' denotes that only doubtful representatives of a species have been observed.

4. Devil's Kitchen, Gellibrand River (sample P22584).

The sample, which was taken from just below the Mesozoic/Palaeocene unconformity, has yielded a sparse microflora referable to the Paradoxa Assemblage. Age: Aptian-Albian.

5. Forrest Bore No. 1, sample 7 (P16770).

The sample yielded a poorly preserved microflora which, in containing *Crybelosporites striatus, Pilosisporites notensis, Foraminisporis asymmetricus, F. wonthaggiensis*, and *Rouseisporites reticulatus*, is probably referable to the Speciosus Assemblage. The occurrence of *Cryebolosporites striatus* together with *Pilosisporites notensis* is indicative of an Aptian age.

6. Bellarine Peninsula, sample P22586.

A well-preserved, prolific microflora representative of the Paradoxa Assemblage was recovered from this sample (see also Cookson and Dettmann 1958a, b). Age: Aptian-Albian.

7. Barrabool Hills, sample P22587.

The presence of the Speciosus Assemblage suggests that the sample was taken from a horizon stratigraphically below the deposit examined by Cookson and Dettmann (1958b). The occurrence of *Pilosisporites notensis* and *Crybelosporites striatus* indicates an Aptian age.

8. Birregurra Bore No. 1 between 1,079 ft and 1,102 ft.

Certain of the species recovered from these horizons are listed by Cookson and Dettmann (1958b, p. 120); these species comprise a microflora referable to the Paradoxa Assemblage. Age: Aptian-Albian.

EASTERN VICTORIA

1. San Remo Peninsula, sample P22588.

A comparatively poorly preserved microflora referable to the Specious Assemblage was recovered from this deposit which was examined by Cookson and Dettmann (1958b). Age: Valanginian-Aptian.

2. Kilcunda, sample M.U.G.D. 2513.

This coal yielded a restricted microflora with species diagnostic of the Speciosus Assemblage. Age: Valanginian-Aptian.

3. Wonthaggi State Coal Mine Area.

Samples P22589 to P22598 inclusive, some of which were examined by Cookson and Dettmann (1958b), all contain the Speciosus Assemblage indicative of a Valanginian-Aptian age.

The coal, P22599, from Kirrak Area yielded *Crybelosporites stylosus*, and is the only Victorian sample in which the Stylosus Assemblage has been identified. Age: lowermost Cretaceous (Valanginian or older).

4. Cape Paterson.

Samples P22600 and P22601 (studied earlier by Cookson and Dettmann 1958b) both contain well-preserved microfloras representative of the Speciosus Assemblage. Species present include *Dictyotosporites speciosus, Cyclosporites hughesi*, and *Pilosisporites notensis*. Age: Valanginian-Aptian.

5. Outtrim.

The highly carbonaceous samples from Bore No. 6, Bore No. 7, and Bore No. 8 have yielded restricted microfloras referable to the Speciosus Assemblage. Age: Valanginian-Aptian.

6. Jumbunna Bore No. 57 between 230 ft and 1,107 ft.

Each of the samples examined contains a poorly-preserved microflora recognizably conformable with the Speciosus Assemblage. Stratigraphically important species include *Dictyotosporites speciosus, Kraeuselisporites linearis,* and *Pilosisporites notensis.* Age: Valanginian-Aptian.

7. Whitelaw Railway Station, sample P12805.

This sample, which was studied by Cookson and Dettmann (1958b), yielded a microflora referable to the Speciosus Assemblage. Age: Valanginian-Aptian.

8. Paradise Creek, Boola Forest; sample P22733.

A prolific, but poorly preserved, microflora referable to the Speciosus Assemblage was obtained from this sample which was collected from near the base of the Tyers Group at Paradise Creek. Stratigraphically important species include *Dictyotosporites speciosus, Murospora florida, Contignisporites cooksonii,* and *Biretisporites spectabilis.* Age: Valanginian-Aptian.

9. Rintoul's Creek, sample P22602.

This outcrop sample of the Tyers Group contains a poorly preserved microflora not certainly identifiable with either the Stylosus or Speciosus Assemblages. *Contignisporites cooksonii* is the only stratigraphically significant species that has been recognized.

Another sample from the Tyers Group (Tyers Bore No. 2 at 860 ft) was studied by Cookson and Dettmann (1958b) and contains the Specious Assemblage indicative of a Valanginian-Aptian age.

10. Bengworden South Bore No. 1 at 3,977 ft.

A well-preserved microflora referable to the Speciosus Assemblage was identified in this horizon from which Cretaceous foraminifera have been reported (Taylor in Webb 1961). Microplanktonic organisms have not been observed in the writer's preparations, and constituent spore species include *Dictyotosporites speciosus, Pilosisporites notensis, Cicatricosisporites hughesi,* and *Cooksonites variabilis.* Age: Valanginian-Aptian.

The following E. Victorian samples, not mentioned above but studied by Cookson and Dettmann (1958b) and Dettmann (1959), contain the Speciosus Assemblage: Korumburra Sunbeam Collieries, shale above coal at 350 ft. Woodside Well No. 2 between 6,402-8,860 ft. Woodside Well No. 3 between 5,711-24 ft. Hedley Well No. 1 between 2,099-2,132 ft. The age of these deposits is considered as Valanginian-Aptian. The sample at 6,892 ft in Woodside Well No. 2 contains *Dictyotosporites speciosus, Cyclosporites hughesi,* and *Crybelosporites striatus* which suggest that the horizons between 6,402 ft and 6,892 ft in this bore are Aptian in age.

E. Victorian deposits in which *Coptospora paradoxa* has been identified include: Woodside Well No. 1 between 5,950-55 ft. Woodside Well No. 2 between 4,114-256 ft. Woodside Well No. 3 at 5,386 ft. The microfloral evidence indicates that these horizons are Aptian-Albian in age.

NEW SOUTH WALES

1. Warren District Bore No. 10528 at 560 ft.

This sample contains a well-preserved but restricted microflora in which the 'index' species of the Stylosus Assemblage has been recognized. Age: Valaginian-Aptian.

From the above it is evident that correlations of Upper Mesozoic strata in SE. Australia (see Table 10) are possible on the sole basis of their contained microfloras. The full stratigraphical significance of the microfloras cannot yet be assessed, but there is some evidence for the belief that they may be used in conjunction with microplankton in the regional correlation of Australian and Papuan Upper Mesozoic sediments. It has already been demonstrated that the Stylosus and Speciosus Assemblages are closely comparable to Western Australian microfloras of Neocomian-Aptian age, and it will be seen from the records presented by Cookson and Dettmann (1958a, b) that the Paradoxa Assemblage is represented in the Albian Styx Coal Measures of Queensland. A number of stratigraphically significant species, which are components of the Speciosus and Paradoxa Assemblages, are also known from Omati, Papua (Cookson and Dettmann loc. cit.).

<table>
<tr><th colspan="2" rowspan="2"></th><th rowspan="2">ASSEMBLAGE</th><th rowspan="2">GREAT ARTESIAN BASIN</th><th colspan="2">OTWAY BASIN</th><th colspan="3">EASTERN VICTORIA</th></tr>
<tr><th>GAMBIER SUNKLANDS</th><th>PORTLAND SUNKLANDS</th><th>WONTHAGGI AREA</th><th>TYERS AREA</th><th>GIPPSLAND SUNKLANDS</th></tr>
<tr><td rowspan="8">LOWER CRETACEOUS</td><td>ALBIAN</td><td rowspan="2">PARADOXA</td><td>TAMBO FORMATION</td><td rowspan="5">RUNNYMEDE FORMATION</td><td rowspan="4">OTWAY GROUP</td><td rowspan="2">? ? ? ?</td><td rowspan="2">? ? ? ?</td><td rowspan="6">Sediments in bores</td></tr>
<tr><td rowspan="2">APTIAN</td><td rowspan="2">ROMA FORMATION</td></tr>
<tr><td rowspan="5">SPECIOSUS</td><td rowspan="6">STRZELECKI GROUP</td><td rowspan="4">TYERS GROUP</td></tr>
<tr><td rowspan="5">NEOCOMIAN</td><td rowspan="5">BLYTHESDALE GROUP</td></tr>
<tr><td rowspan="4">? ? ? ?</td></tr>
<tr><td rowspan="3">MOCAMBORO MEMBER</td></tr>
<tr><td rowspan="2">? ? ? ?</td><td rowspan="2">? ? ? ?</td></tr>
<tr><td>STYLOSUS</td></tr>
</table>

TABLE 10

Correlation of SE. Australian Lower Cretaceous sediments, based on microfloral content.

Some General Conclusions

One of the most notable features of the SE. Australian Cretaceous microfloras is the great variety of types and the large number of Western Australian, Canadian, and Siberian species represented in them. More than 20 of the constituent species of Western Australian Neocomian-Aptian assemblages are components of the Stylosus and Speciosus Assemblages, and all but two of these (*Murospora florida* and *Contignisporites cooksonii*) occur in the Paradoxa Assemblage. The predominance of *Microcachyridites antarcticus*, *Podocarpidites* spp., *Alisporites* spp., *Glei-*

cheniidites cf. *G. cercinidites*, and *Lycopodiumsporites* spp. and rarity of *Tsugaepollenites* spp. in the Western Australian and SE. Australian Lower Cretaceous microfloras is also noteworthy.

Western Canadian Lower Cretaceous microfloras contain more than 14 of the species represented in the Speciosus and Paradoxa Assemblages. These include saccate (*Podocarpidites* spp., *Tsugaepollenites* spp.), trilete (*Foraminisporis asymmetricus, F. wonthaggiensis, Cicatricosisporites australiensis*), and hilate (*Aequitriradites spinulosus, Rouseisporites reticulatus*) species as well as 'alete' types referable to *Schizosporis*. One species, *Cooksonites variabilis*, which has restricted vertical distribution in Canada, shows similar stratigraphical restriction in SE. Australia.

W. Siberian Aptian-Albian and Cenomanian microfloral assemblages contain several stratigraphically significant trilete and hilate components of the Speciosus and/or the Paradoxa Assemblage. These include: *Trilobosporites trioreticulosus, T. tribotrys, T. purverulentus, Cicatricosisporites australiensis, C. pseudotripartitus, Aequitriradites spenulosus, A. verrucosus, Rouseisporites reticulatus*, and *Formanisporis wonthaggiensis.*

On the other hand, the SE. Australian Cretaceous microfloras bear little resemblance to those described from New Zealand, Europe, and E. North America. A few elements such as *Cyathidites australis, C. punctatus, Lycopodiumsporites* spp., and *Osmundacidites wellmanii* occur in the microfloras, but these species appear to be of little stratigraphical value within the Lower Cretaceous and show world-wide distribution. It is relevant to add that *Concavissimisporites, Pilosisporites*, and *Trilobosporites* seem to have appeared earlier in British than in Australian deposits. Forms referable to those genera are unknown in the probably lowermost Cretaceous Stylosus Assemblage but occur in Jurassic and lowermost Cretaceous strata of Britain.

The relationships of the spore and pollen species with described megafloral elements contained in SE. Australian Upper Mesozoic strata can only be deduced at present on the basis of spore morphology. The relatively featureless, smooth-walled forms *Cyathidites minor* and *Gleicheniidites* sp. may well have derived from the cyatheaceous or dicksoniaceous species *'Coniopteris hymenophylloides'* and the gleicheneaceous *Microphyllopteris minuta* Medwell respectively. *Osmundacidites wellmanii* and *Baculatisporites comaumensis* are almost certainly a reflection of the osmundaceous elements that are represented in the megaflora. Araucariacean and podocarpaceous elements occur in the megaflora, and their probable derivatives are *Araucariacites* and *Podocarpidites* respectively. Lycopods are well represented by numerous microspore species (*Lycopodiumsporites, Densoisporites, Ceratosporites*, etc.) and are known in the Victorian megaflora. Hepatic species, which have been described in the Barrabool Sandstone megaflora, may have produced some of the hilate forms (*Aequitriradites, Coptospora, Rouseisporites*, etc.) that are often abundantly represented in horizons of the Otway Basin. The widespread occurrence of *Cicatricosisporites* spp. and *Klukisporites scaberis* suggests the presence of schizaeaceous elements in the contemporaneous flora, and the presence of *Crybelosporites* spp. and *Pyrobolospora* spp. may indicate hydropteridean contributions.

APPENDIX I

Note on the Spore Morphology of Two Recent and One Fossil Hepatic Species

Nothylas breutelii Gottsche

(Pl. XXVII, fig. 12-16)

MATERIAL: ex Herb. Hort. Bot. Reg. Kew; coll. C. Wright from Cuba.

TREATMENT: Method of Erdtman (1960); acetolysis followed by chlorination.

DESCRIPTION: Microspores trilete, biconvex; amb subcircular to convexly subtriangular or subquadrangular. Laesurae straight, extending to periphery. Exine 1·5-2 μ thick, thicker (3-4 μ) equatorially where a narrow, foveolate cingulum is developed. Exine sculptured with either (1) spinulate elements (2-3 μ in basal diameter, 2-4 μ high) distally and reduced spinules proximally, or (2) scattered granules and verrucae (1-6 μ in basal diameter, 1-2 μ high) distally.

DIMENSIONS: (1) Spinulate microspores–equatorial diameter 53 (57) 67 μ; polar diameter 36 (37) 39 μ. (2) Granulate/verrucate microspores–equatorial diameter 45 (51) 56 μ; polar diameter 28 (30) 34 μ.

REMARKS: The two morphologically distinct microspore types which have been recovered from *Nothylas breutelli* Gottsche resemble Australian Mesozoic microspores included within *Foraminisporis* Krutzsch; the spinulate spores (Pl. XXVII, fig. 12-14) are similar in morphology to *F. wonthaggiensis* (Cookson & Dettmann), and the granulate/verrucate forms (Pl. XXVII, fig. 15, 16) resemble *F. dailyi* (Cookson & Dettmann).

Phaeoceros bulbiculosus (Brotero) Prosk.

(Pl. XXVII, fig. 17, 18)

MATERIAL: ex Herb. Hort. Bot. Reg. Kew; coll. Fernandes et al. from Coimbra, Portugal.

TREATMENT: Method of Erdtman (1960); acetolysis only.

DESCRIPTION: Microspores trilete, biconvex; amb subcircular to convexly subtriangular. Laesurae straight, extending to amb, and with slightly elevated lips (2μ wide, 1-2 μ high). Exine scabrate; 1·5-2 μ thick, thicker (3-4 μ) equatorially where a foveolate cingulum is developed. Distal exine thickened in a circular area (15-25μ in diameter) about the pole; thickening foveolate.

DIMENSIONS: Equatorial diameter 48 (60) 67 μ; polar diameter not determined.

REMARKS: The spores resemble *Foraminisporis dailyi* (Cookson & Dettmann), but differ in having a thickened exine about the distal pole and in the absence of distal granules and verrucae.

Naiadita lanceolata Buckman

(Pl. XXVII, fig. 9-11)

MATERIAL: British Museum (Natural History) slides V25309-V25312 inclusive (See Harris, T. M. 1938, p. 45-48; fig. 21, 22; Potonié 1962, p. 36; Pl. 1, fig. 8).

DESCRIPTION: Microspores inaperturate or hilate proximally, rarely with a faint proximal tetrad mark; amb convexly triangular to subcircular. Sclerine two-layered; inner layer scabrate, 2·5-3·5 μ thick; outer layer *c.* 1·5 μ thick, thicker (3-4 μ) equatorially where a narrow cingulum (5-7 μ wide) is developed. Distal and equatorial sclerine verrucate; verrucae 2-3 μ high, 2-3 μ in basal diameter, spaced

2-4 μ apart. Proximal sclerine sculptured with granules and reduced verrucae which are more closely spaced about the pole; an irregular rupture (hilum) as much as 42 μ in diameter is sometimes developed in this area.

DIMENSIONS: Equatorial diameter; overall 78 (100) 111 μ, spore cavity 62 (80) 89 μ. Overall polar diameter (5 specimens) 42 (43) 45 μ.

REMARKS: These fossil spores may be hilate proximally and show some resemblance to *Couperisporites tabulatus* sp. nov., but differ in having a greater development of equatorial thickening and a larger size.

APPENDIX II

Data on Samples Studied

Outcrop and bore (core, cutting, and sludge) samples are listed and described macroscopically under headings of localities from which they were collected; relevant stratigraphical data are noted. Robe Bore No. 1 samples are lodged in the South Australian Museum, and the Mines Department of South Australia holds material of all other South Australian material examined. Unless otherwise indicated, samples taken from bores put down by the Victorian Department of Mines are lodged with that department. Samples that have been allocated registered numbers prefixed 'P' and 'MUGD' are deposited in the collections of the National Museum of Victoria and the Melbourne University Geology Department respectively. Preparation numbers of each sample are stated—those prefixed 'ICC' were prepared by Dr I. C. Cookson; 'D' indicates preparation by the writer.

GREAT ARTESIAN BASIN (SOUTH AUSTRALIAN PORTION)

1. Oodnadatta Bore No. 1, sunk by South Australian-Northern Territory Oil Search Ltd (Santos). Core and sludge samples comprise:

Depth (ft)	Core/ sludge	Rock type	Stratigraphical unit	Age if previously assessed on marine faunal evidence	Preparation
87	core	greenish-grey mudstone	Tambo Formation	Middle and Upper Albian (Sprigg in Glaessner and Parkin 1958, Brunnschweiler 1959)	D362
127	"	" "	" "	" "	D387
167	"	greenish-grey micaceous siltstone	" "	" "	D386
248	"	grey mudstone	" "	" "	D383
327	"	" "	" "	" "	D354
407	"	dark grey mudstone, calcareous	" "	" "	D379, D391
447	"	greenish-grey mudstone	Roma Formation	Aptian (Sprigg in Glaessner and Parkin 1958, Brunnschweiler 1959)	D378, D390
557	"	grey mudstone	" "	" "	D377, D389
642	"	" "	" "	" "	D376, D388
743	"	grey-micaceous siltstone	" "	" "	D355
842	"	grey, laminated mudstone	" "	" " " "	D356
862	"	grey mudstone	" "	" "	D382
914	"	dark grey mudstone	" "	" "	D381
964	"	" "	" "	" "	D380
1,052-61	sludge	grey mudstone	Blythesdale Group		D357
1,087-92	"	" "	" "		D385
1,147-52	"	" "	" "		D384
1,213	core	" "	" "		D231, D235, D282
1,227-32	sludge	sand with grey shale	" "		D238, D281
1,287-92	"	" "	" "		D237

2. Oodnadatta Bore No. 2, sunk by Santos Ltd, at 47 ft. Core sample; dark grey mudstone, Tambo Formation; Middle and Upper Albian; D363.
3. Kopperamanna Bore, 60 miles E. of Lake Eyre, at 2,970 ft. Grey shale, Blythesdale Group (Sprigg in Glaessner and Parkin 1958); D230, D234, D241.

4. Haddon Downs Bore No. 5, NE. South Australia. Core samples examined include:

Depth	Rock type	Stratigraphical unit	Preparation
452 ft 7 in.	grey siltstone	Winton Formation	D360
465 ft	grey shale	,, ,,	D351, D359
801 ft 8 in.	dull coal	,, ,,	D352, D374
1,406 ft	grey mudstone	,, ,,	D353, D361

5. Tilcha Bore No. 2, E. of Lake Callabonna. Sludge samples from:
   (a) 460-80 ft, grey siltstone; D218, D222.
   (b) 1,040-50 ft, grey mudstone; D371.

6. Cootabarlow Bore No. 2, SE. of Lake Callabonna. Core and sludge samples examined comprise:

Depth (ft)	Core/ sludge	Rock type	Stratigraphical unit	Age if previously assessed on marine faunal evidence	Preparation
581	core	lignitic clay	Tambo Formation		D368
581-603	,,	lignitic mudstone	,, ,,		D327, D333
660-80	sludge	carbonaceous mudstone and sand	,, ,,		D244
770-880	,,	glaucontic clay	Roma Formation		D243
810-20	,,	dark grey mudstone	,, ,,		D369
1,040-50	core	brownish sandstone, fine-grained	,, ,,		D324, D332
1,330-48	,,	,, ,,	,, ,,		D303, D338
1,340	,,	,, ,,	,, ,,		D290
1,348-52	,,	grey mudstone	,, ,,		D331
1,354	,,	,, ,,	,, ,,	Aptian (Ludbrook, unpublished)	D228, D232, D242, D274
1,376-77	,,	,, ,,	,, ,,		D289
1,391-92	,,	grey sandstone, fine-grained	Blythesdale Group		D288
1,401-02	,,	grey mudstone	,, ,,		D334
1,403-04	,,	grey sandstone with thin carbonaceous bands	,, ,,		D329
1,427-47	,,	grey sandstone	,, ,,		D297, D306
1,447	,,	grey shale	,, ,,		D328
1,447-64	,,	grey sandstone, fine-grained	,, ,,		D296, D305
1,465-68	,,	,, ,,	,, ,,		D229, D233, D243, D275
1,468-70	,,	brownish sandstone, fine-grained	,, ,,		D302, D336
1,471-72	,,	,, ,,			D304, D337

MURRAY BASIN

SOUTH AUSTRALIA

1. Loxton Bore, sunk by Australian Oil and Gas Co. Ltd, Sec. 6B, Hundred of Bookpurnong (see Ludbrook 1961b). Sludge samples from:
   (a) 1,410-15 ft, greenish-grey mudstone; D364.
   (b) 1,465-70 ft, greenish-grey siltstone; D365.

OTWAY BASIN (GAMBIER SUNKLANDS AND PORTLAND SUNKLANDS)

SOUTH AUSTRALIA

1. Robe Bore No. 1, sunk by South Australian Oil Wells, Sec. 714, Hundred of Waterhouse (see Ludbrook 1961b). Labelled specimens (cuttings) examined comprise:

Depth (ft)	Rock type	Stratigraphical Unit	Preparation
1,400	grey mudstone	Runnymede Formation	D217, D224, D257, ICC60/4
1,780	greenish-grey, micaceous siltstone	,, ,,	D247, D258, D339
2,325	grey mudstone	,, ,,	D246, D256
2,630	grey, laminated siltstone	,, ,,	D225, D259
3,325	greenish-grey, sandy siltstone	,, ,,	D245, D263, D280
3,500	greenish-grey, laminated siltstone; highly carbonaceous	,, ,,	D244, D261
3,860	grey mudstone with fragments of *Unio* sp.	,, ,,	D226
4,300	dark grey, carbonaceous mudstone	,, ,,	D227

2. Penola Bore No. 1, sunk by Oil Development No Liability, Hundred of Penola. Core and cutting samples examined include:

Depth (ft)	Core/ cutting	Rock type	Stratigraphical Unit	Preparation
1,200-210	core	grey, laminated, carbonaceous siltstone	Runnymede Formation, Upper Member	D273
1,400-410	,,	greenish-grey, micaceous siltstone	,, ,,	D285, D301
1,610-20	,,	,, ,,	,, ,,	D283, D295
1,805-15	,,	grey, sandy siltstone	,, ,,	D286, D294
2,010-20	,,	,, ,,	,, ,,	D287, D293
2,200-210	,,	greenish-grey mudstone	,, ,,	D284, D292
2,380-90	,,	greenish-grey siltstone	,, ,,	D272
2,586-96	,,	dark grey, carbonaceous mudstone	,, ,,	D343
2,790-98	,,	dark grey mudstone	,, ,,	D346
2,990-3,000	,,	grey, micaceous siltstone	,, ,,	D345, D349
3,180-90	,,	grey sandstone	,, ,,	D342
3,363-73	,,	grey mudstone	,, ,,	D341
3,514-24	,,	,, ,,	Runnymede Formation, Lower Member	D340
3,715-21	,,	grey, laminated sandstone	,, ,,	D344, D348
3,850-55	cutting	coal	,, ,,	D276
4,392	core	grey mudstone with coalified plant remains	Mocamboro Member	D392
4,618	,,	grey carbonaceous siltstone	,, ,,	D394
4,766-76	,,	pale grey sandstone with carbonaceous matter	,, ,,	D393

3. Comaum Bore No. 2, sunk by South Australian Department of Mines, Hundred of Comaum (see Ludbrook 1961b). Core samples of the Runnymede Formation from:
    (a) 651 ft, grey mudstone; D367.
    (b) 708 ft, grey siltstone; D248, D262.

VICTORIA

1. Dergholm Bore No. 1, sunk by Victorian Department of Mines, Parish of Dergholm. Earth socket sample from 532 ft; brownish-grey mudstone; D210, D216, D299, ICC60/1.
2. Devil's Kitchen, 3½ miles SE. of mouth of Gellibrand River. Outcrop sample; grey mudstone from below Mesozoic/Palaeocene unconformity, Otway Group; coll. G. Baker, P22584; D219, D223.
3. Barongarook Creek, W. branch, 3 miles SE. of Colac. Outcrop sample; brownish siltstone with plant fragments, Otway Group; coll. E. D. Gill, P22585; D203.
4. Forrest Bore No. 1, sunk by Victorian Department of Mines. Core sample 7; dark grey mudstone containing *Velesunio* sp., Otway Group; P16770; D165.
5. Parish of Bellarine. Grey mudstone probably from No. 2 shaft marked on Q.S. 23 SE.; P22586; D163.
6. Barrabool Hills. Grey mudstone from carbonaceous conglomerate outcrop along Barwon River, Barrabool Sandstone; P22587; D249.

EASTERN VICTORIA

1. San Remo Peninsula. Outcrop sample; dark grey mudstone containing *Sphenopteris hispoli* Oldham & Morris from above coal measures; Strzelecki Group; P22588; D145, D150.
2. Kilcunda. Dull coal from outcrop on beach, Strzelecki Group; MUGD 2513; D134.
3. Wonthaggi State Coal Mine Area.
    (a) Grey shale, from an unspecified locality, containing '*Coniopteris hymenophylloides*' Brongn., Strzelecki Group; P22589; D239, D240.
    (b) No. 18 shaft. Banded coal, Strzelecki Group; coll. A. B. Edwards, P22590; D143, D278.
    (c) No. 18 shaft, Bore No. 2 at base of pillar. Coal, Strzelecki Group; coll. A. B. Edwards, P22591; D193.
    (d) No. 20 shaft, bottom seam, 1 E. (SE. dip). Blue coal, Strzelecki Group; coll. A. B. Edwards, P22592; D140.
    (e) No. 20 shaft, bottom seam, 1 E. (SE. dip). Splint and blue coal, Strzelecki Group; coll. A. B. Edwards, P22593; D141.
    (f) Western Area, top seam (W. dip). Coal, Strzelecki Group; P22594; D170.
    (g) Western Area, bottom seam (W. dip). Coal, Strzelecki Group; P22595; D171.
    (h) Western Area, top seam (E. workings). Coal, Strzelecki Group P22596; D142, D277.
    (i) Western Area, Bore No. ? at 100-140 ft. Coal, Strzelecki Group; P22597; D138.
    (j) Kirrak Area, W. heading (2). Coal. Strzelecki Group; coll. A. M. S. Ketch, P22598; D137.
    (k) Kirrak Area, W. heading (41^2). Coal, Strzelecki Group; coll. A. M. S. Ketch, P22599; D139.
4. Cape Paterson.
    (a) Shore platform near Petrel Rock, between Inverloch and Cape Paterson. Outcrop sample; grey mudstone, Strzelecki Group; coll. A. Baker, P22600; D146, D149.
    (b) Shore platform E. of dyke marked on Q.S. 76 SW., W. of Inverloch. Outcrop sample; grey laminated siltstone with plant fragments, Strzelecki Group; coll. E. D. Gill, P22601; D162.
5. Parish of Outtrim.
    (a) Bore No. 6, sunk by Victorian Department of Mines, at 225-6 ft. Core sample; coal, Strzelecki Group; D309.
    (b) Bore No. 7, sunk by Victorian Department of Mines, at 669·9 ft. Core sample; coaly shale, Strzelecki Group; D310.
    (c) Bore No. 8, sunk by Victorian Department of Mines, at 325·9 ft. Core sample; coaly shale, Strzelecki Group; D311.

6. Parish of Jumbunna E. Bore No. 57, sunk by Victorian Department of Mines. Core samples examined include:

Depth (ft)	Rock type	Stratigraphical unit	Preparation
230	coal	Strzelecki Group	D269
252	coaly shale	,, ,,	D271
1,022	coal	,, ,,	D279
1,065	coaly shale	,, ,,	D270
1,107	,, ,,	,, ,,	D268

7. Whitelaw Railway Station. Outcrop sample; shale containing *Brachyphyllum gippslandicum* McCoy, Strzelecki Group (see Medwell 1954b); P12805; D176.
8. Paradise Creek, Boola Forest. Outcrop sample; highly carbonaceous slate from near base of Tyers Group; coll. J. Douglas, P22733; D397.
9. Rintoul's Creek, N. of Traralgon. Outcrop sample; coal from lowest seam, Tyers Group (see Philip 1958); coll. G. M. Philip, P22602; D316.
10. Parish of Bengworden South. Bore No. 1, sunk by commission of Commonwealth and Victorian Governments near W. shore of Lake Victoria, at 3,977 ft. Core sample; grey mudstone (see Crespin 1941, Webb 1961); Victorian Department of Mines No. 44627; D315.

New South Wales

1. County Gregory, Warren District; Portion 6, Parish Nina; Bore No. 10528 at 560 ft. Coal; P22603; D319.

References

Arkell, W. J., 1956. *Jurassic Geology of the World*. Oliver and Boyd, London.

Baker, G., and Cookson, I. C., 1955. Age of Nelson Bore sediments. *Aust. J. Sci.* 17: 133-134.

Balme, B. E., 1956. Plant microfossils and the geological age of the Donnybrook Sandstone. *Aust. J. Sci.* 18: 127-128.

————, 1957. Spores and pollen grains from the Mesozoic of Western Australia. *C.S.I.R.O. Aust., Coal Res. Sect.* T.C. 25: 1-48.

————, 1963. Plant microfossils from the Lower Triassic of Western Australia. *Palaeontology* 6: 12-40.

Bennie, J., and Kidston, R., 1886. On the occurrence of spores in the Carboniferous Formation of Scotland. *Proc. Roy. Phys. Soc. Edinb.* 9: 82-117.

Bhardwaj, D. C., 1957a. The palynological investigations of the Saar coals (Part I—Morphography of Sporae dispersae). *Palaeontographica* B101: 73-125.

————, 1957b. The spore flora of Velener Schichten (Lower Westphalian D) in the Ruhr Coal Measures. *Palaeontographica* B102: 110-138.

Bolkhovitina, N. A., 1953. Spores and pollen characteristic of Cretaceous deposits of central regions of U.S.S.R. *Tr. Inst. Geol., Akad. Nauk S.S.S.R.* 145 (Geol. Ser. 61): 184 p. (in Russian).

————, 1956. Atlas of the spores and pollen grains in Jurassic and Lower Cretaceous coals of the Viliusk Basin. *Tr. Inst. Geol., Akad. Nauk S.S.S.R.* 2: 185 p. (in Russian).

————, 1959. Spore-pollen complexes of the Mesozoic deposits in the Viliusk Basin and their stratigraphical significance. *Tr. Inst. Geol., Akad. Nauk S.S.S.R.* 24: 185 p. (in Russian).

————, 1961. Fossil and recent spores in the Schizaeaceae. *Tr. Inst. Geol., Akad. Nauk S.S.S.R.* 40: 176 p. (in Russian).

Boutakoff, N., 1956. The significance of oil discovery in South Gippsland. *Min. Geol. J.* 6: 15-21.

Brunnschweiler, R. O., 1959. New Aconeceratinae (Ammonoidea) from the Albian and Aptian of Australia. *Bull. Bur. Min. Resour. Aust.* 54: 20 p.

Butterworth, M. A., and Williams, R. W., 1958. The small spore floras of coals in the Limestone Coal Group and Upper Limestone Group of the Lower Carboniferous of Scotland. *Trans. Roy. Soc. Edinb.* 63: 353-392.

Byran, W. H., and Jones, O. A., 1946. The Geological History of Queensland. A stratigraphical outline. *Pap. Dept Geol. Univ. Qd* 2: 103 p.

Chaloner, W. G., 1953. A new species of *Lepidostrobus* containing unusual spores. *Geol. Mag.* 90: 97-110.

————, 1958. *Polysporia mirabilis* Newberry, a fossil lycopod cone. *J. Paleont.* 32: 199-209.

Chaloner, W. G., and Clarke, R. F. A., 1962. A new British Permian spore. *Palaeontology* 4: 648-652.

Chapman, F., 1908. Report on Jurassic plants. *Rec. Geol. Surv. Vict.* 2: 212-220.

————, 1909. Jurassic plant remains from Gippsland. *Rec. Geol. Surv. Vict.* 3: 103-111.

Chlonova, A. F., 1960. Specific content of pollen and spores in Upper Cretaceous sediments of Chulymo-eniseiskoi Basin. *Tr. Inst. Geol. Geophys., Akad. Nauk S.S.S.R. Novosibirsk* 3: 104 p. (in Russian).

————, 1961. Spores and pollen of the upper part of the Upper Cretaceous from the eastern part of the Western Siberian depression. *Tr. Inst. Geol. Geophys., Akad. Nauk S.S.S.R. Novosibirsk* 7: 138 p. (in Russian).

Condon, M. A., Fisher, N. H., and Terpstra, G. R. J., 1960. Summary of oil-search activities in Australia and New Guinea to June, 1959. *Rep. Bur. Min. Resour. Aust.* 41A: 68 p.

Cookson, I. C., 1947. Plant microfossils from the lignites of Kerguelen Archipelago. *B.A.N.Z. Antarctic Res. Exp. 1929-31, Rep.* A2: 127-142.

————, 1953. Difference in microspore composition of some samples from a bore at Comaum, South Australia. *Aust. J. Bot.* 1: 462-473.

————, 1954. A palynological examination of No. 1 bore, Birregurra, Victoria. *Proc. Roy. Soc. Vict.* 66: 119-128.

————, 1956. Additional microplankton from Australian late Mesozoic and Tertiary sediments. *Aust. J. Mar. Freshw. Res.* 7: 183-191.

————, 1961. *Hoegisporis*, a new Australian Cretaceous form genus. *Palaeontology* 3: 485-486.

Cookson, I. C., and Balme, B. E., 1962. *Amosopollis cruciformis* gen. et sp. nov., a pollen tetrad from the Cretaceous of Western Australia. *J. Roy. Soc. W. Aust.* 45: 97-99.

Cookson, I. C., and Dettmann, M. E., 1958a. Cretaceous 'megaspores' and a closely associated microspore from the Australian region. *Micropaleontology* 4: 39-49.

————, ————, 1958b. Some trilete spores from Upper Mesozoic deposits in the eastern Australian region. *Proc. Roy. Soc. Vict.* 70: 95-128.

————, ————, 1959a. Microfloras in bore cores from Alberton West, Victoria. *Proc. Roy. Soc. Vict.* 71: 31-38.

————, ————, 1959b. On *Schizosporis*, a new form genus from Australian Cretaceous deposits. *Micropaleontology* 5: 213-216.

————, ————, 1959c. *Cyclosporites*, Cretaceous microspore: corrected name. *Aust. J. Sci.* 21: 260.

————, ————, 1959d. Corrigenda for 'Some trilete spores from Upper Mesozoic deposits in the eastern Australian region'. (1958b above) *Proc. Roy. Soc. Vict.* 71: 138.

————, ————, 1961. Reappraisal of the Mesozoic microspore genus *Aequitriradites*. *Palaeontology* 4: 425-427.

Cookson, I. C., and Duigan, S. L., 1951. Tertiary Araucariaceae from south-eastern Australia, with notes on living species. *Aust. J. Sci. Res.* B4: 415-449.

Cookson, I. C., and Eisenack, A., 1958. Microplankton from Australian and New Guinea Upper Mesozoic sediments. *Proc. Roy. Soc. Vict.* 70: 19-79.

————, ————, 1960a. Microplankton from Australian Cretaceous sediments. *Micropaleontology* 6: 1-18.

————, ————, 1960b. Upper Mesozoic microplankton from Australia and New Guinea. *Palaeontology* 2: 243-261.

————, ————, 1961. Upper Cretaceous microplankton from the Belfast No. 4 bore, south-western Victoria. *Proc. Roy. Soc. Vict.* 74: 69-76.

————, ————, 1962. Additional microplankton from Australian Cretaceous sediments. *Micropaleontology* 8: 485-507.

Cookson, I. C., and Pike, K. M., 1954. The fossil occurrence of *Phyllocladus* and two other podocarpaceous types in Australia. *Aust. J. Bot.* 2: 60-68.

Coulson, A., 1930. Notes on the Jurassic rocks of the Barrabool Hills near Geelong, Victoria. *Proc. Roy. Soc. Vict.* 43: 36-41.

————, 1960. Some structural features in the Barrabool Hills. *Proc. Roy. Soc. Vict.* 72: 45-52.

Couper, R. A., 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. *N.Z. Geol. Surv. Pal. Bull.* 22: 77 p.

———, 1958. British Mesozoic microspores and pollen grains, a systematic and stratigraphic study. *Palaeontographica* B103: 75-179.

———, 1960. New Zealand Mesozoic and Cainozoic plant microfossils. *N.Z. Geol. Surv. Pal. Bull.* 32: 88 p.

Crespin, I., 1941. Palaeontological review of the Holland's Landing Bore, Gippsland. *Min. Geol. J.* 2: 252-256.

———, 1954. The Nelson Bore, south-western Victoria, micropalaeontology and stratigraphical succession. *Rep. Bur. Min. Resour. Aust.* 11: 39 p.

Cundill, J., and Bollen, P. W., 1961. Completion Report, Oil Development N.L. Penola Well No. 1. R. Hare and Associates, Melbourne.

Deflandre, G., and Cookson, I. C., 1954. Sur le microplancton fossile conservé dans diverses roches sédimentaires Australiennes s'étageant du Cretacé inferieur au Miocene superiéur. *C.R. Acad. Sci.* 239: 1235-1238.

———, ———, 1955. Fossil microplankton from Australian late Mesozoic and Tertiary sediments. *Aust. J. Mar. Freshw. Res.* 6: 242-313.

Delcourt, A. F., Dettmann, M. E., and Hughes, N. F., 1963. Revision of some Lower Cretaceous microspores from Belgium. *Palaeontology* 6: 282-292.

Delcourt, A., and Sprumont, G., 1955. Les spores et grains de pollen du Wealdien du Hainaut. *Mem. Soc. Belg. Geol.* 4: 73 p.

———, ———, 1957. Quelques microfossiles du Wealdien de Féron-Glageon. *Bull. Soc. Belge Geol. Pal. Hydr.* 66: 57-67.

———, ———, 1959. Spores, grains de pollen, Hystrichosphères et Peridiniens dans le Wealdien de Féron-Glageon. *Ann. Soc. Geol. Nord.* 79: 29-64.

Dettmann, M. E., 1959. Upper Mesozoic microfloras in well cores from Woodside and Hedley, Victoria. *Proc. Roy. Soc. Vict.* 71: 99-105.

———, 1961. Lower Mesozoic megaspores from Tasmania and South Australia. *Micropaleontology* 7: 71-86.

Dettmann, M. E., and Playford, G., 1963. Sections of some spores from the Lower Carboniferous of Spitsbergen. *Palaeontology* 5: 679-681.

Dev, S., 1961. The fossil flora of the Jabalpur Series—3. Spores and pollen grains. *Palaeobotanist* 8: 43-56.

Dijkstra, S. J., 1951. Wealden megaspores and their stratigraphical value. *Meded. Geol. Sticht. N.S.* 5: 7-23.

Döring, H., 1961. Planktonartige Fossilien des Jura/Kreide-Grenzbereichs der Bohrungen Werle (Mecklenburg). *Geologie* 10: Beih. 32, 110-121.

Douglas, J., 1961a. Microplankton of the Deflandreidae Group in Western District sediments. *Min. Geol. J.* 6: 17-32.

———, 1961b. *Ginkgoites* cuticle from Port Campbell. *Min. Geol. J.* 6: 47-50.

———, 1962. The occurrence of *Otozamites* in south-eastern Victoria. *Proc. Roy. Soc. Vict.* 75: 41-43.

Duigan, S. L., and Cookson, I. C., 1956. The occurrence of *Azolla filiculoides* L. and associated vascular plants in a Quaternary deposit in Melbourne, Australia. *Proc. Roy. Soc. Vict.* 69: 5-13.

Duthie, A. V., and Garside, S., 1936. Studies in South African Ricciaceae. 1, Three annual species. *R. plana* Taylor, *R. cupulifera* sp. nov., and *R. curtisii* T. P. James. *Trans. Roy. Soc. S. Afr.* 24: 93-133.

Edwards, A. B., and Baker, G., 1943. Jurassic arkose in southern Victoria. *Proc. Roy. Soc. Vict.* 55: 195-228.

Edwards, A. B., Baker, G., and Knight, J. L., 1944. The geology of the Wonthaggi Coalfield. *Proc. Aust. Inst. Min. Engrs.* 134: 54 p.

Eisenack, A., and Cookson, I. C., 1960. Microplankton from Australian Lower Cretaceous sediments. *Proc. Roy. Soc. Vict.* 72: 1-10.

Erdtman, G., 1947. Suggestions for the classification of fossil and recent pollen grains and spores. *Svensk bot. Tidskr.* 41: 104-114.

———, 1952. *Pollen Morphology and Plant Taxonomy. Angiosperms.* Waltham, Mass.

———, 1957. *Pollen and Spore Morphology/Plant Taxonomy; Gymnospermae, Pteridophyta, Bryophyta.* Almqvist and Wiksells, Stockholm.

———, 1960. The acetolysis method, a revised description. *Svensk bot. Tidskr.* 54: 561-564.

Erdtman, G., and Straka, H., 1961. Cormophyte spore classification. *Geol. Fören. Stockh. Förh.* 83: 65-78.

FAEGRI, K., and IVERSEN, J., 1950. *Text-book of Modern Pollen Analysis.* Munksgaard, Copenhagen.

FLORIN, R., 1952. On two conifers from the Jurassic of south-eastern Australia. *Palaeobotanist* 1: 177-182.

FULFORD, M., 1956. The young stages of leafy Hepaticea. *Phytomorphology* 6: 199-235.

GLAESSNER, M. F., and PARKIN, L. W. (Eds), 1958. *The Geology of South Australia.* Melbourne University Press, Australia.

GLAESSNER, M. F., and RAO, V. R., 1955. Lower Cretaceous plant remains from the vicinity of Mount Babbage, South Australia. *Trans. Roy. Soc. S. Aust.* 78: 134-140.

GROOT, J. J., and PENNY, J. S., 1960. Plant microfossils and age of nonmarine Cretaceous sediments of Maryland and Delaware. *Micropaleontology* 6: 225-236.

GROOT, J. J., PENNY, J. S., and GROOT, C. R., 1961. Plant microfossils and age of Raritan, Tuscaloosa, and Magothy formations of the Eastern United States. *Palaeontographica* B108: 121-140.

HAMMEN, TH. VAN DER, 1956a. A palynological systematic nomenclature. *Boletin Geologico* 4: 63-101.

————, 1956b. Description of some genera and species of fossil pollen and spores. *Boletin Geologico* 4: 111-112.

HARRIS, T. M., 1938. *The British Rhaetic Flora.* British Museum (Natural History), London.

————, 1961. *The Yorkshire Jurassic Flora I, Thallophyta—Pteridophyta.* British Museum (Natural History), London.

HARRIS, W. F., 1955. A manual of the spores of New Zealand. Pteridophyta. *Bull. New Zealand Dept. Sci. Indust. Res.* 116: 186 p.

HILL, D., and DENMEAD, A. K. (Eds), 1960. The geology of Queensland. *J. Geol. Soc. Aust.* 7: 474 p.

HUGHES, N. F., 1955. Wealden plant microfossils. *Geol. Mag.* 92: 201-217.

————, 1958. Palaeontological evidence for the age of the English Wealden. *Geol. Mag.* 95: 41-49.

HUGHES, N. F., and COUPER, R. A., 1958. Palynology of the Brora Coal of the Scottish Middle Jurassic. *Nature* 181: 1482-1483.

HUGHES, N. F., DETTMANN, M. E., and PLAYFORD, G., 1962. Sections of some Carboniferous dispersed spores. *Palaeontology* 5: 247-252.

International Code of Botanical Nomenclature adopted by the ninth International Botanical Congress, Montreal, August 1959—Utrecht 1961.

ISHCHENKO, A. M., 1952. Atlas of the microspores and pollen of the Middle Carboniferous of the western part of the Donetz Basin. *Izd. Akad. Nauk Ukrainian S.S.R., Inst. Geol. Nauk*: 83 p. (in Russian).

IVERSEN, J., and TROELS-SMITH, J., 1950. Pollenmorphologiske definitioner og typer. *Danm. geol. Unders.* 3: 54 p.

JANSONIUS, J., 1962. Palynology of Permian and Triassic sediments, Peace River area, western Canada. *Palaeontographica* B110: 35-98.

JERSEY, N. J. DE, 1951. Microspore correlation, Burrum Coalfield, *Qd Govt Min. J.* 52: 780-789.

————, 1955. Microspore correlation, Styx Coalfield. *Appendix 1 to Publ. geol. Surv. Qd* 281: 8-13.

————, 1959. Jurassic spores and pollen grains from the Rosewood Coalfield. *Qd Govt Min. J.* 60: 346-366.

————, 1962. Triassic spores and pollen grains from the Ipswich Coalfield. *Qd Dept Mines Publ.* 307: 18 p.

KARA-MURZA, E. N., 1954. Spores and pollen in Mesozoic deposits of the northern Eniseiko-lenskoi region (Jurassic—Cretaceous). *Tr. Nauk-issl Invest. geol. Arctic* 54 (in Russian).

————, 1960. Palynological evidence for the stratigraphical division of Mesozoic deposits of the Khatanga depression. *Tr. Nauk-issl Invest. geol. Arctic* 109: 134 p. (in Russian).

KEDVES, M., 1960. Etudes palynologiques dans le Bassin de Dorog—I. *Pollen et Spores* 2: 89-118.

————, 1961. Etudes palynologiques dans le Bassin de Dorog—II. *Pollen et Spores* 3: 101-154.

KENLEY, P. R., 1954. The occurrence of Cretaceous sediments in south-western Victoria. *Proc. Roy. Soc. Vict.* 66: 1-16.

————, 1959. The occurrence of marine Cretaceous sediments in the Belfast No. 4 bore, Port Fairy. *Min. geol. J.* 6: 55-56.

Klaus, W., 1960. Sporen der karnischen Stufe der ostalpinen Trias. *Jb. geol. Reichsanst.* 5: 107-184.

Knox, E. M., 1938. The spores of Pteridophyta with observations on microspores in coals of Carboniferous age. *Trans. Bot. Soc. Edinb.* 32: 438-466.

————, 1950. The spores of *Lycopodium*, *Phylloglossum*, *Selaginella*, and *Isoetes*, and their value in the study of microfossils of Palaeozoic age. *Trans. Bot. Soc. Edinb.* 35: 209-357.

Kremp, G. O. W., *Catalog of fossil spores and pollen: vol. 4. Cretaceous and Tertiary spores and pollen* (prepared by G. O. W. Kremp, H. T. Ames, and A. J. Kovar). The Pennsylvania State University, Pennsylvania.

Krutzsch, W., 1959. Mikropaläontologische (sporenpaläontologische) Untersuchungen in der Braunkohle des Geiseltales. *Geologie* 8 (Beih. 21/22): 425 p.

————, 1962. *Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nördlichen Mitteleuropas. 1. Laevigate und toriate Sporenformen.* Deutscher Verlag der Wissenschaften, Berlin.

Kuyl, O. S., Muller, J., and Waterbolk, H. T., 1955. The application of palynology to oil geology, with special reference to western Venezuela. *Geologie en Mijnbouw* 17: 49-75.

Ladyzhenskaja, K. I., 1961. Study of the spores of Hepaticae. *Bot. Mat. Otd. sporov. Rastenij, U.S.S.R.* 14: 243-252 (in Russian).

Lantz, J., 1958a. Étude des spores et pollens d'un échantillon purbeckien de l'ile d'Oléron. *Rev. Micropaléont.* 1: 33-37.

————, 1958b. Étude palynologique et quelques échantillons Mésozoiques due Dorset (Grande-Bretagne). *Rev. Inst. Franç. Pétrole* 13: 917-943.

Leschik, G., 1955. Die Keuperflora von Neuewelt bei Basel, II. Iso- und Mikrosporen. *Schweiz. palaeont. Abh.* 72: 9-70.

Ludbrook, N. H., 1961a. Mesozoic non-marine Mollusca (Pelecypoda Unionidae) from the north of South Australia. *Trans. Roy. Soc. S. Aust.* 84: 139-147.

————, 1961b. Stratigraphy of the Murray Basin in South Australia. *Bull. S.A. Dept. Mines* 36: 96 p.

————, 1963a. Material from the Frome Embayment. Appendix to Ker, D, Geology and Hydrology of the Frome Embayment. *Rep. Invest. Geol. Surv. S.A.* 25 (in press).

————, 1963b. Palaeontological report on Penola No. 1 Well. Appendix to Penola No. 1 Well Completion Report. *Pet. Search Subsidy Act* 42 (in press).

McCoy, F., 1867. On the recent zoology and palaeontology of Victoria. *Ann. Mag. Nat. Hist. Ser.* 3, 20: 196.

McQueen, A. F., 1961. The geology of the Otway Basin. *Aust. Oil & Gas J.* 8 (2): 8-13.

McWhae, J. H. R., et al., 1958. *The Stratigraphy of Western Australia.* Melbourne University Press, Australia.

Maljavikina, V. S., 1949. Identification of spores and pollen of the Jurassic and Cretaceous. *VNIGRI (Tr. All Union Petrol. Sci. Res., Geol. Expl. Inst.)* 33: 137 p. (in Russian).

————, 1958. Lower Cretaceous spores and pollen from the Gobi Oriental Basin. *VNIGRI (Tr. Vses. Neft. Nauchno-Issl Geol. Razved. Inst.)* 119: 131 p. (in Russian).

Manum, S., 1960. On the genus *Pityosporites* Seward 1941, with a new description of *Pityosporites antarcticus* Seward. *Nytt. Mag. Bot.* 8: 11-16.

————, 1962. Studies in the Tertiary flora of Spitsbergen, with notes on Tertiary floras of Ellesmere Island, Greenland, and Iceland. *Norsk. Polarinstitutt Skrifter* 125: 127 p.

Medwell, L. M., 1954a. A review and revision of the flora of the Victorian Lower Jurassic. *Proc. Roy. Soc. Vict.* 65: 63-111.

————, 1954b. Fossil plants from Killara near Casterton, Victoria. *Proc. Roy. Soc. Vict.* 66: 17-24.

Nakamura, J., and Shibasaki, T., 1959. Diagnostic characters of fern spores, I. Ophioglossaceae, Helminthostachyaceae, and Osmundaceae. *Res. Rep. Kôchi Univ.* 8: 11 p.

Naumova, S. N., 1939. Spores and pollen of coals of the U.S.S.R. *Rep. Int. Geol. Congr., 17th Session U.S.S.R* 1: 353-364

————, 1953. Spore-pollen complexes of the Upper Devonian of the Russian Platform and their stratigraphical value. *Tr. Inst. Geol. Nauk, Akad. Nauk S.S.S.R.* 143 (Geol. Ser. No. 60): 204 p. (in Russian).

Neves, R., 1961. Namurian plant spores from the Southern Pennines, England. *Palaeontology* 4: 247-279.

Nilsson, T., 1958. Uber das Vorkommen eines mesozoischen Sapropelgesteins in Schonen. *Lunds Universitets Årsskrift*, N.F., Avd. 2, 54: 112 p.

O'Driscoll, B. E., 1960. The hydrology of the Murray Basin Province in South Australia. *Bull. S.A. Dept Mines* 35: 149-300.

Pacltova, B., 1961. On some plant microfossils from fresh-water sediments of the Upper Cretaceous (Senonian) in the south Bohemian Basin. Part I. *Sborn. Ustred. Ust. Geol., odd palaeont.* 26: 47-102.

Pant, D. D., 1954. Suggestions for the classification and nomenclature of fossil spores and pollen grains. *Bot. Rev.* 20: 33-60.

Philip, G. M., 1958. The Jurassic sediments of the Tyers Group, Gippsland, Victoria. *Proc. Roy. Soc. Vict.* 70: 181-199.

Pierce, R. L., 1961. Lower Upper Cretaceous plant microfossils from Minnesota. *Bull. Minn. Geol. Surv.* 42: 86 p.

Playford, G., 1962. Lower Carboniferous microfloras of Spitsbergen—Part I. *Palaeontology* 5: 550-618.

Pocock, S. J., and Jansonius, J., 1961. The pollen genus *Classopollis* Pflug, 1953. *Micro-* western Canada and Australia. *J. Paleont.* 35: 1231-1234.

————, 1962. Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the western Canada plains. *Palaeontographica* B111: 1-95.

Pocock, S. J., and Jansonius, J., 1961. The pollen genus *Classopollis* Pflug, 1953. *Micropaleontology* 7: 439-449.

Potonie, R., 1931. Zur Mikroskopie der Braunkohlen. Tertiäre Sporen- und Blütenstaubformen. *Z. Braunkohle* 27: 554-556.

————, 1934. Zur Morphologie der fossilen Pollen und Sporen. *Arb. Inst. Paläob. Petrogr. Brennsteine* 4: 5-24.

————, 1951. Revision stratigraphisch wichtiger Sporomorphen des mitteleuropaischen Tertiars. *Palaeontographica* B91: 131-151.

————, 1956. Synopsis der Gattungen der Sporae dispersae. I. Teil: Sporites. *Beih. Geol. Jahrb.* 23: 103 p.

————, 1958. Synopsis der Gattungen der Sporae dispersae. II. Teil: Sporites (Nachträge), Saccites, Aletes, Praecoplates, Polyplicates, Monocolpates. *Beih. Geol. Jahrb.* 31: 114 p.

————, 1960. Synopsis der Gattungen der Sporae dispersae. III. Teil: Nachträge Sporites, Fortsetzung Pollenites. Mit Generalregister zu Teil I-III. *Beih. Geol. Jahrb.* 39: 189 p.

————, 1962. Synopsis der Sporae in situ. *Beih. Geol. Jahrb.* 52: 204 p.

Potonié, R., and Gelletich, J., 1933. Uber Pteridophyten-Sporen einer eözanen Braunkohle aus Dorog in Ungarn. *S.B. Ges. naturf. Fr. Berl.* 33: 517-526.

Potonié, R., and Kremp, G., 1954. Die Gattungen der paläozoischen Sporae dispersae und ihre Stratigraphie. *Geol. Jahrb.* 69: 111-194.

————, ————, 1955. Die Sporae dispersae des Ruhrkarbons, ihre Morphographie und Stratigraphie mit Ausblicken auf Arten anderer Gebiete und Zeitabschnitte Teil I. *Palaeontographica* B98: 1-136.

————, ————, 1956. Idem Teil II. *Palaeontographica* B99: 85-191.

Potonié, R., and Venitz, A., 1934. Zur Mikrobotanik des miozänen Humodils der niederrheinischen Bucht. *Arb. Inst. Paläob. Petrogr. Brennsteine* 5: 1-54.

Raatz, G. V., 1937. Mikrobotanisch-stratigraphische Untersuchung der Braunkohle des Muskauer Bogens. *Abb. preuss. geol. L.-A.N.F.* 183: 1-48.

Raistrick, A., 1934. The correlation of coal seams by microspore content. Pt 1: The seams of Northumberland. *Trans. Inst. Mining Engineers* 88: 142-153.

Reinhardt, P., 1962. Sporae dispersae aus dem Rhät Thüringens. *Monatsber. Deutschen Akad. Wiss. Berlin* 3 (Heft 11/12): 704-711.

Reissinger, A., 1950. Die 'Pollenanalyse' ausgedehnt auf alle Sedimentgesteine der geologischen Vergangenheit. *Palaeontographica* B90: 99-126.

Rogalska, M., 1956. Analiza sporowo-pylkowa liasowych osadów obszaru mroczków-rozwady w powicie opoczynskim. *Bull. Serv. géol. Pologne* 104: 1-89.

Ross, N. E., On a Cretaceous pollen and spore bearing clay deposit of Scania. *Bull. geol. Instn. Univ. Upsala* 34: 27-43.

Rouse, G. E., 1957. The application of a new nomenclatural approach to Upper Cretaceous plant microfossils from western Canada. *Can. J. Bot.* 35: 349-375.

————, 1959. Plant microfossils from Kootenay coal-measures strata of British Columbia. *Micropaleontology* 5: 303-324.

Sah, S., 1953. Spores and other micro-remains from a carbonaceous shale (Jurassic) in Andigama, Ceylon. *Spolia zeylan* 27: 1-12.

Samoilovitch, S. R., et al., 1961. Pollen and spores of western Siberia; Jurassic to Palaeocene. *VNIGRI (Tr. All Union Petrol. Sci. Res. Geol. Expl. Inst.)* 177: 657 p. (in Russian).

Sato, S., 1961. Pollen analysis of carbonaceous matter from the Hakobuchi Group in the Enbetsu district, northern Hokkaido, Japan. Palynological study on Cretaceous sediments (1). *J. Fac. Sci. Hokkaido Univ. (Geol.)* 11: 77-94.

Schopf, J. M., 1938. Spores from the Herrin (No. 6) Coal Bed in Illinois. *Rep. Invest. Ill. Geol. Surv.* 50: 73 p.

Schopf, J. M., Wilson, L. R., and Bentall, R., 1944. An annotated synopsis of Paleozoic fossil spores and the definition of generic groups. *Rep. Invest. Ill. geol. Surv.* 91: 112 p.

Selling, O. H., 1944. Studies in the recent and fossil species of *Schizaea*, with particular reference to their spore characters. *Acta Hort. Gothoburg.* 16: 1-113.

————, 1946. Studies in Hawaiian pollen statistics. I. The spores of the Hawaiian Pteridophytes. *Spec. Publ. Bishop Mus.* 37: 1-87.

Seward, A. C., 1904. On a collection of Jurassic plants from Victoria. *Rec. Geol. Surv. Vict.* 1: 155-187.

Sitholey, R. V., 1955. The Mesozoic and Tertiary floras of India—a review. *Palaeobotanist* 3: 55-69.

Spath, L. F., 1933. Revision of the Jurassic cephalopod fauna of Kachh (Cutch). *Palaeont. indica* N.S. 9: 659-945.

Staplin, F. L., 1960. Upper Mississippian plant spores from the Golata formation, Alberta, Canada. *Palaeontographica* B107: 1-40.

Thiergart, F., 1949. Der stratigraphische Wert mesozoischer Pollen und Sporen. *Palaeontographica* B89: 1-34.

————, 1950. Pollenfloren aus den tertiären Braunkohlen vom Niederrhein. *Geol. Jb.* 65: 81-106.

Thomson, P. W., and Pflug, H., 1952. Die alttertiäre Braunkohle der Tongrube Zievel. *Neues Jb. Min. Geol. Paläont.* 96: 1-26.

————, ————, 1953. Pollen und Sporen des Mitteleuropäischen Tertiärs. *Palaeontographica* B94: 1-138.

Udar, R., 1957. Culture studies in the genus *Riccia* (Mich.) L. *J. Indian bot. Soc.* 36: 580-586.

Van Campo, M., 1961. Mécanique aperturale. *Grana Palynologica* 2: 93-97.

Verbitskaya, E. I., 1958. Spore-pollen complexes of Cretaceous deposits in the Suchansky Coal Basin. *Tr. Lab. Geol. Ugl., Akad. Nauk S.S.S.R.* 8: 314-322 (in Russian).

————, 1962. Palynological evidence and stratigraphical subdivision of Cretaceous deposits of the Suchansky Coal Basin. *Tr. Lab. Geol. Ugl., Akad. Nauk S.S.S.R.* 15: 165 p. (in Russian).

Vishnu-Mittre, 1955. Petrified spores and pollen grains from the Jurassic rocks of Rajmahal Hills, Bihar. *Palaeobotanist* 3: 117-127.

Wadia, D. N., 1953. *Geology of India.* 3rd edition. Macmillan & Co., London.

Walkom, A. B., 1928. Fossil plants from Plutoville, Cape York Peninsula. *Proc. Linn. Soc. N.S.W.* 53: 145-150.

Webb, E. A., 1961. The geology and petroleum potentialities of the Gippsland area of Victoria. *Aust. Oil & Gas J.* 8 (2): 14-28.

Weyland, H., and Greifeld, G., 1953. Uber strukturbietende Blätter und pflanzliche Mikrofossilien aus den untersenonen Tonen der Gegend von Quedlinburg. *Palaeontographica* B95: 30-52.

Weyland, H., and Krieger, W., 1953. Die Sporen und Pollen der Aachener Kreide und ihre Bedeutung für die Charakterisierung des Mittleren Senons. *Palaeontographica* B95: 6-29.

Whitehouse, F. W., 1926. The correlation of the marine Cretaceous deposits of Australia. *Rep. Aust. Ass. Adv. Sci.* 18: 275-280.

————, 1955. Artesian water supplies in Queensland. Appendix G. The geology of the Queensland portion of the Great Artesian Basin. *Pap. Dep. Geol. Univ. Qd* 53: 20 p.

Whittle, A. W. G., and Chebotarev, N., 1952. Stratigraphic correlations by petrographic methods applied to artesian bores in the Lake Frome area. *Sir Douglas Mawson Anniversary Vol., Univ. of Adelaide*: 184-202.

Wigglesworth, V. B., 1959. A simple method for cutting sections in the 0·5 to 1 μ range, and for sections of chitin. *Quart. J. Micr. Sci.* 100: 315-320.

Wilson, L. R., and Webster, R. M., 1946. Plant microfossils from a Fort Union Coal of Montana. *Americ. J. Bot.* 33: 271-278.

Winslow, M. R., 1959. Upper Mississippian and Pennsylvanian megaspores and other plant microfossils from Illinois. *Bull. Ill. Geol. Surv.* 86: 135 p.

Woodard, G. D., 1955. The stratigraphic succession in the vicinity of Mount Babbage Station, South Australia. *Trans. Roy. Soc. S. Aust.* 78: 8-17.

WOODS, J. E. T., 1883. Physical structure and geology of Australia. *Proc. Linn. Soc. N.S.W.* 7: 371-389.

ZAUER, V. V., 1954. Fossil species of the genus *Cedrus* and their significance to the stratigraphy of continental deposits. *Information on palynology and stratigraphy; VNIGRI (Tr. All Union Nauk-Invest. Geol. Inst.)*: 10-85 (in Russian).

ZAUER, V. V., and MTCHEDLICHVILI, N. D., 1954. Spore-pollen complexes of Mesozoic and Cainozoic deposits in the region of the village Tyumeni. *Information on palynology and stratigraphy; VNIGRI (Tr. All Union Nauk-Invest. Geol. Inst.)*: 124-159 (in Russian).

Explanation of Plates

PLATE I

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-3—*Cyathidites australis* Couper. 1, Proximal focus; Robe Bore No. 1 at 4,300 ft, D227b/2 49·2 127·5 (P21960). 2, Distal focus; Robe Bore No. 1 at 3,860 ft, D226/1 54·9 121·3 (P21961). 3, Proximal focus of corroded specimen; Wonthaggi, sample P22589, D239/2 39·3 119·8 (P21962).

Fig. 4, 5—*Cyathidites minor* Couper. 4, distal view; Tilcha Bore No. 2 at 460-80 ft, D218/1 40·6 127·0 (P21963). 5, Proximal focus, Wonthaggi No. 20 shaft, sample P22593, D141/1 55·6 127·9 (P21964).

Fig. 6-9—*Cyathidites punctatus* (Delcourt & Sprumont). 6, 7, Proximal and distal foci; Penola Bore No. 1 at 1,805-15 ft, D294/1 29·9 110·2 (P21965). 8, Optical section of specimen showing 'lips' at margins of one laesura; Penola Bore No. 1 at 1,805-15 ft, D286/2 54·9 127·1 (P21966). 9, Proximal view of corroded specimen; Robe Bore No. 1 at 1,400 ft, D217/9 35·5 119·3 (P21967).

Fig. 10-16—*Cyathidites asper* (Bolkhovitina). 10, 11, Proximal and sectional foci; Penola Bore No. 1 at 1,805-15 ft, D286/2 54·7 110·0 (P21966). 12, 13, Sectional and distal foci; Penola Bore No. 1 at 1,610-20 ft, D295/1 55·5 108·7 (P21968). 14, Corroded specimen, proximal view; Robe Bore No. 1 at 1,400 ft, D224/1 33·7 112·2 (P21969). 15, lateral view; Penola Bore No. 1 at 1,610-20 ft, D295/2 35·0 120·8 (P21970). 16, Section showing one-layered exine which is weakly thickened at laesurate margins; Robe Bore No. 1 at 1,400 ft, D217/S58b/1 27·2 117·3 (P21971).

Fig. 17-19—*Cyathidites concavus* (Bolkhovitina). 17, Distal focus; Cootabarlow Bore No. 2 at 1,330-48 ft, D338/1 34·9 123·8 (P21972). 18, 19, Proximal and sectional foci; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/9 33·8 116·7 (P21973).

Fig. 20, 21—*Stereisporites antiquasporites* (Wilson & Webster). 20, × 750 showing distal polar and equatorial radial thickenings; Cape Paterson, sample P22600, D146/1 57·8 115·2 (P21974). 21, Proximal view × 750; Robe Bore No. 1 at 3,325 ft, D245/2 48·9 123·8 (P21975).

PLATE II

All figures × 500 and from unretouched negatives

Fig. 1, 2—*Biretisporites* cf. *B. potoniaei* Delcourt & Sprumont. Proximal and distal foci; Robe Bore No. 1 at 1,780 ft, D339/1 47·0 110·2 (P21976).

Fig. 3, 4—*Biretisporites spectabilis* sp. nov. Holotype; proximal surface, high and low foci. Cootabarlow Bore No. 2 at 1,376-77 ft, D289/3 46·5 123·8 (P21977).

Fig. 5-8—*Biretisporites spectabilis* sp. nov. 5, Proximal view; Kopperamanna Bore at 2,970 ft, D241/1 47·3 121·3 (P21978). 6, Lateral view; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/35 22·1 110·0 (P21979). 7, 8, Sections showing one-layered exine which forms the elevated laesurate lips; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S69/1-2 55·3 124·0 and 46·0 123·0 (P21980).

Fig. 9-12—*Dictyophyllidites pectinataeformis* (Bolkhovitina). 9, Proximal view showing thickened laesurate margins and membraneous lips; Penola Bore No. 1 at 1,805-15 ft, D286/2 57·4 125·0 (P21966). 10-12, Proximal, sectional, and distal foci; Robe Bore No. 1 at 1,400 ft, D224/1 22·6 116·6 (P21969).

PLATE III

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1, 2—*Dictyophyllidites crenatus* sp. nov. Holotype, proximal and sectional foci. Cootabarlow Bore No. 2 at 1,469-70 ft, D302/17 38·0 119·4 (P21981).

Fig. 3-5—*Dictyophyllidites crenatus* sp. nov. 3, Proximal view; Penola Bore No. 1 at 3,850-55 ft, D276/2 32·5 120·0 (P21982). 4, Deviating spore showing four laesurae; Robe Bore No. 1 at 4,300 ft, D227b/2 55·5 115·4 (P21960). 5, Lateral view showing membraneous lips; Robe Bore No. 1 at 4,300 ft, D227a/1 36·3 124·2 (P21983).

Fig. 6-9—*Leptolepidites verrucatus* Couper. 6, 7, Proximal views (7, × 1,000); Wonthaggi, Kirrak Area, sample P22599, D139/1 56·5 127·5 (P21984). 8, 9, Proximal and distal foci; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/2 24·8 116·6 (P21985).

Fig. 10-12—*Leptolepidites major* Couper. 10, Distal view; Cape Paterson, sample P22600, D146/2 52·2 127·9 (P21986). 11, 12, Proximal views (12, × 1,000); Wonthaggi, Kirrak Area, sample P22599, D139/2 53·3 115·4 (P21987).

Fig. 13-15—*Concavissimisporites penolaensis* sp. nov. Holotype, proximal, sectional, and distal foci. Penola Bore No. 1 at 1,610-20 ft, D295/1 54·9 108·9 (P21968).

Fig. 16—*Concavissimisporites penolaensis* sp. nov. Distal focus; Robe Bore No. 1 at 1,400 ft, ICC60/4 40·7 119·0 (P21988).

Fig. 17, 18—*Osmundacidites mollis* (Cookson & Dettmann). Lateral views, high and sectional foci; Barrabool Hills, sample P22587, D249/2 49·1 111·9 (P21989).

Fig. 19-21—*Osmundacidites wellmanii* Couper. 19, Proximal view of specimen showing coalescent granules; Koppcramanna Bore at 2,970 ft, D241/3 44·4 122·3 (P21990). 20, Optical section of a more finely sculptured specimen; Cootabarlow Bore No. 2 at 1,340 ft, D290/1 45·7 126·0 (P21991). 21, Proximal view showing granulate margins of laesurae; Penola Bore No. 1 at 1,805-15 ft, D294/1 53·4 121·9 (P21965).

Fig. 22, 23—*Baculatisporites comaumensis* (Cookson). Proximal and sectional foci; Barongarook Creek, sample P22585, D203/1 43·5 109·9 (P21992).

Plate IV

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-5—*Pilosisporites notensis* Cookson & Dettmann. 1, Proximal view; Robe Bore No. 1 at 4,300 ft. D227b/2 54·1 111·8 (P21960). 2, Lateral view; Cootabarlow Bore No. 2 at 1,354 ft, D242/4 51·8 126·5 (P21993). 3, Proximal focus of deviating specimen; Penola Bore No. 1 at 3,715-21 ft, D344/1 29·2 123·4 (P21994). 4, 5, Sections of a specimen from Robe Bore No. 1 at 3,860 ft; 4, D226/S70a/1-2 43·3 120·3 (P21995); 5, × 1,000, D226/S70a/3 54·6 126·9 (P21996).

Fig. 6, 7—*Pilosisporites parvispinosus* sp. nov. Holotype, proximal and distal foci. Comaum Bore No. 2 at 708 ft, D248/1 26·8 116·3 (P21997).

Fig. 8—*Pilosisporites parvispinosus* sp. nov. Proximal view of specimen figured by Cookson and Dettmann 1958b (Pl. 15, fig. 2); Robe Bore No. 1 at 3,860 ft, Cookson and Dettmann's slide B27 35·8 111·1 (P21998).

Plate V

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1, 2—*Pilosisporites grandis* sp. nov. Holotype, proximal and distal foci. Pretty Hill Bore No. 1 at 2,928-40 ft; ICC/1 41·3 111·8 (P22098).

Fig. 3—*Pilosisporites grandis* sp. nov. Sectional focus; Cootabarlow Bore No. 2 at 770-880 ft, D325/3 37·3 117·1 (P22000).

Fig. 4, 5—*Neoraistrickia truncatus* (Cookson). Proximal and sectional foci; Penola Bore No. 1 at 3,514-24 ft, D340/2 49·2 117·7 (P22001).

Fig. 6-8—*Ceratosporites equalis* Cookson & Dettmann. 6, Optical section; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/1 32·1 126·9 (P22002). 7, Distal view; Cootabarlow Bore No. 2 at 1,354 ft, D242/2 34·2 117·1 (P22003). 8, Lateral view; Wonthaggi, Kirrak Area, sample P22599, D139/2 29·0 115·2 (P21987).

Fig. 9-12—*Kuylisporites lunaris* Cookson & Dettmann. 9, Proximal focus × 750; Cootabarlow Bore No. 2 at 1,340 ft, D290/1 42·9 115·9 (P21991). 10, 11, Proximal and distal foci; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/34 43·8 114·3 (P22004). 12, Distal surface × 1,000 showing microreticulate surface pattern and detail of scutula; Penola Bore No. 1 at 2,010-20 ft, D293/2 39·8 118·3 (P22005).

Fig. 13-15—*Tripartina* cf. *T. variabilis* Maljavikina. 13, Distal focus; Oodnadatta Bore No. 1 at 1,287-92 ft, D237/1 36·7 117·3 (P22006). 14, 15, Proximal focus (15, × 1,000); San Remo, sample P22588, D145/1 54·5 128·8 (P22007).

Plate VI

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1, 2—*Lycopodiacidites asperatus* sp. nov. Holotype; Proximal surface, high and low foci. Koppcramanna Bore at 2,970 ft, D241/4 36·5 118·3 (P22008).

Fig. 3—*Lycopodiacidites asperatus* sp. nov. Distal focus; Kopperamanna Bore at 2,970 ft, D234/10 34·3 120·4 (P22009).

Fig. 4-7—*Cyclosporites hughesi* (Cookson & Dettmann). 4, Proximal surface; Cape Paterson, sample P22601, D162/2 35·0 118·4 (P22010). 5, Distal surface; Robe Bore No. 1 at 3,860 ft, D226/6 38·8 118·7 (P22011). 6, 7, × 1,000 showing proximal muri in surface view and optical section; Cape Paterson, sample P22600, D146/2 46·4 116·2 (P21986).

Fig. 8-13—*Foveotriletes parviretus* (Balme). 8-12, Specimen from Cootabarlow Bore No. 2 at 1,469-70 ft, D302/7 29·0 121·4 (P22012); 8, 9, proximal and distal foci; 10-12, × 1,000 optical section and surface views (high and low foci) of exine. 13, Distal surface of specimen having smaller foveolae; Cootabarlow Bore No. 2 at 1,447-64 ft, D296/2 52·9 111·4 (P22013).

Fig. 14-17—*Foveosporites canalis* Balme. 14, 15, Proximal and distal foci; San Remo, sample P22588, D145/1 50·1 127·3 (P22007). 16, 17, Proximal views (17, × 1,000); Cape Paterson, sample P22600, D149/2 41·8 112·2 (P22014).

Fig. 18-21—*Lycopodiumsporites austroclavatidites* (Cookson). 18, Proximal surface; Robe Bore No. 1 at 1,780 ft, D247/1 47·4 121·0 (P22015). 19-21, Specimens from Barongarook Creek, sample P22585; 19, 20, distal and lateral views, D203/1 58·9 109·8 and 54·2 110·1 respectively (P21992); 21, × 1,000 showing distal reticulum D203/2 40·8 114·1 (P22016).

Plate VII

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-3—*Lycopodiumsporites circolumenus* Cookson & Dettmann. 1, 2, Proximal and distal foci; Kopperamanna Bore at 2,970 ft, D241/1 29·7 124·2 (P21978). 3, × 1,000 showing portion of distal reticulum; Oodnadatta Bore No. 1 at 1,213 ft, D235/3 39·6 111·5 (P22017).

Fig. 4-7—*Lycopodiumsporites reticulumsporites* (Rouse). 4, 5, Proximal views (5, × 1,000); Wonthaggi, Kirrak Area, sample P22599, D139/2 39·9 124·3 (P21987). 6, 7, Proximal and distal foci; Penola Bore No. 1 at 3,850-55 ft, D276/1 48·0 123·3 (P22018).

Fig. 8-10—*Lycopodiumsporites eminulus* sp. nov. 8, 9, Proximal and distal foci; Penola Bore No. 1 at 3,850-55 ft, D276/2 56·4 123·4 (P21982). 10, Lateral view; Cape Paterson, sample P22601, D162/1 58·2 113·2 (P22019).

Fig. 11, 12—*Lycopodiumsporites eminulus* sp. nov. Holotype. Distal views (12, × 1,000); Wonthaggi, No. 20 shaft, sample P22593, D141/1 38·9 121·4 (P21964).

Fig. 13, 14—*Lycopodiumsporites nodosus* sp. nov. Holotype. Proximal and distal foci. Penola Bore No. 1 at 3,850-55 ft, D276/1 26·9 118·7 (P22018).

Fig. 15, 16—*Lycopodiumsporites nodosus* sp. nov. 15, Portion of distal surface, × 1,000, showing reticulum and granules; Wonthaggi, Kirrak Area, sample P22598, D137/1 23·5 116·6 (P22020). 16, Optical section of muri × 1,000; Robe Bore No. 1 at 3,860 ft, D226/1 49·3 117·9 (P21961).

Fig. 17-20—*Lycopodiumsporites facetus* sp. nov. Holotype. 17, 18, Proximal and distal foci; 19, 20, high and sectional foci of proximal reticulum × 1,000. Wonthaggi, Kirrak Area, sample P22599, D139/2 34·6 110·2 (P21987).

Fig. 21, 22—*Lycopodiumsporites facetus* sp. nov. 21, Distal view; Wonthaggi, Kirrak Area, sample P22599, D139/2 50·5 123·4 (P21987). 22, Optical section of two-layered exine, × 1,000, showing granulate exoexine; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/2 28·3 128·2 (P22021).

Fig. 23-26—*Reticulatisporites pudens* Balme. 23-25, Specimen from Comaum Bore No. 2 at 708 ft, D262/1 39·9 125·0 (P22022); 23, distal surface × 1,000; 24, 25, proximal and distal foci. 26, Distal view; Loxton Bore at 1,465-70 ft, D365/1 25·3 113·4 (P22023).

Plate VIII

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-7—*Klukisporites scaberis* (Cookson & Dettmann). 1, Proximal view; Cape Paterson, sample P22601, D162/2 32·0 118·6 (P22010). 2, Optical section; Wonthaggi sample P22589, D239/2 41·4 121·0 (P21962). 3-5, Specimen from Robe Bore No. 1 at 4,300 ft, D227b/1 44·8 117·0 (P22024); 3, distal focus; 4, 5, high and low foci of portion of distal reticulum × 1,000. 6, 7, Sections × 1,000 Wonthaggi, Kirrak Area, sample P22599, D139/S72b/1-2 49·1 121·7 and 22·9 121·7 respectively (P22025).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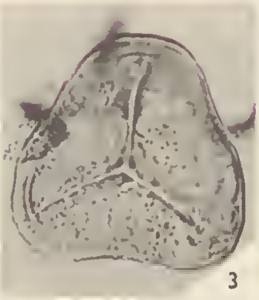
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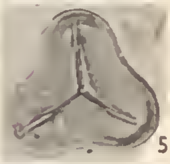
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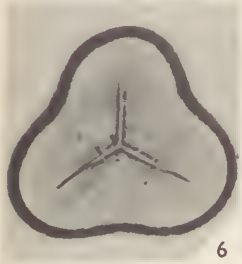
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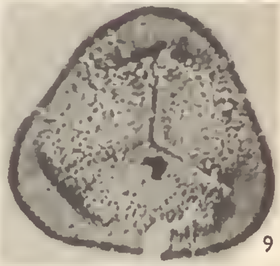
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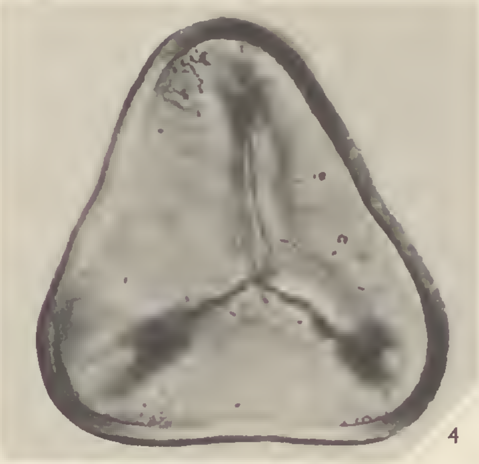
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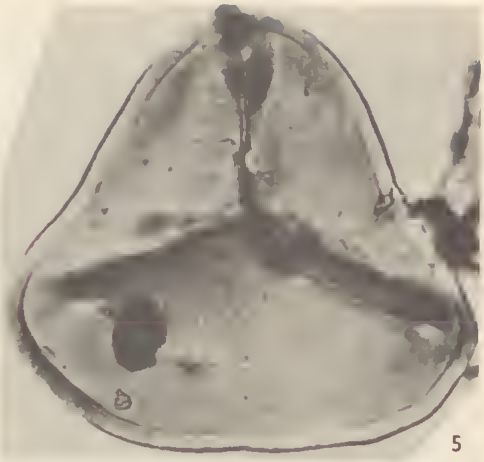
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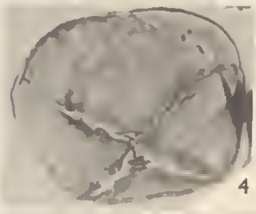
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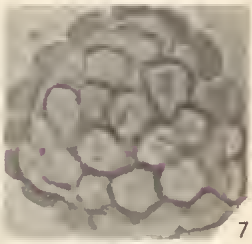
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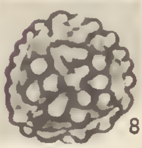
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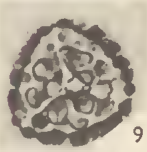
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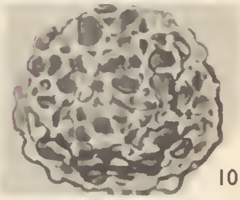
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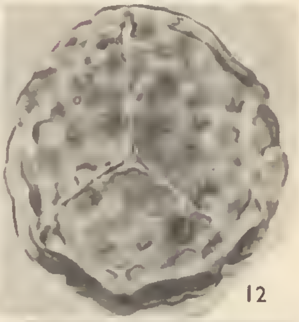
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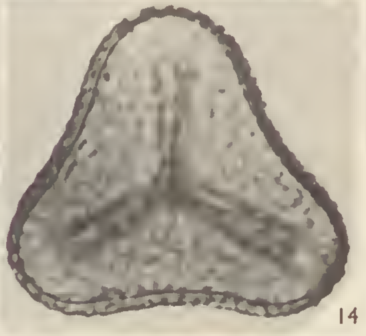
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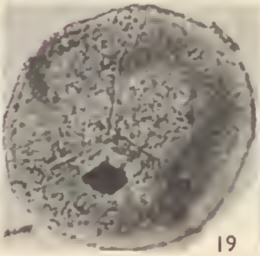
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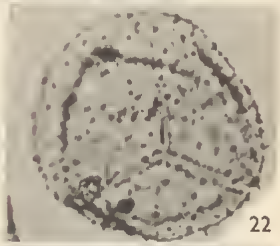
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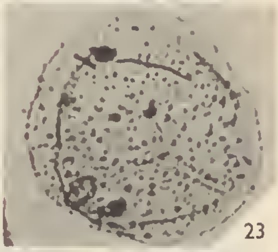
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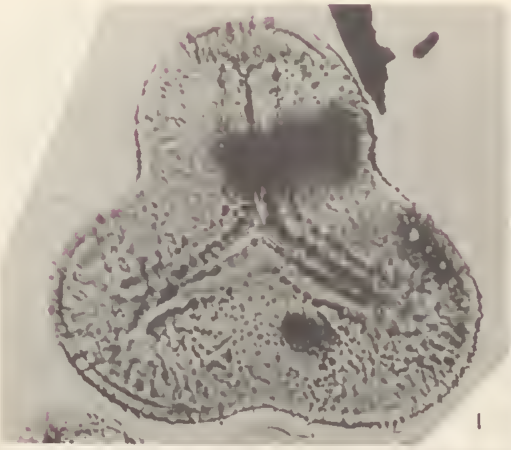
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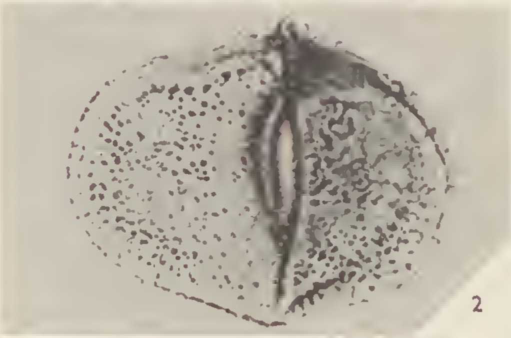
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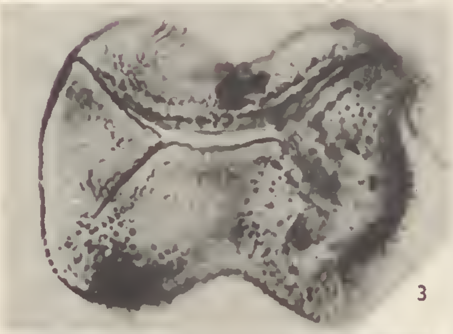
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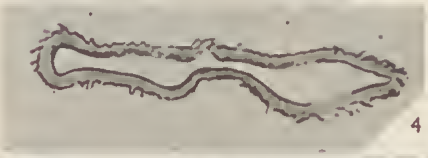
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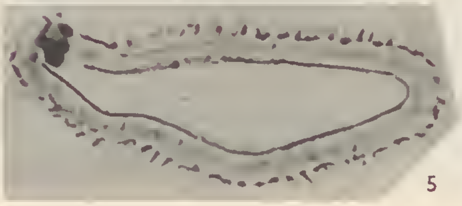
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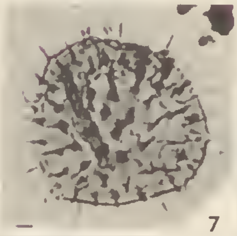
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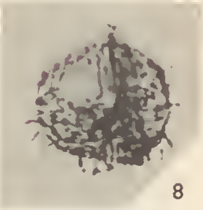
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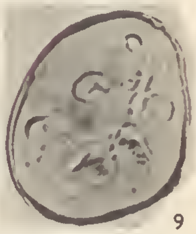
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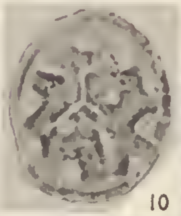
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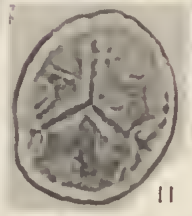
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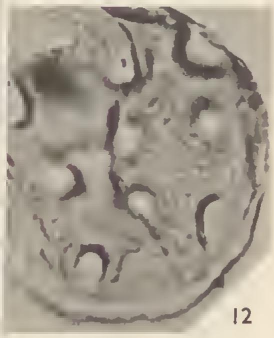
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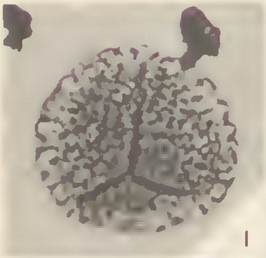
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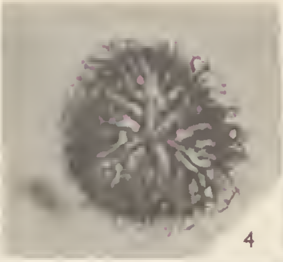
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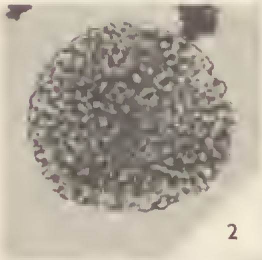
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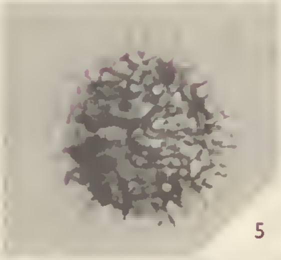
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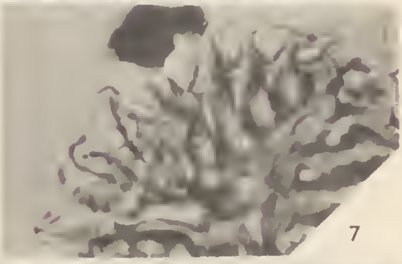
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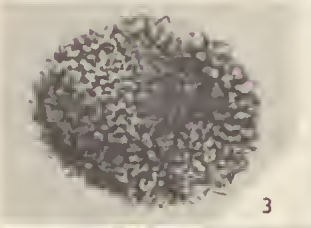
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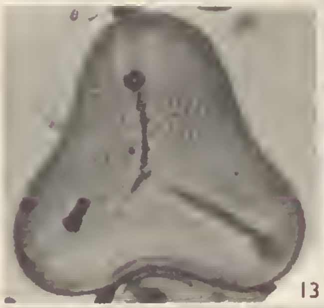
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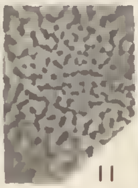
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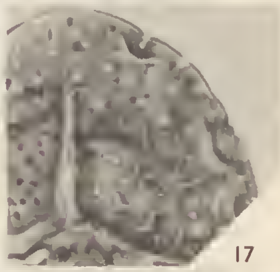
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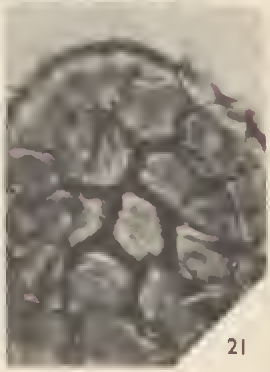
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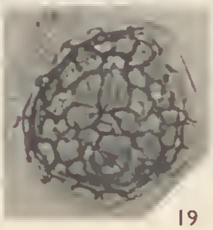
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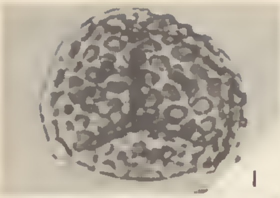
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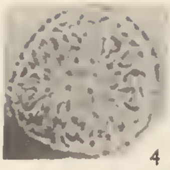
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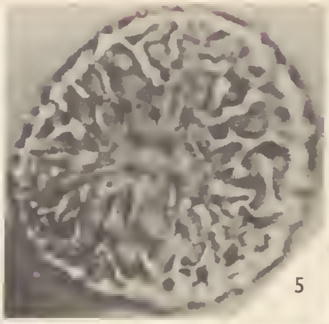
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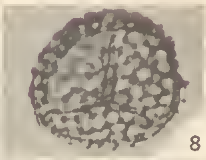
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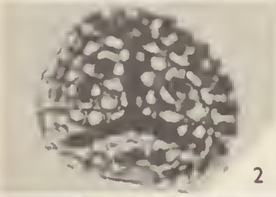
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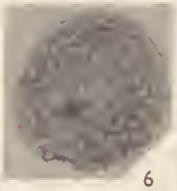
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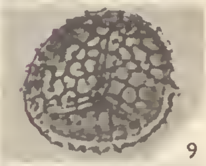
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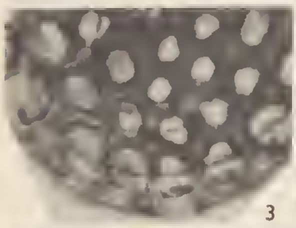
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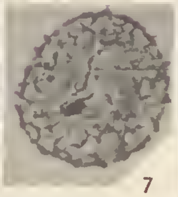
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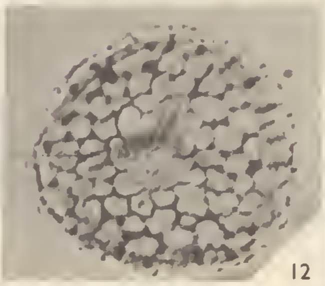
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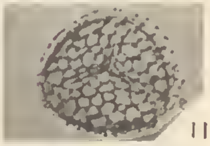
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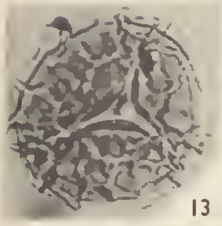
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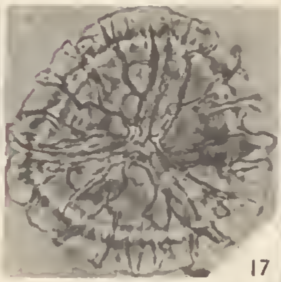
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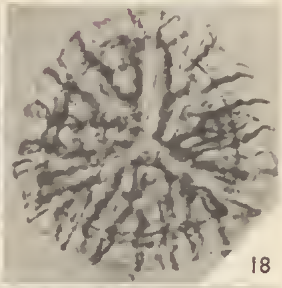
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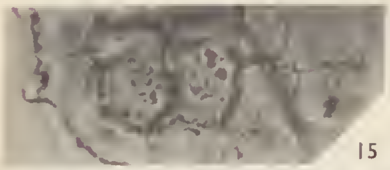
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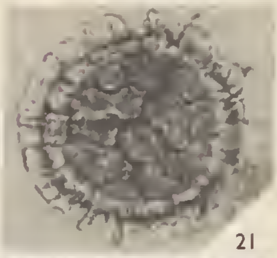
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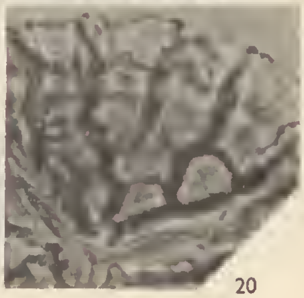
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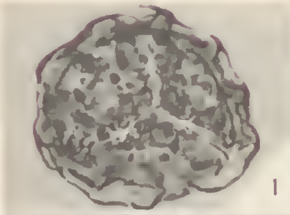
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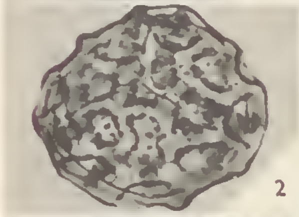
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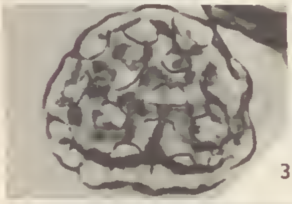
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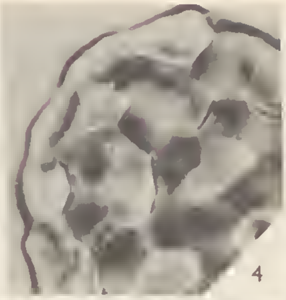
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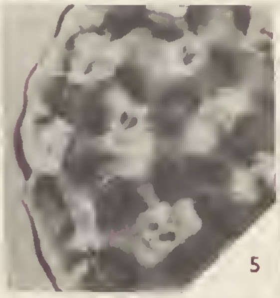
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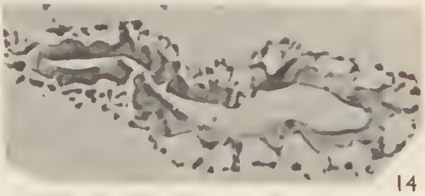
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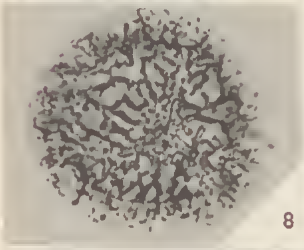
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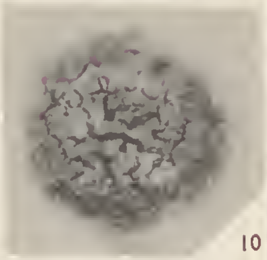
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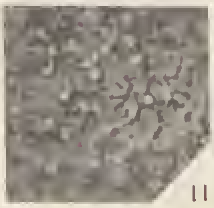
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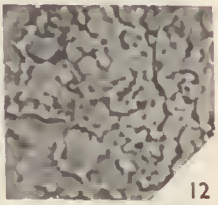
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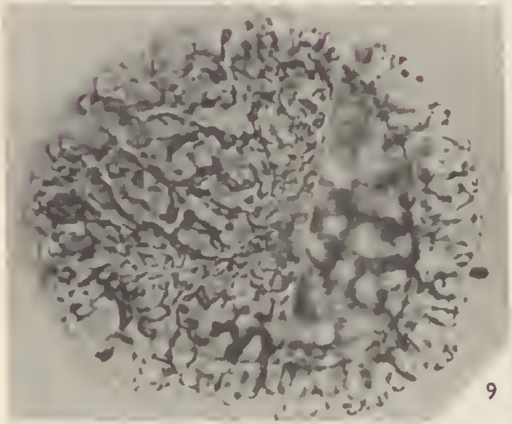
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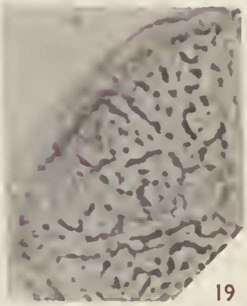
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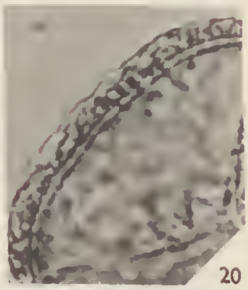
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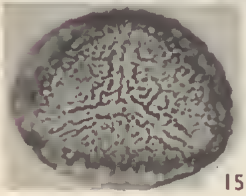
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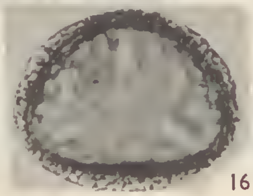
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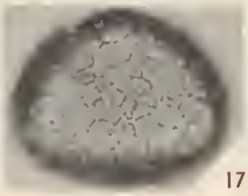
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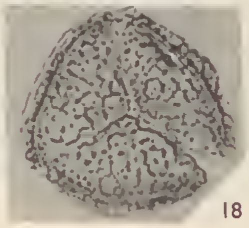
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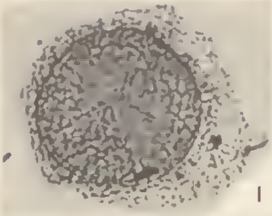
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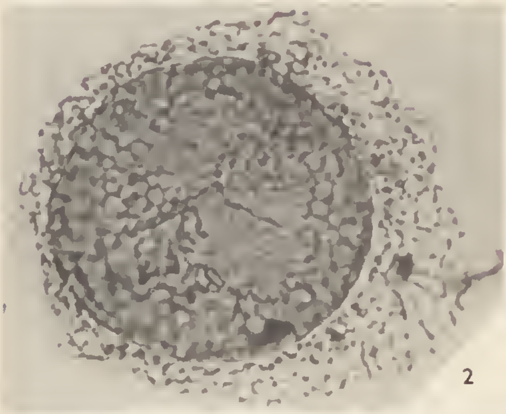
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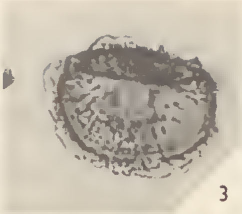
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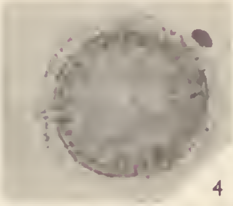
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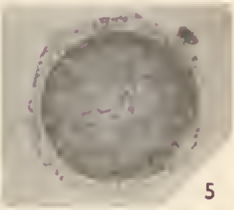
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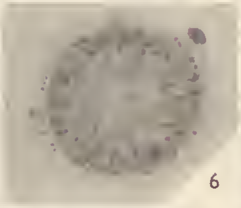
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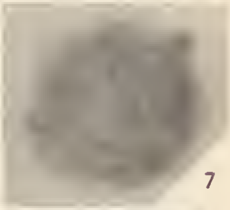
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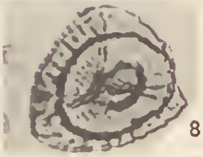
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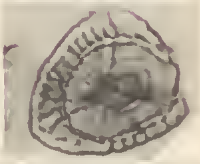
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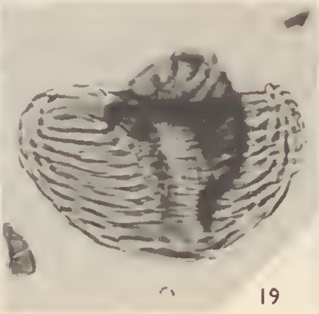
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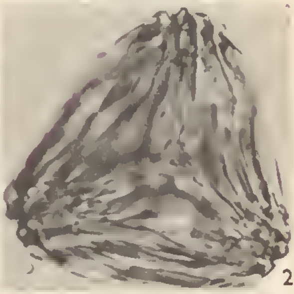
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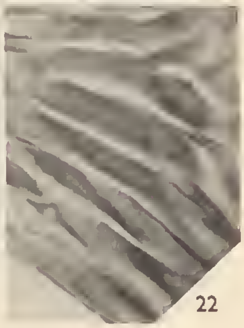
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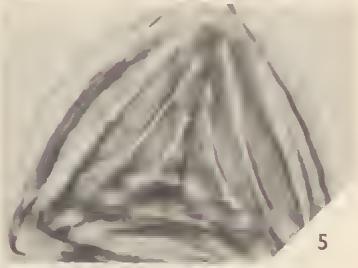
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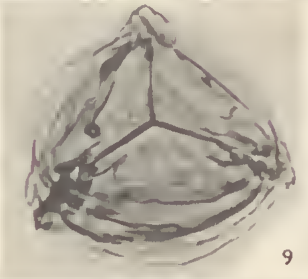
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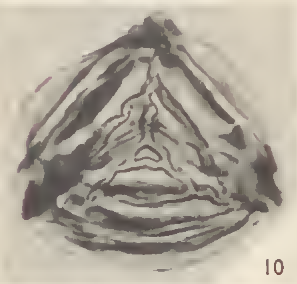
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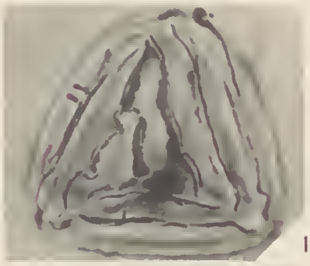
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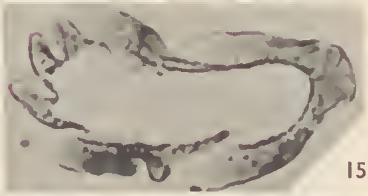
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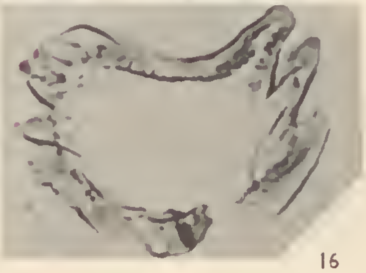
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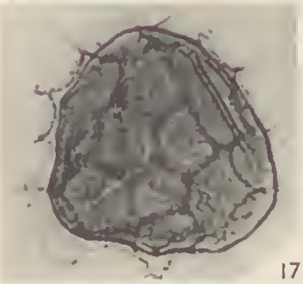
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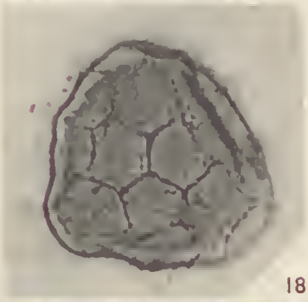
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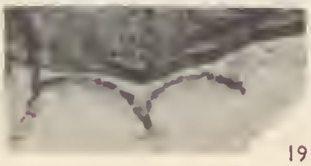
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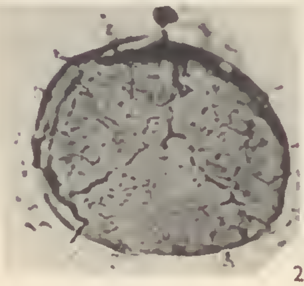
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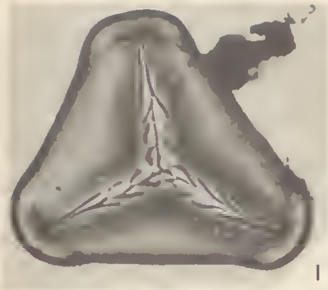
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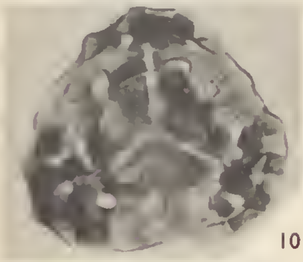
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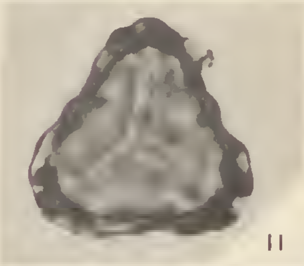
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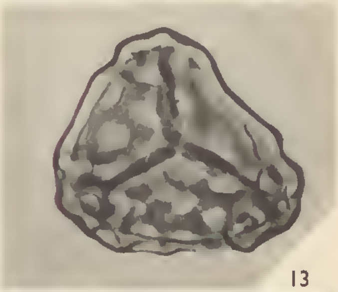
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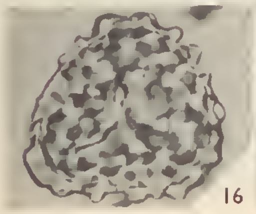
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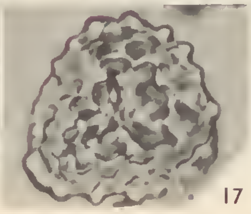
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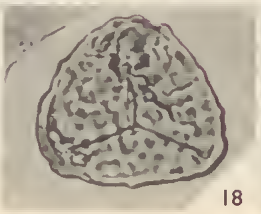
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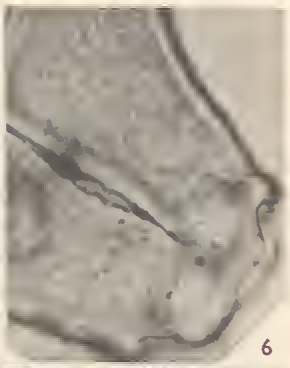
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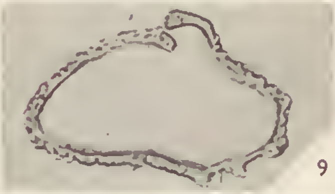
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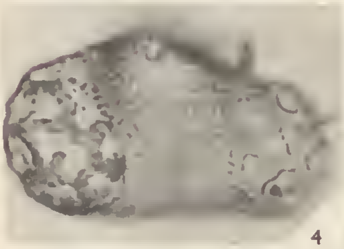
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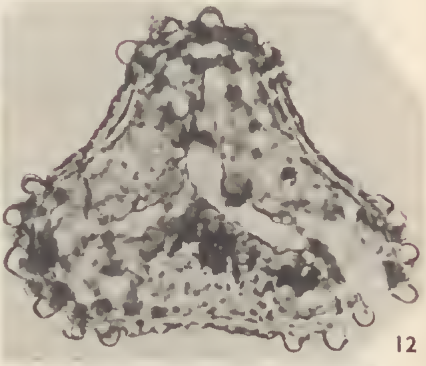
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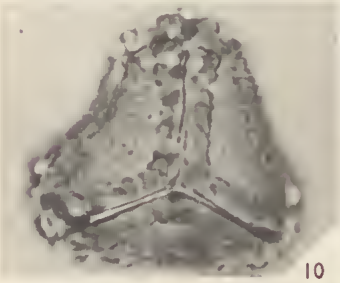
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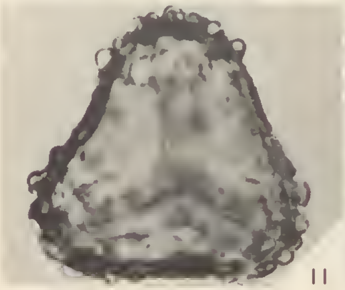
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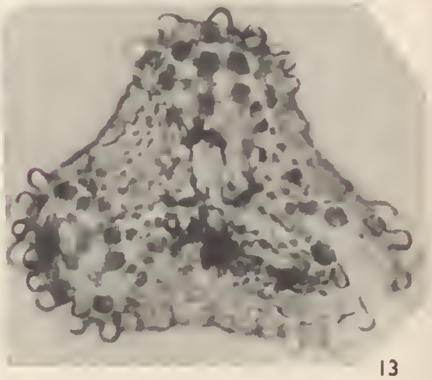
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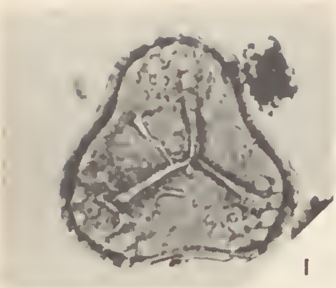
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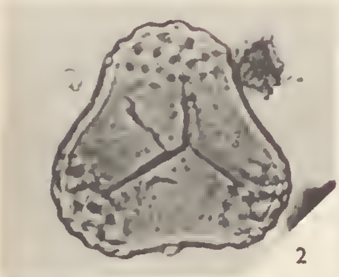
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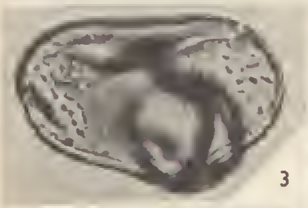
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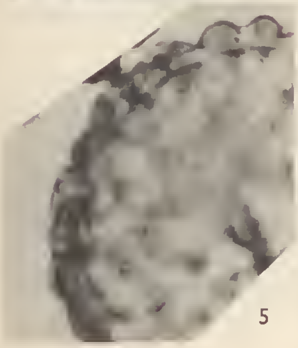
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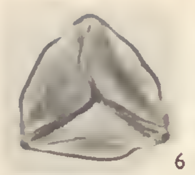
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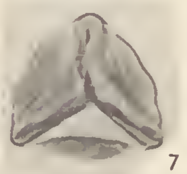
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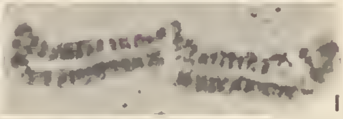
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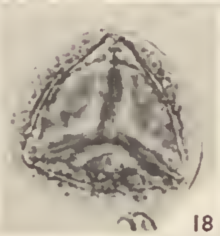
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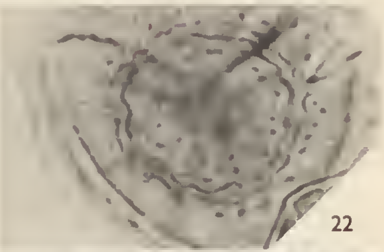
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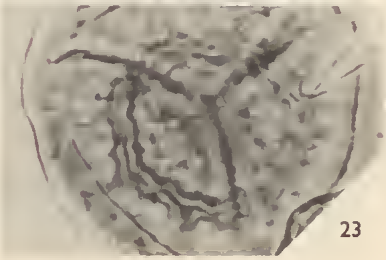
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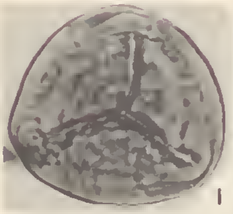
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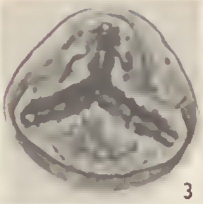
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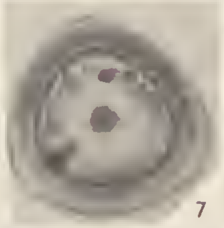
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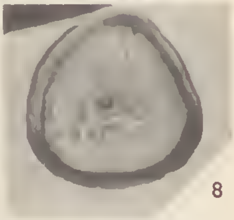
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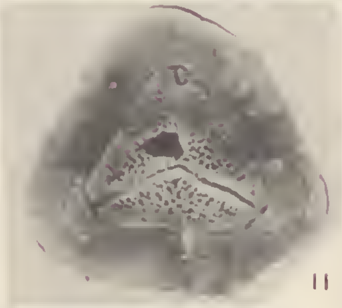
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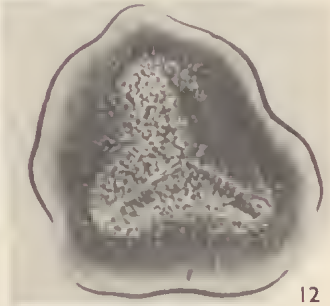
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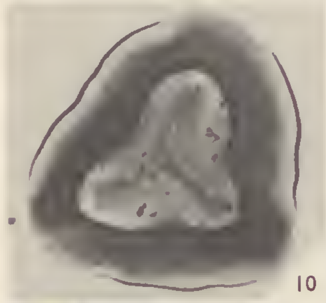
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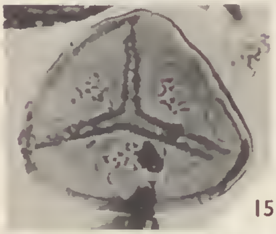
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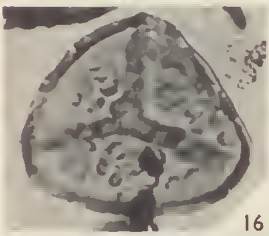
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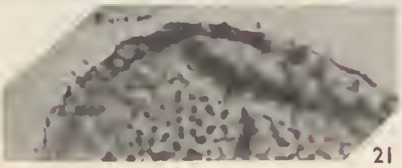
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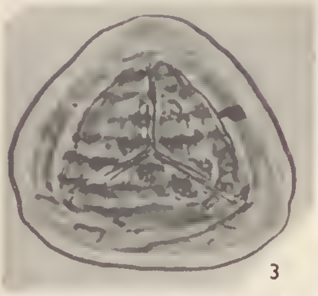
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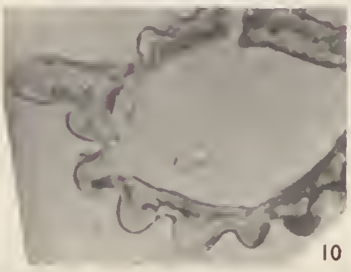
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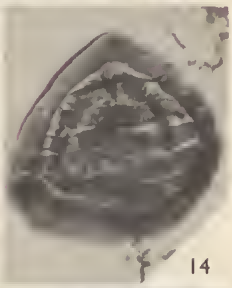
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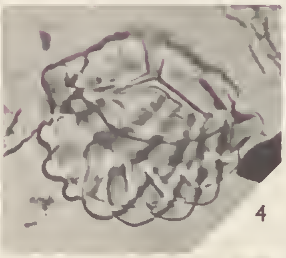
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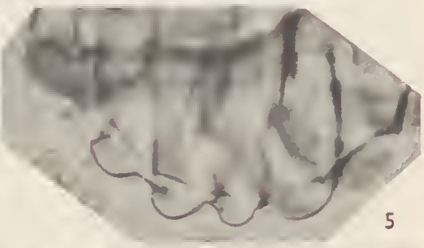
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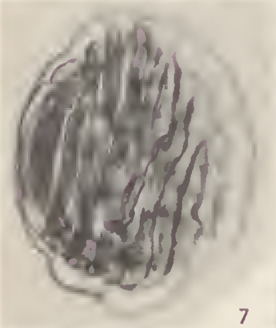
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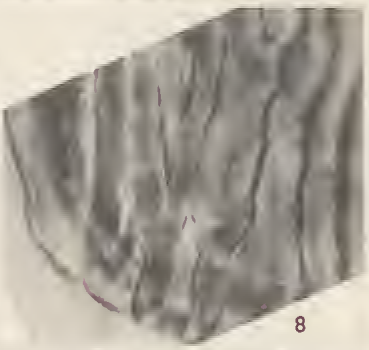
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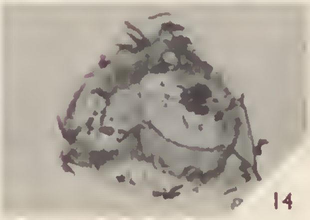
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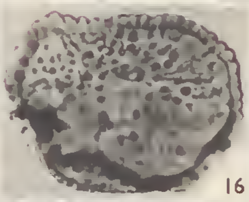
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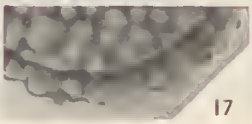
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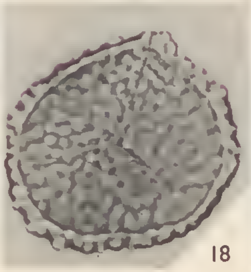
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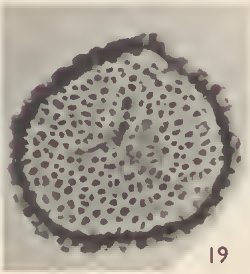
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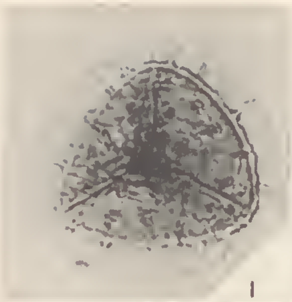
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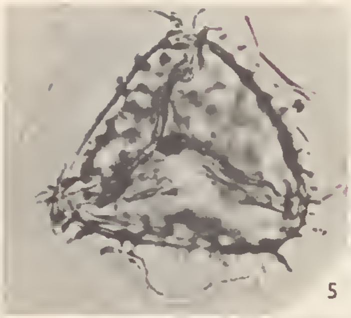
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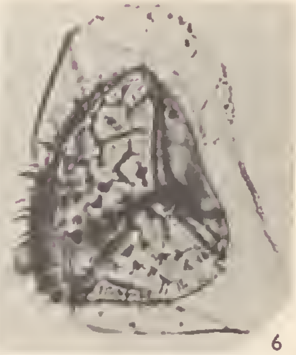
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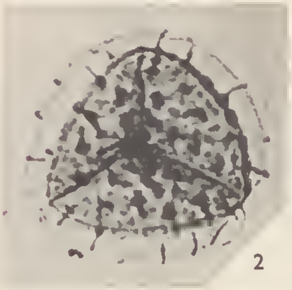
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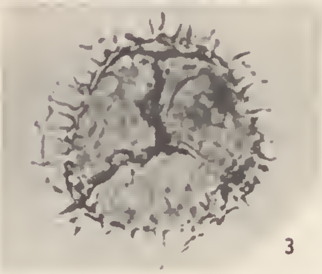
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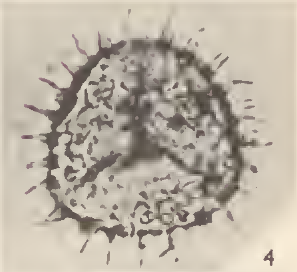
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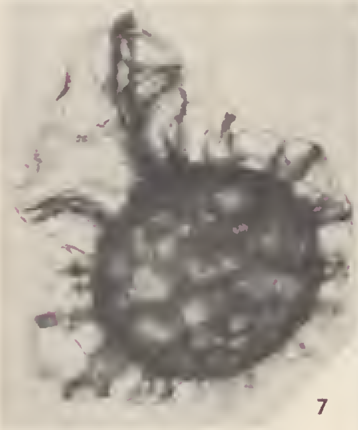
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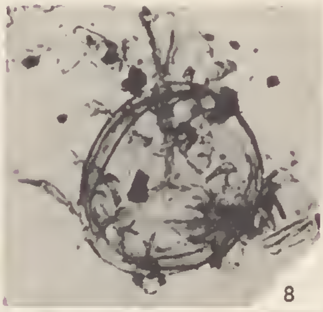
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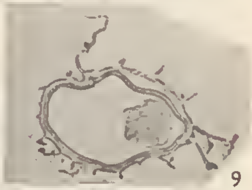
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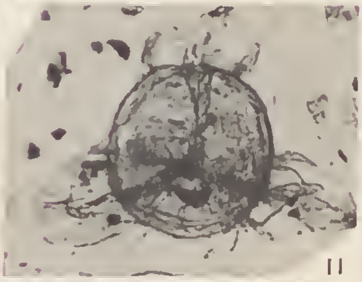
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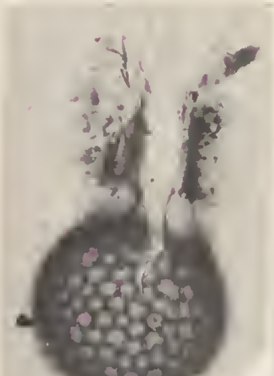
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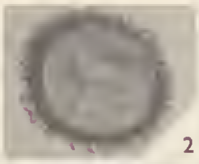
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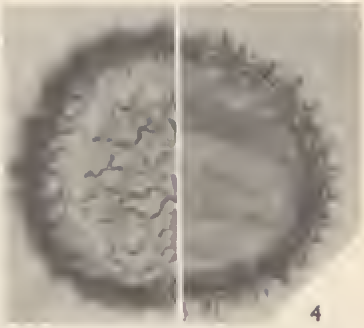
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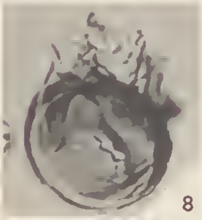
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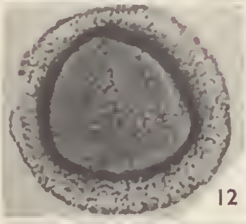
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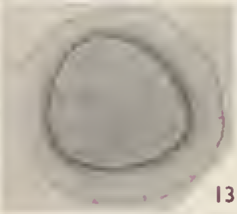
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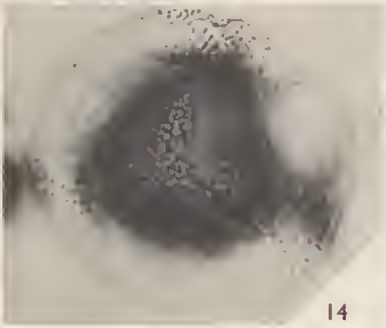
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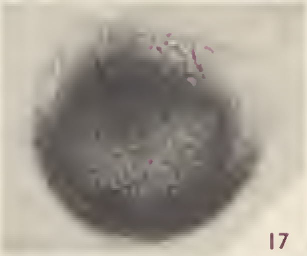
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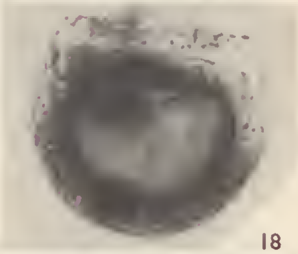
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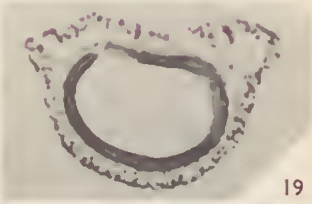
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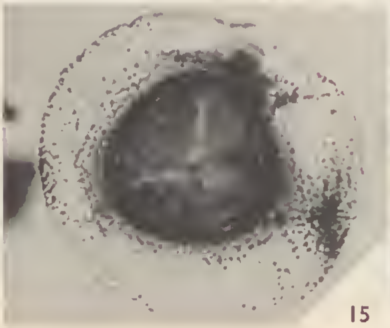
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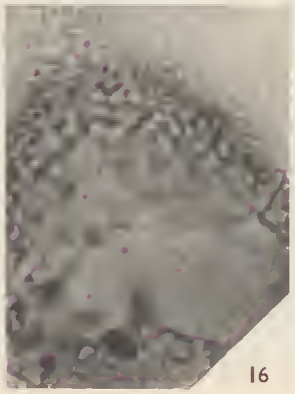
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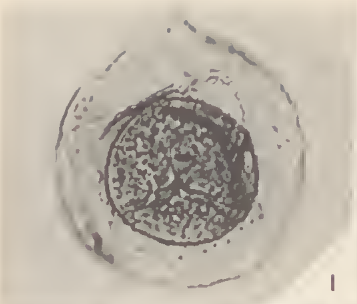
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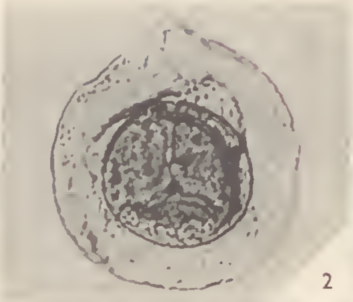
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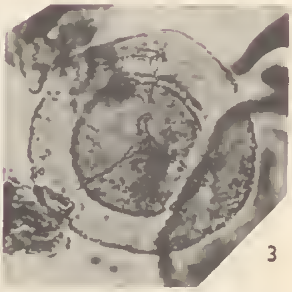
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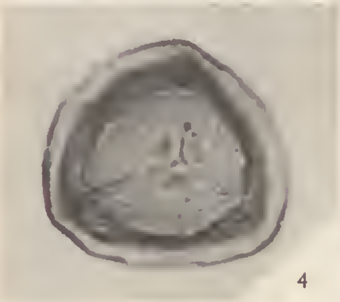
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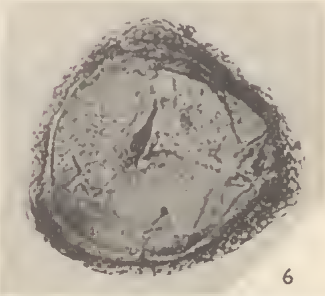
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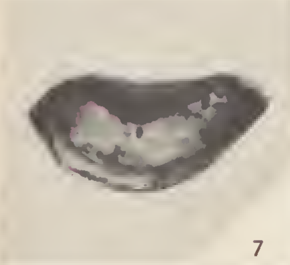
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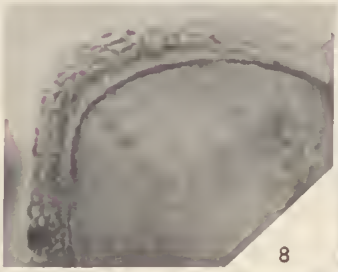
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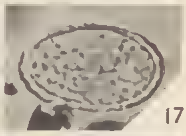
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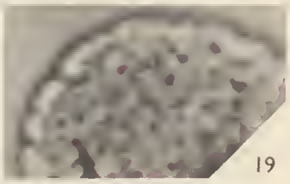
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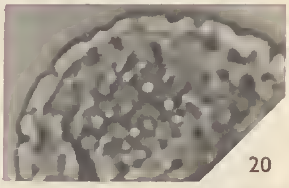
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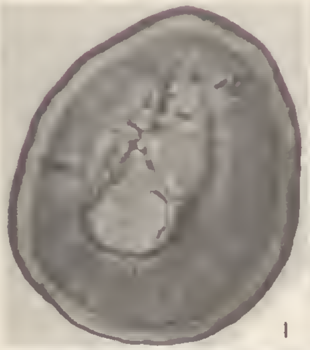
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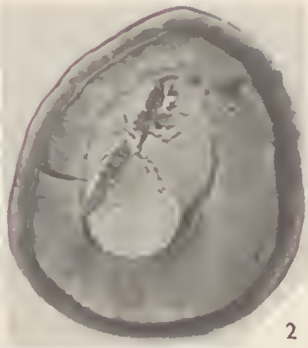
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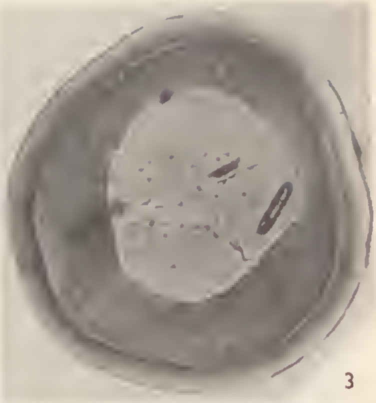
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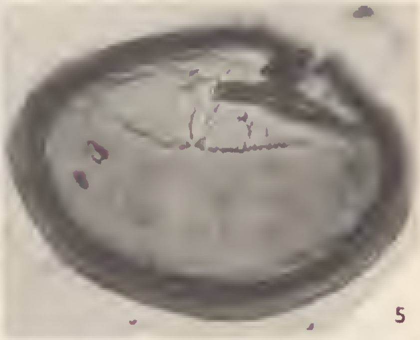
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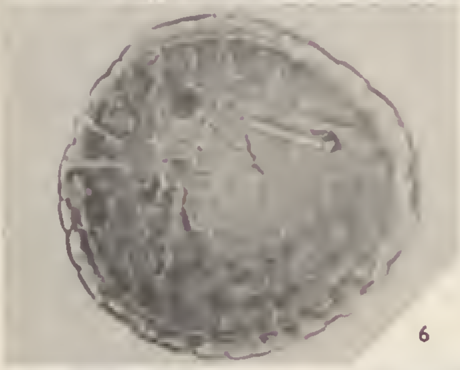
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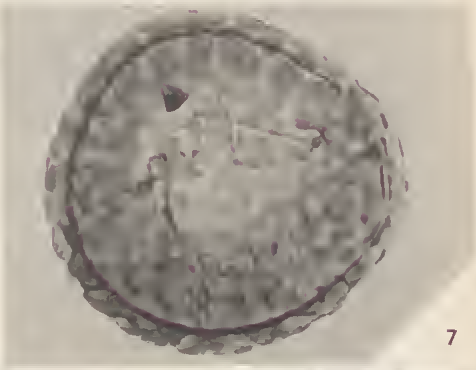
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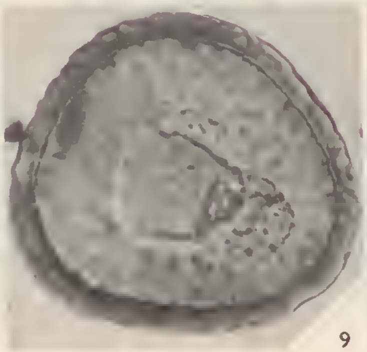
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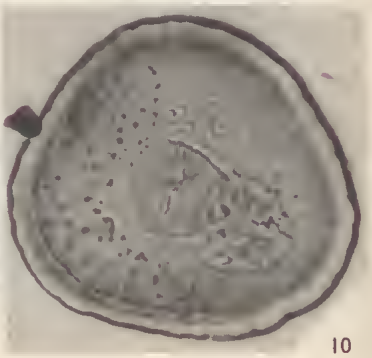
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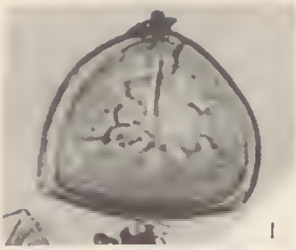
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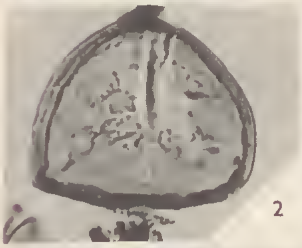
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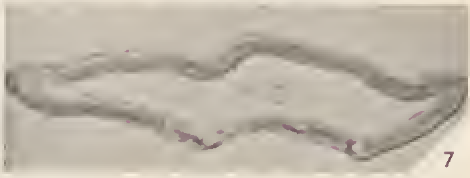
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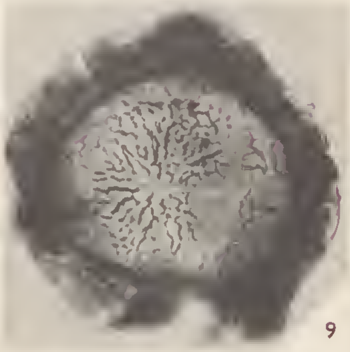
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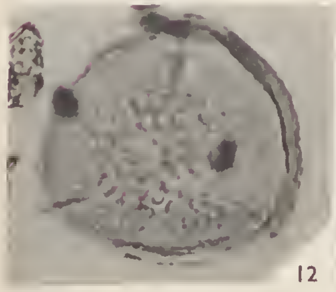
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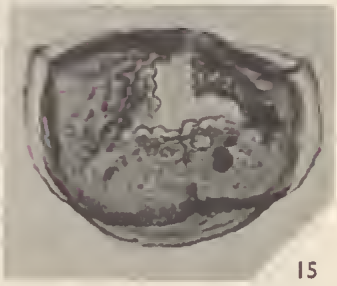
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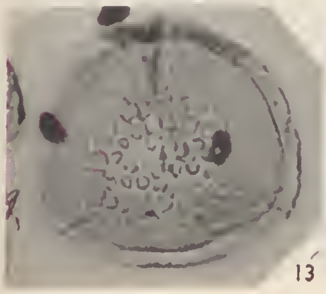
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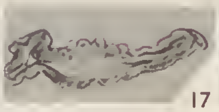
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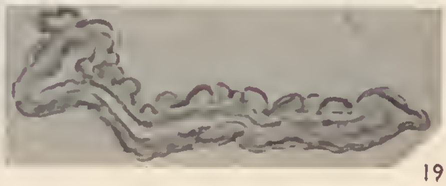
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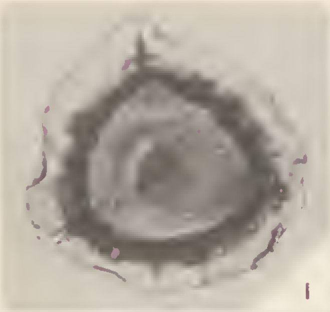
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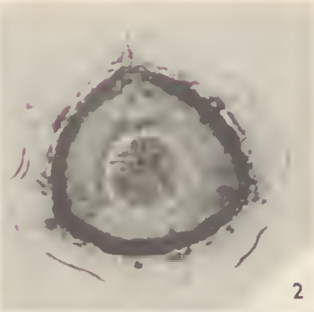
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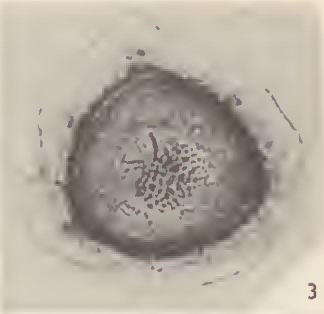
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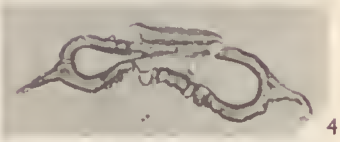
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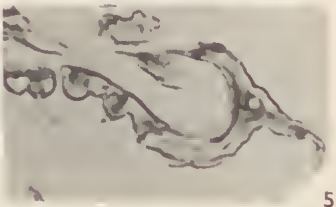
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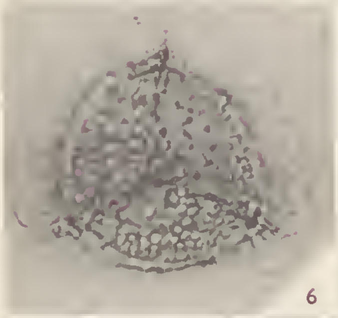
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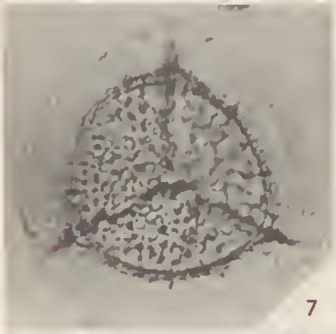
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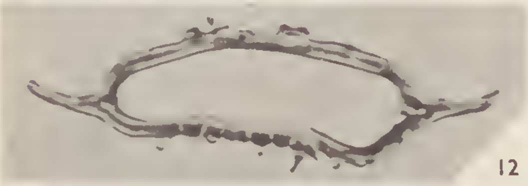
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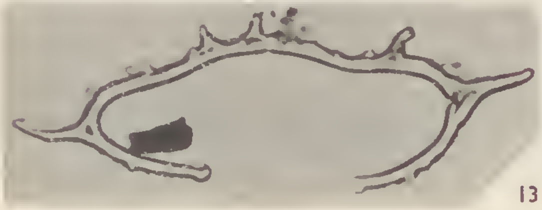
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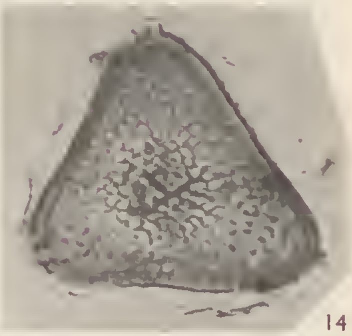
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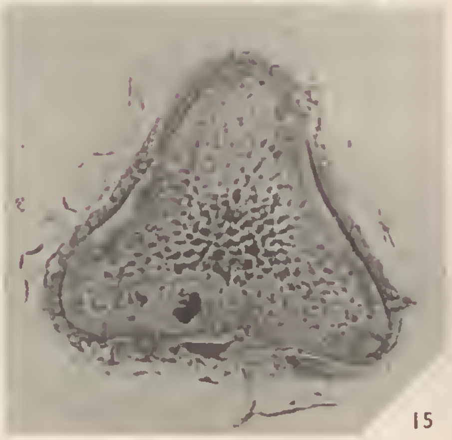
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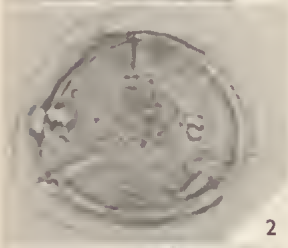

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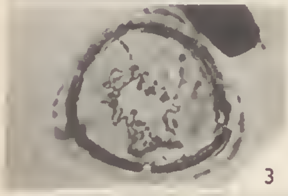

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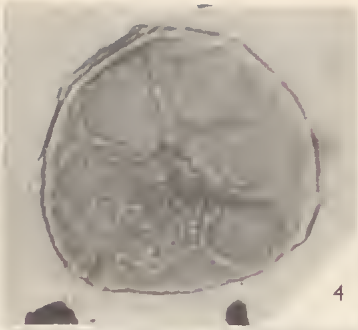

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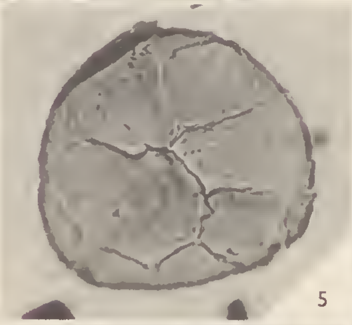

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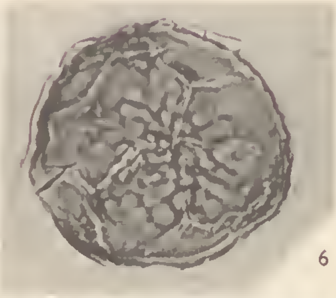

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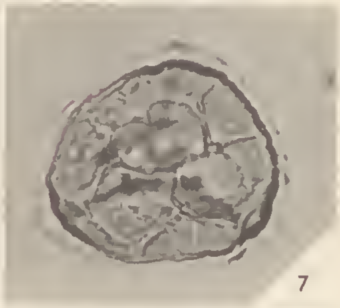

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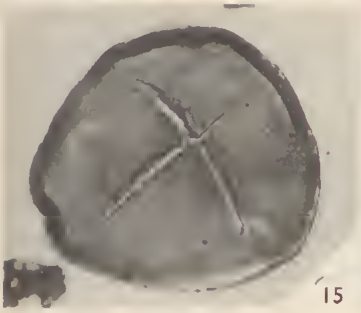

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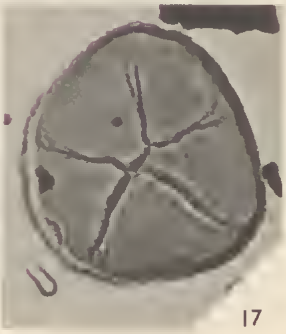

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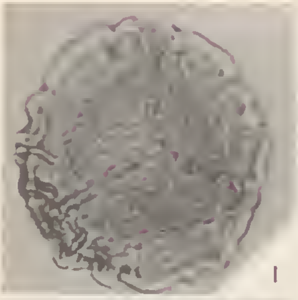
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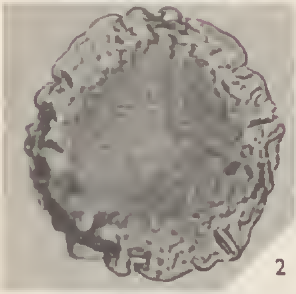
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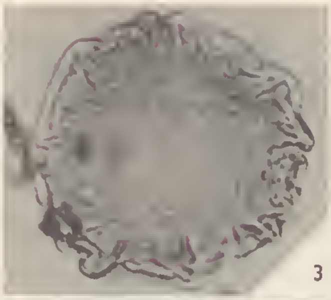
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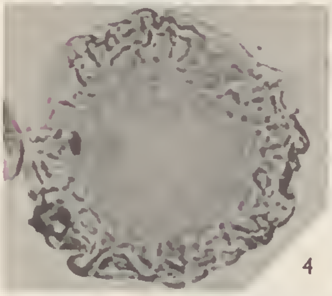
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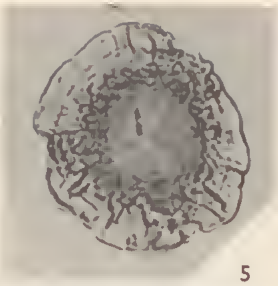
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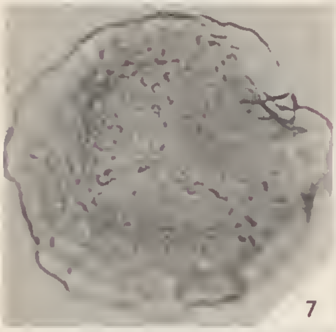
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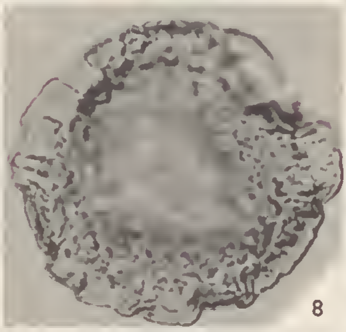
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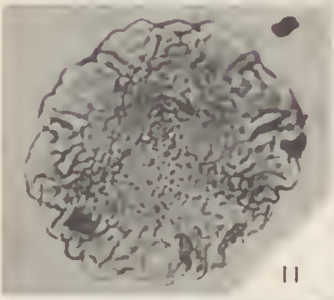
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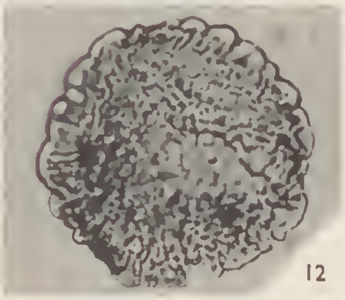
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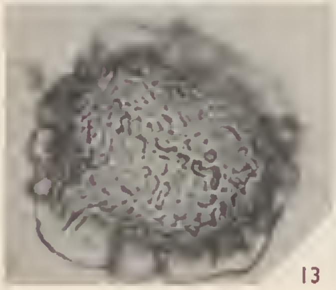
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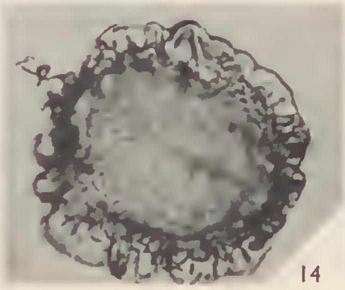
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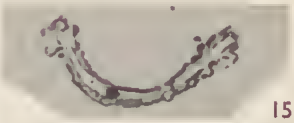
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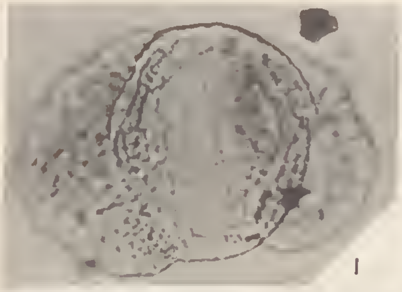
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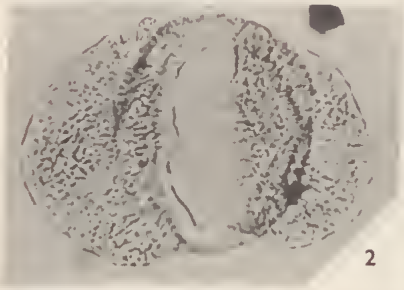
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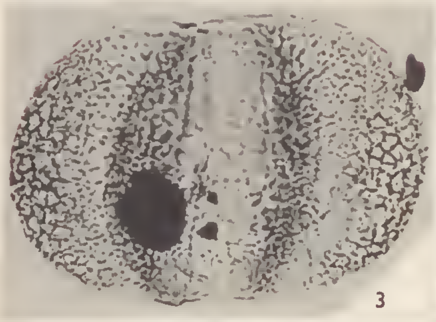
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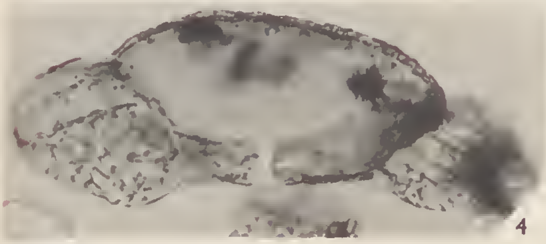
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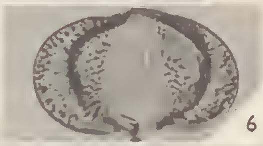
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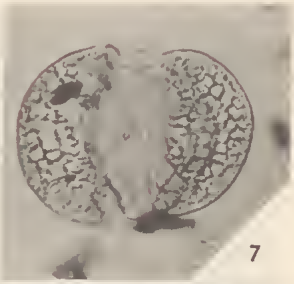
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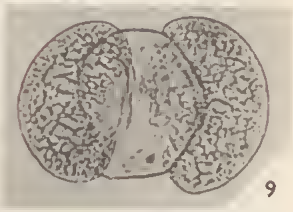
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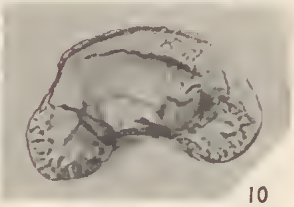
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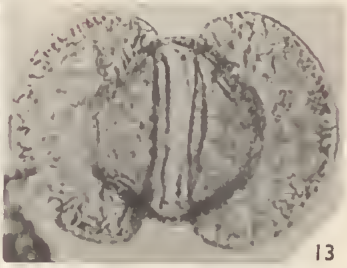
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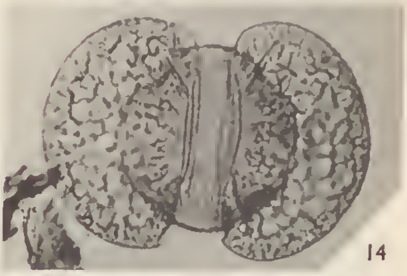
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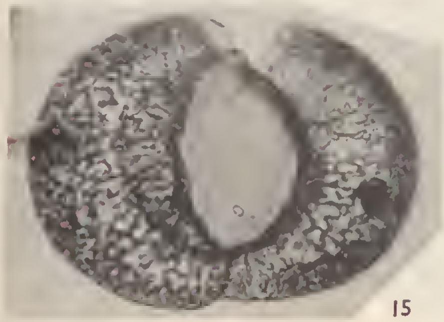
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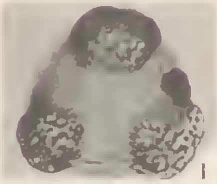
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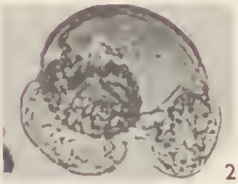
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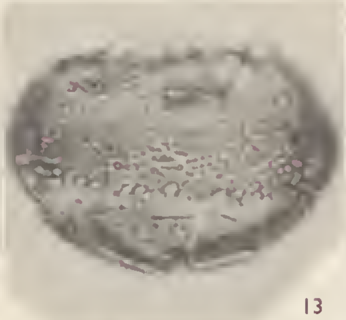
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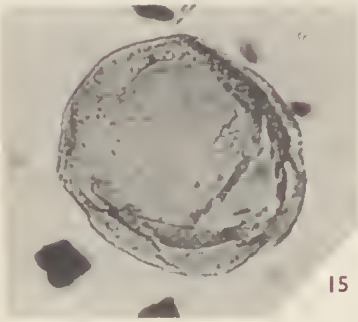
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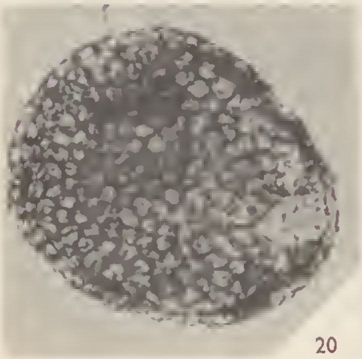
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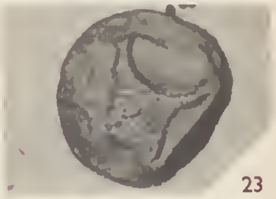
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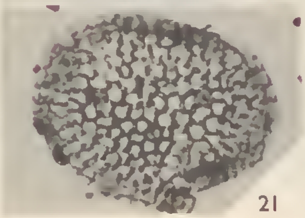
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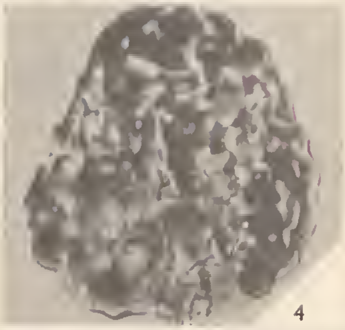
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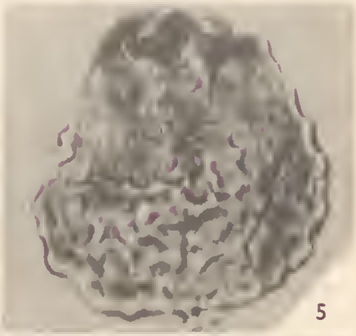
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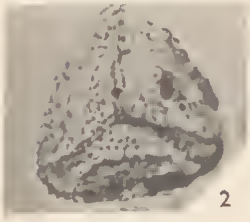
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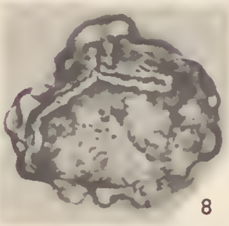
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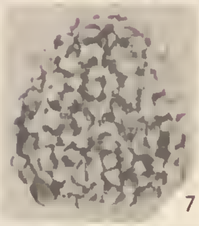
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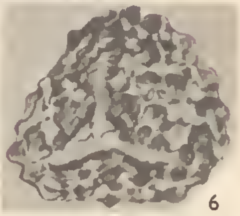
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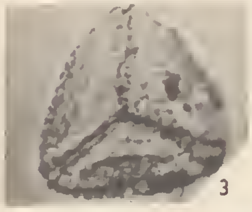
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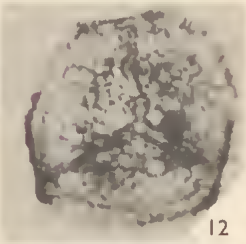
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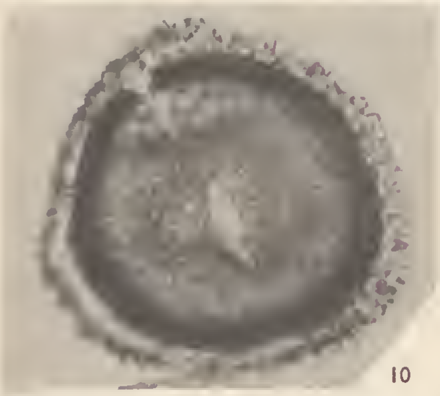
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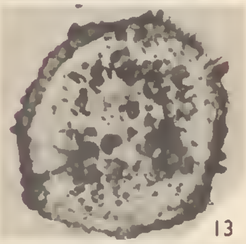
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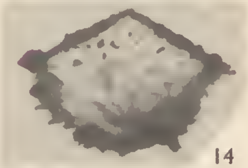
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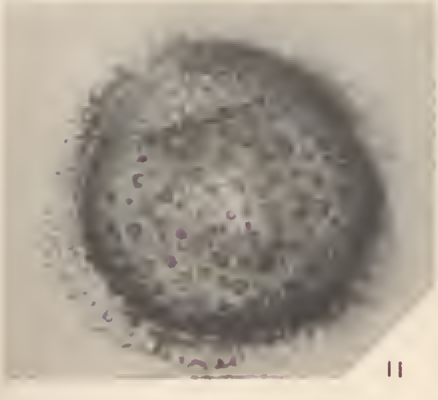
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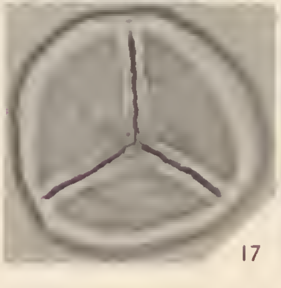
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Fig. 8-14—*Dictyotosporites speciosus* Cookson & Dettmann. 8, 9, Specimen from Comaum Bore No. 2 at 708 ft, D248/1 50·6 114·7 (P21997); 8, proximal focus; 9, × 1,000, proximal focus (left) and optical section. 10, Distal focus; Comaum Bore No. 2 at 708 ft, D248/2 44·4 127·5 (P22026). 11, 12, Portion of distal reticulum × 1,000, high and low foci respectively; Robe Bore No. 1 at 3,860 ft, D226/18 33·7 119·8 (P22027). 13, 14, Sections × 1,000 showing bifurcating muri of one-layered exine; Robe Bore No. 1 at 3,860 ft, D226/S73/1-2 30·9 115·2 and 40·9 116·0 respectively (P22028).

Fig. 15-17—*Dictyotosporites filosus* sp. nov. Holotype. Proximal, sectional, and distal foci; Penola Bore No. 1 at 2,790-98 ft, D346/9 31·2 121·6 (P22029).

Fig. 18-20—*Dictyotosporites filosus* sp. nov. Specimen from Penola Bore No. 1 at 2,790-98 ft, D346/8 36·4 117·0 (P22030); 18, proximal focus; 19, 20, proximal and sectional foci × 1,000.

PLATE IX

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1, 2—*Dictyotosporites complex* Cookson & Dettmann. Holotype. Distal views (2, × 1,000). Robe Bore No. 1 at 3,860 ft, Cookson and Dettmann's slide B59 37·2 124·1 (P17619).

Fig. 3-7—*Dictyotosporites complex* Cookson & Dettmann. 3, Crumpled specimen showing bifurcating primary capilli, and from which portion of surface reticulum has become detached; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/2 49·1 124·9 (P21985). 4-7, Subproximal, sectional, subdistal, and distal foci; Cootabarlow Bore No. 2 at 1,447-64 ft, D305/1 51·6 113·1 (P22031).

Fig. 8, 9—*Staplinisporites caminus* (Balme). Proximal and distal foci; Robe Bore No. 1 at 3,860 ft, D226/2 34·2 113·0 (P22032).

Fig. 10-16—*Cicatricosisporites australiensis* (Cookson). 10, 11, Proximal and distal foci; Penola Bore No. 1 at 3,715-21 ft, D348/1 20·1 124·3 (P22033). 12, 13, 15, Specimen from Robe Bore No. 1 at 2,630 ft, D259/4 38·7 120·1 (P22034); 12, 13, proximal and distal foci; 15, detail, × 1,000, of proximo-equatorial muri in radial region. 14, Lateral view; Penola Bore No. 1 at 1,805-15 ft, D294/2 50·6 123·9 (P22035). 16, × 1,000 showing distal muri; Dergholm Bore No. 1 at 532 ft, D299/3 35·9 119·7 (P22036).

Fig. 17, 18—*Cicatricosisporites ludbrooki* sp. nov. Holotype. Proximal surface, high and low foci. Penola Bore No. 1 at 2,790-98 ft, D346/1 40·3 110·9 (P22037).

Fig. 19-22—*Cicatricosisporites ludbrooki* sp. nov. 19, Lateral view; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/1 49·9 115·9 (P22038). 20-22, Specimen from Cootabarlow Bore No. 2 at 1,348-52 ft, D331/4 34·9 119·2 (P22039); 20, 21, proximal and distal foci; 22, × 1,000 showing distal muri.

PLATE X

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-5—*Cicatricosisporites pseudotripartitus* (Bolkhovitina). 1, 2, Proximal and distal foci; Penola Bore No. 1 at 1,805-15 ft, D286/1 24·9 113·2 (P22040). 3, Lateral view; Penola Bore No. 1 at 1,805-15 ft, D286/2 52·1 124·6 (P21966). 4, 5, Distal views (5, × 1,000); Penola Bore No. 1 at 1,805-15 ft, D286/10 25·7 117·0 (P22041).

Fig. 6-8—*Cicatricosisporites hughesi* sp. nov. Holotype. Proximal, sectional, and distal foci. Penola Bore No. 1 at 1,805-15 ft, D294/1 20·9 110·7 (P21965).

Fig. 9-16—*Cicatricosisporites hughesi* sp. nov. 9, 10, Proximal and distal foci of specimen situated in off-polar aspect; Tilcha Bore No. 2 at 460-80 ft, D222/7 38·2 118·1 (P22042). 11, 12, Distal views (12, × 1,000); Tilcha Bore No. 2 at 460-80 ft, D222/1 50·3 120·3 (P22043). 13, 14, Lateral views (14, × 1,000); Penola Bore No. 1 at 1,805-15 ft, D286/2 55·3 124·5 (P21966). 15, 16, Sections, × 1,000, of a specimen from Penola Bore No. 1 at 1,805-15 ft, D286/S61e/1-2 59·7 123·8 and 41·3 122·4 respectively (P22044).

Fig. 17-19—*Januasporites spinulosus* sp. nov. Holotype. 17, 18, Proximal and distal foci; 19, optical section of two-layered sclerine × 1,000. Cootabarlow Bore No. 2 at 1,376-77 ft, D289/43 39·5 117·8 (P22045).

Fig. 20—*Januasporites spinulosus* sp. nov. Proximal focus; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/44 36·7 118·9 (P22046).

PLATE XI

All figures × 500 and from unretouched negatives

Fig. 1, 2—*Matonisporites cooksoni* sp. nov. Holotype. Proximal and sectional foci. Penola Bore No. 1 at 1,805-15 ft, D294/1 22·7 112·1 (P21965).

Fig. 3-8—*Matonisporites cooksoni* sp. nov. 3, 4, Proximal and sectional foci; Penola Bore No. 1 at 1,805-15 ft, D286/9 40·4 118·2 (P22047). 5, Distal view of corroded specimen; Robe Bore No. 1 at 1,400 ft, D224/2 46·3 109·5 (P22048). 6, Lateral view; Penola Bore No. 1 at 1,805-15 ft, D294/8 41·0 114·5 (P22049). 7, 8, Sections showing one-layered exine which is thickened in equatorial radial regions and at laesurate margins; Robe Bore No. 1 at 1,400 ft, D217/S59/1 39·4 120·5 and 51·1 121·7 respectively (P22050).

Fig. 9-15—*Ischyosporites punctatus* Cookson & Dettmann. 9, 10, Proximal and distal foci; Kopperamanna Bore at 2,970 ft, D234/1 56·0 121·1 (P22051). 11, Optical section of uncompressed specimen; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/3 38·2 116·9 (P22052). 12, Lateral view; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/1 26·8 126·8 (P22002). 13, Distal view; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/9 37·4 118·8 (P22053). 14, 15, Sections showing thickenings and sculpture of one-layered exine; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S75/1-2 29·6 120·5 (P22054) and D289/S75/3 57·3 110·6 (P22055) respectively.

Fig. 16-19—*Trilites* cf. *T. tuberculiformis* Cookson. 16, 17, Sectional and distal foci; Cootabarlow Bore No. 2 at 660-80 ft, D326/2 27·0 119·9 (P22056). 18, Proximal focus; Cootabarlow Bore No. 2 at 1,348-52 ft, D331/1 49·2 112·0 (P22057). 19, Lateral view; Cootabarlow Bore No. 2 at 1,340 ft, D290/2 46·1 124·5 (P22058).

PLATE XII

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-9—*Trilobosporites trioreticulosus* Cookson & Dettmann. 1, 2, Sectional and distal foci; Robe Bore No. 1 at 1,400 ft, D224/1 48·3 118·2 (P21969). 3, Proximal focus; Robe Bore No. 1 at 1,400 ft, D224/2 49·1 113·5 (P22048). 4, Lateral view, high focus showing reticulate exine in equatorial, radial regions; Penola Bore No. 1 at 1,805-15 ft, D286/1 40·9 109·8 (P22040). 5, × 1,000 showing detail of equatorial, radial exine of specimen situated in lateral aspect; Penola Bore No. 1 at 1,805-15 ft, D286/2 38·2 108·6 (P21966). 6, 7, Proximal and sectional focus showing proximal, radial exine of specimen situated in polar aspect; Penola Bore No. 1 at 1,805-15 ft, D286/1 25·7 118·9 (P22040). 8, 9, Sections of specimen from Penola Bore No. 1 at 1,805-15 ft, D286/S62/3 29·5 121·8 (P22059) and D286/S63/1-2 35·9 114·5 (P22060) respectively.

Fig. 10, 11—*Trilobosporites tribotrys* sp. nov. Holotype. Proximal and sectional foci. Robe Bore No. 1 at 1,400 ft, D217/22 34·5 118·9 (P22061).

Fig. 12-14—*Trilobosporites tribotrys* sp. nov. Specimen from Robe Bore No. 1 at 1,400 ft, D217/14 35·1 118·8 (P22062); 12, 13, proximal and distal foci; 14, × 1,000 showing detail of equatorial, radial exine.

PLATE XIII

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-5—*Trilobosporites purverulentus* (Verbitskaya). 1, 2, Proximal and distal foci; Cootabarlow Bore No. 2 at 1,354 ft, D242/1 38·8 116·0 (P22063). 3, Lateral view; Cootabarlow Bore No. 2 at 1,348-52 ft, D331/5 35·0 119·7 (P22064). 4, 5, High and sectional foci of equatorial, radial exine × 1,000; Cootabarlow Bore No. 2 at 1,330-48 ft, D338/1 33·3 112·6 (P21972).

Fig. 6-10—*Gleicheniidites* cf. *G. cercinidites* (Cookson). 6, 7, Proximal and sectional foci; Robe Bore No. 1 at 1,400 ft, D224/3 55·9 124·5 (P22065). 8, 9, Sectional and distal foci; Robe Bore No. 1 at 1,780 ft, D247/1 59·0 113·2 (P22015). 10, Optical section × 750; Robe Bore No. 1 at 1,400 ft, D224/1 32·9 121·5 (P21969).

Fig. 11-16—*Sestrosporites pseudoalveolatus* (Couper). 11, Optical section; Cootabarlow Bore No. 2 at 1,401-02 ft, D334/1 37·5 111·7 (P22066). 12, 13, Proximal and sectional foci; Cootabarlow Bore No. 2 at 1,471-72 ft, D337/3 35·0 119·9 (P22067). 14, Proximal focus of 'zonate' specimen from Oodnadatta Bore No. 1 at 743 ft, D355/2 61·6 109·1 (P22068). 15, 16, Sections, × 750, showing cavate equatorial thickenings of specimen from Cootabarlow Bore No. 2 at 1,469-70 ft, D302/S80a/1-2 31·2 110·4 and 26·7 110·5 respectively (P22069).

Fig. 17-19—*Coronatispora perforata* sp. nov. Holotype. Proximal, sectional, and distal foci. Cootabarlow Bore No. 2 at 1,471-72 ft, D304/2 18·5 109·7 (P22070).

Fig. 20-23—*Coronatispora perforata* sp. nov. 20, Optical section; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/1 30·9 109·2 (P22038). 21-23, 'Zonate' specimen from Cootabarlow Bore No. 2 at 1,465-68 ft, D233/4 55·0 124·2 (P22071); 21, distal focus; 22, 23, high and low foci of distal, polar exine × 1,000.

PLATE XIV

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-4—*Coronatispora telata* (Balme). 1, Optical section; Kopperamanna Bore at 2,970 ft, D241/4 26·4 112·5 (P22008). 2-4, Proximal, sectional, and distal foci; Kopperamanna Bore at 2,970 ft, D234/11 34·5 119·1 (P22072).

Fig. 5-8—*Cingutriletes clavus* (Balme). 5, Distal focus of specimen with granules and verrucae about the distal pole; Robe Bore No. 1 at 1,780 ft, D258/1 52·3 110·4 (P22073). 6, 7, Sectional and distal foci of specimen, × 750, with distal, polar thickening; Penola Bore No. 1 at 1,200-1,210 ft, D273/1 22·6 118·1 (P22074). 8, Proximal view of specimen, × 750, with narrow cingulum and distal, polar verrucae; Comaum Bore No. 2 at 708 ft, D248/1 19·9 116·2 (P21997).

Fig. 9-14—*Murospora florida* (Balme). 9, 10, Proximal and distal foci; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/13 39·5 118·3 (P22075). 11, Distal focus of corroded specimen which is pitted in the polar regions; Koppermanna Bore at 2,970 ft, D234/9 36·5 119·0 (P22076). 12, Proximal focus of corroded specimen in which the exine is pitted about the poles and along the inner margin of the cingulum; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/6 37·9 118·4 (P22077). 13, 14, Sections showing equatorially thickened, one-layered exine; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S63/2 23·3 121·7 and 29·3 122·7 respectively (P22078).

Fig. 15-18—*Foraminisporis dailyi* (Cookson & Dettmann). 15, 16, Proximal and distal foci; Barrabool Hills, sample P22587, D249/1 29·6 115·2 (P22079). 17, 18, Proximal and sectional foci; Dergholm Bore No. 1 at 532 ft, D299/2 60·3 119·8 (P22080).

Fig. 19-23—*Foraminisporis wonthaggiensis* (Cookson & Dettmann). 19-21, Specimen situated in off-polar aspect showing that the equatorial exine is weakly thickened; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/1 20·2 122·3 (P22038); 19, 20, proximal and distal foci; 21, × 1,000, optical section of portion of equatorial (left) and distal (right) exine. 22, 23, Proximal and distal foci; Robe Bore No. 1 at 3,860 ft, D226/2 34·5 110·2 (P22032).

PLATE XV

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1, 2—*Contignisporites glebulentus* sp. nov. Holotype. Proximal and distal foci showing that the distal muri parallel one laesura. Penola Bore No. 1 at 1,805-15 ft, D286/5 34·9 119·6 (P22081).

Fig. 3-10—*Contignisporites glebulentus* sp. nov. 3, 4, Proximal and distal foci of specimen in which the distal muri are orientated at right angles to one laesura and in which the cingulum is cavate; Robe Bore No. 1 at 1,400 ft, D217/12 41·7 118·8 (P22082). 5, 6, Proximal and sectional foci of corroded specimen showing concentrically striated cingulum; Robe Bore No. 1 at 1,400 ft, D224/2 48·1 122·1 (P22048). 7, Surface view of distal muri × 1,000; Penola Bore No. 1 at 1,805-15 ft, D286/8 33·0 118·2 (P22083). 8-10, Sections (10, × 1,000) cut transversely to the distal muri of a specimen with cavate muri and cingulum; Robe Bore No. 1 at 1,400 ft, 8, 9, D217/S60/3 27·2 118·2 and 37·5 119·1 respectively (P22084); 10, D217/S60/1 59·5 111·9 (P22085).

Fig. 11-18—*Contignisporites cooksonii* (Balme). 11, 12, Proximal and distal foci of specimen in which the distal muri parallel one laesura; Kopperamanna Bore at 2,970 ft, D241/2 50·8 121·3 (P22086). 13, 14, Proximal and distal foci showing distal muri orientated at right angles to one laesura; Kopperamanna Bore at 2,970 ft, D241/1 52·4 112·7 (P21978). 15, Oblique proximal view; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/2 52·5 113·1 (P21985). 16, Distal muri × 1,000; Cootabarlow Bore No. 2 at 1,401-02 ft, D334/1 43·5 117·2 (P22066). 17, 18, Sections cut obliquely to the distal muri of a specimen with a cavate cingulum; Cootabarlow

Bore No. 2 at 1,376-77 ft, D289/S66a/1 52·8 118·4 and 42·0 120·1 respectively (P22087).

PLATE XVI

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-3—*Contignisporites fornicatus* sp. nov. Holotype. 1, 2, Proximal and distal foci; 3, surface view, × 1,000, of distal muri which are orientated at right angles to one laesura. Tilcha Bore No. 2 at 460-80 ft, D222/11 41·5 119·3 (P22088).

Fig. 4, 5—*Contignisporites fornicatus* sp. nov. Lateral views; 5, × 1,000 showing distal muri and cingulum in optical section. Tilcha Bore No. 2 at 460-80 ft, D222/4 57·7 110·4 (P22089).

Fig. 6-8—*Contignisporites multimuratus* sp. nov. Holotype. 6, 7, Proximal and distal foci; 8, surface view, × 1,000, of distal muri which parallel one laesura. Cootabarlow Bore No. 2 at 1,348-52 ft, D331/1 54·4 113·2 (P22057).

Fig. 9-13—*Contignisporites multimuratus* sp. nov. 9, 10, Lateral views, low and high foci; Cootabarlow Bore No. 2 at 1,348-52 ft, D331/2 33·6 113·8 (P22090). 11-13, Sections, cut transversely to the distal muri, of a specimen from Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S66e/1-2 (P22091); 11, 46·0 113·5; 12, 13 (× 1,000), 52·8 112·4.

Fig. 14—*Minerisporites marginatus* (Dijkstra). Proximal focus × 100; Robe Bore No. 1 at 1,400 ft, ICC60/4 39·3 117·4 (P21988).

Fig. 15-19—*Foraminisporis asymmetricus* (Cookson & Dettmann). 15, Oblique proximal view; Robe Bore No. 1 at 2,325 ft, D246/2 57·2 127·1 (P22092). 16, Specimen in off-polar aspect showing weakly thickened equatorial exine (top) and thinner distal exine (bottom) in optical section; Robe Bore No. 1 at 3,325 ft, D245/2 22·4 114·9 (P21975). 17-19, Specimen from Robe Bore No. 1 at 3,325 ft, D245/1 55·8 129·4 (P22093); 17, optical section of equatorial exine × 1,000; 18, 19, proximal and distal foci.

PLATE XVII

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1, 2—*Kraeuselisporites linearis* (Cookson & Dettmann). Holotype, originally illustrated by Cookson and Dettmann (1958b; Pl. 19, fig. 3, 4). Proximal and distal foci. Wonthaggi, Kirrak Area. floor of coal seam at 103 ft; Cookson and Dettmann's slide B58 37·2 119·6 (P17630).

Fig. 3, 4—*Kraeuselisporites linearis* (Cookson & Dettmann). Proximal and distal foci; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/6 33·6 126·5 (P22094).

Fig. 5, 6—*Kraeuselisporites majus* (Cookson & Dettmann). Proximal focus; Penola Bore No. 1 at 1,410-18 ft, D301/4 37·0 119·0 (P22095). 6, Oblique proximal view; Tilcha Bore No. 2,460/80 ft, D222/6 38·0 118·4 (P22096).

Fig. 7-10—*Balmeisporites holodictyus* Cookson & Dettmann. 7, Lateral view × 200; Dergholm Bore No. 1 at 532 ft, ICC60/1 37·3 124·1 (P22097). 8, Proximal focus × 200; Tilcha Bore No. 2 at 460-80 ft, D222/4 27·0 118·8 (P22089). 9, Section, × 200, showing stratified exine, the outer layer of which forms the elevated laesurate lips and the surface reticulum; Robe Bore No. 1 at 1,400 ft, D217/S57/2 47·3 120·1 (P22099). 10, Portion of section showing exine stratification; Robe Bore No. 1 at 1,780 ft, D247/S56/1 64·3 121·6 (P22100).

Fig. 11, 12—*Balmeisporites tridictyus* Cookson & Dettmann. 11, Proximal view × 200; Tilcha Bore No. 2 at 1,040-50 ft, D371/1 44·6 122·5 (P22101). 12, Lateral view × 200; Robe Bore No. 1 at 1,400 ft, D224/1 21·8 117·8 (P21969).

Fig. 13-16—*Pyrobolospora reticulata* Cookson & Dettmann. 13, Lateral view × 100; Robe Bore No. 1 at 1,780 ft, D247/3 32·9 118·6 (P22102). 14-16, Sections of a specimen from Robe Bore No. 1 at 1,780 ft, D247/S55/3-4 35·1 126·1, 39·2 125·4, and 16·7 123·8 respectively (P22103); 14, × 100 off-polar section; 15, × 200 showing stratified exine, the outermost layer of which forms the laesurate lips and surface reticulum; 16, showing detail of exine stratification.

PLATE XVIII

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-6—*Crybelosporites striatus* (Cookson & Dettmann). 1-4, Specimen from Robe Bore No. 1 at 1,400 ft, D224/1 52·6 120·3 (P21969); 1-3, proximal, sectional, and distal foci; 4, distal (left) and sectional (right) foci showing detail of sclerine × 1,000. 5, High focus of specimen situated in off-polar aspect; Robe Bore No. 1 at 1,780 ft, D247/1 24·6 111·2 (P22015). 6, Lateral view, sectional focus; Robe Bore No. 1 at 1,780 ft, D247/2 25·5 116·9 (P22104).

Fig. 7, 8—*Crybelosporites punctatus* sp. nov. Holotype. Lateral view, high and sectional foci. Oodnadatta Bore No. 1 at 248 ft, D383/1 37·5 128·5 (P22105).

Fig. 9-11—*Crybelosporites punctatus* sp. nov. 9, Lateral view; Cootabarlow Bore No. 2 at 1,040-1,050 ft, D332/2 30·2 126·6 (P22106). 10, 11, High and low foci showing surface pattern and sclerine stratification of portion of specimen, × 1,000, situated in lateral aspect. Tilcha Bore No. 2 at 460-80 ft, D218/2 33·2 109·4 (P22107).

Fig. 12, 13—*Crybelosporites stylosus* sp. nov. Holotype. Proximal and sectional foci. Cootabarlow Bore No. 2 at 1,469-70 ft, D302/1 23·8 113·0 (P22002).

Fig. 14-20—*Crybelosporites stylosus* sp. nov. 14-16, Specimen from Cootabarlow Bore No. 2 at 1,469-70 ft, D302/2 33·9 124·3 (P22021); 14, 15, proximal and sectional foci; 16, high focus of portion of proximal sclerine × 1,000. 17, 18, Lateral views, high and sectional foci Cootabarlow Bore No. 2 at 1,469-70 ft, D302/2 43·6 128·7 (P22021). 19, 20, Sections showing sclerine stratification and cavate sculptine of specimen from Cootabarlow Bore No. 2 at 1,469-70 ft, D302/S79b/1-2 32·0 115·5 and 47·7 121·8 respectively (P22108).

PLATE XIX

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-3—*Velosporites triquetrus* (Lantz). 1, 2, Proximal and sectional foci; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/16 35·2 120·0 (P22109). 3, Proximal focus; Wonthaggi, Kirrak Area, sample P22599, D139/2 45·8 122·4 (P21987).

Fig. 4-8—*Densoisporites velatus* Weyland & Krieger. 4, 5, Proximal and sectional foci; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/28 39·4 117·3 (P22110). 6, Proximal view, Cootabarlow Bore No. 2 at 1,376-77 ft, D289/19 36·8 118·8 (P22111). 7, Lateral view, sectional focus showing equatorially thickened sculptine and cavate sclerine; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/31 35·3 119·2 (P22112). 8, Portion of sclerine × 1,000; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/2 41·0 118·7 (P22021).

Fig. 9-11—*Laevigatosporites ovatus* Wilson & Webster. 9, Group of specimens; Robe Bore No. 1 at 1,780 ft, D258/1 49·0 121·8 (P22073). 10, Proximal view; Penola Bore No. 1 at 1,805-15 ft, D294/1 51·1 116·6 (P21965). 11, Lateral view; Tilcha Bore No. 2 at 460-80 ft, D222/4 55·9 126·9 (P22089).

Fig. 12-14—*Reticuloidosporites arcus* (Balme). 12, Proximal view; Cootabarlow Bore No. 2 at 1,469-70 ft, D336/1 46·6 115·5 (P22113). 13, 14, Lateral view, high and sectional foci; Cootabarlow Bore No. 2 at 1,469-70 ft, D336/2 57·2 117·5 (P22114).

Fig. 15, 16—*Microfoveolatosporis canaliculatus* sp. nov. Holotype. Oblique lateral aspect, high and sectional foci. Cootabarlow Bore No. 2 at 581 ft, D368/2 32·1 112·7 (P22115).

Fig. 17-21—*Microfoveolatosporis canaliculatus* sp. nov. 17, Proximal view, sectional focus; Tilcha Bore No. 2 at 460-80 ft, D222/4 37·4 127·6 (P22089). 18, Lateral view; Cootabarlow Bore No. 2 at 1,040-1,050 ft, D332/1 47·6 110·7 (P22116). 19-21, Portion of exine × 1,000, high, median, and low foci; Tilcha Bore No. 2 at 460-80 ft, D222/2 29·8 123·8 (P21999).

PLATE XX

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1, 2—*Coptospora striata* sp. nov. Holotype. Proximal? and distal? foci. Robe Bore No. 1 at 2,630 ft, D225/10 34·3 117·3 (P22117).

Fig. 3-5—*Coptospora striata* sp. nov. 3, 4, Specimen from Robe Bore No. 1 at 2,630 ft, D225/90 55·5 119·0 (P22118); 3, distal? focus; 4, × 1,000 showing ruptured (hilate) distal?, polar exine. 5, Lateral view; Robe Bore No. 1 at 2,630 ft, D225/2 37·4 125·6 (P22119).

Fig. 6-8—*Coptospora* sp. A. 6, 7, Proximal? and sectional foci; Robe Bore No. 1 at 2,630 ft, D225/13 39·2 119·6 (P22120). 8, Distal? focus of hilate specimen; Robe Bore No. 1 at 2,630 ft, D225/5 34·6 118·7 (P22121).

Fig. 9, 10—*Coptospora* sp. B. Sectional and distal? foci; Penola Bore No. 1 at 2,990-3,000 ft, D345/2 51·3 125·7 (P22122).

PLATE XXI

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-7—*Coptospora paradoxa* (Cookson & Dettmann). 1, 2, Proximal and distal foci of a hilate specimen; Penola Bore No. 1 at 1,805-15 ft, D286/1 56·3 112·5 (P22040). 3, Distal focus; Barongarook Creek, sample P22585, D203/1 50·2 109·8 (P21992). 4, Portion of distal polar exine, × 1,000, showing fractures which surround hexagonal areas; Robe Bore No. 1 at 2,630 ft, D225/1 35·1 109·8 (P22123). 5-7, Sections of a specimen from Penola Bore No. 1 at 2,380-90 ft; 5, section cut near equator D272/S85b/3 24·3 121·7 (P22124); 6, 7, off-polar sections (7 × 1,000) showing fractured distal polar exine, D272/S85b/1-2 58·3 121·2 and 19·9 119·1 respectively (P22125).

Fig. 8-11—*Cooksonites variabilis* Pocock. 8, Proximal focus; Koppcramanna Bore at 2,970 ft, D234/2 27·9 117·9 (P22126). 9, Distal focus showing polar hilum; Penola Bore No. 1 at 3,715-21 ft, D348/9 33·4 117·1 (P22127). 10, Lateral view; Penola Bore No. 1 at 3,715-21 ft, D348/1 46·9 108·8 (P22033). 11, Section; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S74b/1-2 48·1 123·5 (P22128).

Fig. 12, 13—*Couperisporites tabulatus* sp. nov. Holotype. Distal and proximal foci. Cootabarlow Bore No. 2 at 1,376-77 ft, D289/2 53·1 119·9 (P21985).

Fig. 14-19—*Couperisporites tabulatus* sp. nov. 14, 15, Oblique aspect, high (off-distal) and low (off-proximal) foci showing proximal hilum; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/38 33·8 116·6 (P22129). 16, Proximal focus of inner layer; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/1 51·6 114·7 (P22038). 17-19, Sections of a specimen from Cootabarlow Bore No. 2 at 1,376-77 ft showing two-layered sclerine, the outer layer of which forms the proximal verrucae and the equatorial 'zona'; D289/S64/1 17·4 114·0 (fig. 17) and 30·3 116·2 (fig. 18, 19—19 × 1,000) (P22130).

PLATE XXII

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-5—*Aequitriradites verrucosus* (Cookson & Dettmann). 1-3, Proximal, sectional, and distal foci; Penola Bore No. 1 at 2,586-96 ft, D343/1 26·8 108·5 (P22131). 4, 5, Sections of a specimen from Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S67/3 30·5 119·2 (fig. 4) and 37·5 120·6 (fig. 5) (P22132); 5, × 1,000 showing distal 'verrucae' and cavate zona.

Fig. 6-13—*Aequitriradites spinulosus* (Cookson & Dettmann). 6, 7, Proximal and distal foci of specimen having closely-spaced, narrow-based spinules; Cootabarlow Bore No. 2 at 1,401-02 ft, D334/2 21·9 118·2 (P22133). 8, Distal focus of hilate specimen having broad-based spinules; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/2 52·2 127·4 (P21985). 9, Distal focus of specimen with sparsely arranged, narrow-based spinules; Penola Bore No. 1 at 1,805-15 ft, D294/1 51·9 125·3 (P21965). 10-13, Sections of a hilate specimen from Cootabarlow Bore No. 2 at 1,376-77 ft, all mounted on slide D289/S65d/1-2 (P22134); 10, off-polar section cut through distal hilum 27·1 112·6; 11, 48·7 111·7; 12, × 1,000 showing one-layered exine, discrete, distal polar spinules, and cavate zona 44·1 111·6; 13, section, × 1,000, cut through distal hilum 31·7 112·4.

Fig. 14, 15—*Aequitriradites* sp. 14, Distal focus showing fractured distal polar area; Kopperamanna Bore at 2,970 ft, D241/13 47·5 117·6 (P22135). 15, Distal focus; Kopperamanna Bore at 2,970 ft, D234/5 38·2 120·2 (P22136).

PLATE XXIII

All figures × 500 and from unretouched negatives

Fig. 1, 2—*Aequitriradites tilchaensis* (Cookson & Dettmann). Holotype, originally figured by Cookson and Dettmann (1958b; Pl. 18, fig. 7). Proximal and distal foci; Tilcha Bore No. 2 at 460-80 ft, Cookson and Dettmann's slide 6 33·5 120·3 (P17625).

Fig. 3—*Aequitriradites tilchaensis* (Cookson and Dettmann). Distal focus of hilate specimen; Tilcha Bore No. 2 at 460-80 ft, D218/2 21·0 125·1 (P22107).

Fig. 4-9—*Rouseisporites reticulatus* Pocock. 4, 5, Proximal and distal foci showing tetrad mark, equatorial invaginations, and distal muroid ridges; Robe Bore No. 1 at 2,630 ft, D225/2 20·9 120·6 (P22119). 6, Distal focus; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/14 41·8 117·4 (P22137). 7, Distal focus; Penola Bore No. 1 at 2,380/90 ft, D272/8 37·3 118·2 (P22138). 8, 9, Sections showing two-layered sclerine, the outer layer of which forms the zona and distal muroid ridges; Cootabarlow Bore No. 2 at 1,376-77 ft, D289/S68/2 30·5 126·4 and 35·8 127·0 respectively (P22139).

Fig. 10-12—*Rouseisporites simplex* (Cookson & Dettmann). 10, 11, Proximal and distal foci; Penola Bore No. 1 at 2,380-90 ft, D272/2 51·8 118·0 (P22140). 12, Distal focus showing distal muroid ridges and equatorial invaginations; Penola Bore No. 1 at 2,380-90 ft, D272/2 48·6 124·1 (P22140).

Fig. 13, 14, 17—*Rouseisporites radiatus* sp. nov. 13, 14, Proximal and distal foci; Penola Bore No. 1 at 2,380-90 ft, D272/1 55·8 120·3 (P22141). 17, Distal focus of specimen having six, distal, muroid ridges; Robe Bore No. 1 at 2,630 ft, D259/2 25·9 127·4 (P22159).

Fig. 15, 16—*Rouseisporites radiatus* sp. nov. Holotype. Distal foci showing hollow muroid ridges and equatorial invaginations; Penola Bore No. 1 at 2,380-90 ft, D272/2 43·2 127·6 (P22140).

Plate XXIV

All figures × 500 and from unretouched negatives

Fig. 1-5—*Tsugaepollenites dampieri* (Balme). 1, 2, Proximal and sectional foci of specimen with a tetrad mark; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/8 33·7 120·2 (P22142). 3, 4, Distal and sectional foci; Oodnadatta Bore No. 1 at 1,227-32 ft, D238/1 31·8 108·9 (P22143). 5, Sectional focus; Cootabarlow Bore No. 2 at 1,391-92 ft, D288/1 53·1 127·9 (P22144).

Fig. 6-10—*Tsugaepollenites trilobatus* (Balme). 6, Sectional focus; Penola Bore No. 1 at 3,180-90 ft, D342/2 49·9 127·8 (P22145). 7, 8, Proximal and sectional foci; Cootabarlow Bore No. 2 at 1,391-92 ft, D288/1 25·3 124·1 (P22144). 9, 10, Sections of a specimen from Cootabarlow Bore No. 2 at 1,469-70 ft, showing two-layered exine which is equatorially monosaccate; 9, D302/S76b/1-2 23·6 112·6 (P22146); 10, D302/S76b/3-4 46·4 125·9 (P22147).

Fig. 11-16—*Tsugaepollenites* cf. *T. segmentatus* (Balme). 11, Proximal focus showing tetrad mark and proximal vesiculae; Kopperamanna Bore at 2,970 ft, D241/3 42·9 109·1 (P21990). 12, Polar focus; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/1 27·4 120·8 (P22002). 13, 14, Proximal and sectional foci; Cootabarlow Bore No. 2 at 1,330-48 ft, D338/2 27·9 120·0 (P22148). 15, 16, Sections of a specimen from Cootabarlow Bore No. 2 at 1,469-70 ft, showing two-layered exine which is monosaccate equatorially and vesiculate in the polar regions; 15, D302/S76a/3-4 30·7 114·9 (P22149); 16, D302/S76a/1-2 39·1 116·1 (P22150).

Plate XXV

All figures × 500 and from unretouched negatives

Fig. 1-4—*Alisporites grandis* (Cookson). 1, 2, Proximal and distal foci showing distal aperture of an uncompressed specimen; Tilcha Bore No. 2 at 460-80 ft, D222/2 43·1 108·2 (P21999). 3, Distal view of a compressed specimen; Robe Bore No. 1 at 2,630 ft, D225/2 25·4 116·9 (P22119). 4, Lateral view, sectional focus; Robe Bore No. 1 at 1,780 ft, D247/1 38·4 126·6 (P22015).

Fig. 5-7—*Alisporites similis* (Balme). 5, 6, Sectional and distal foci showing distal aperture of an uncompressed specimen; Cootabarlow Bore No. 2 at 1,469-70 ft, D336/1 49·1 123·7 (P22113). 7, Distal focus showing aperture; Robe Bore No. 1 at 1,780 ft, D247/2 22·5 111·4 (P22104).

Fig. 8-12—*Podocarpidites* cf. *P. ellipticus* Cookson. 8, 9, Proximal and distal foci; Cootabarlow Bore No. 2, at 1,469-70 ft, D336/1 54·4 114·1 (P22113). 10, Lateral view, sectional focus; Penola Bore No. 1 at 1,200-1,210 ft, D273/1 56·1 118·5 (P22074). 11, 12, Sections cut parallel to the polar axis and obliquely to both the greatest breadth and the distal tenuitas of two grains from Cootabarlow Bore No. 2 at 1,469-70 ft; 11, D302/S77b/3-4 47·5 124·5 (P22151); 12, D302/S77a/1-2 39·4 124·1 (P22152).

Fig. 13-16—*Podocarpidites* cf. *P. multesimus* (Bolkhovitina). 13, 14, Proximal and distal foci; Cootabarlow Bore No. 2 at 1,469-70 ft, D336/1 37·1 110·1 (P22113). 15, Distal focus; Cootabarlow Bore No. 2 at 1,471-72 ft, D304/1 30·3 115·2 (P22153). 16, Section cut parallel to both the polar axis and the greatest breadth of a grain from Cootabarlow Bore No. 2 at 1,469-70 ft, D302/S81/2-3 52·1 112·2 (P22154).

Plate XXVI

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-5—*Microcachyridites antarcticus* Cookson. 1, Distal focus; Robe Bore No. 1 at 3,500 ft, D261/2 43·2 128·2 (P22155). 2, Lateral view; Dergholm Bore No. 1 at 532 ft, D299/1 46·9 124·2 (P22156). 3, Distal focus of specimen with four sacci; Cootabarlow Bore No. 2 at 1,469-70 ft, D336/1 49·7 127·3 (P22113). 4, 5, Sections cut parallel to the polar axis of a grain from Cootabarlow Bore No. 2 at 1,469-70 ft, D302/S82a/1-2 47·7 112·0 and 52·3 111·4 respectively (P22157).

Fig. 6, 7—*Podosporites microsaccatus* (Couper). 6, Distal focus; Robe Bore No. 1 at 1,400 ft, D224/4 57·3 127·6 (P22158). 7, Distal focus; Robe Bore No. 1 at 2,630 ft, D259/2 45·6 128·8 (P22159).

Fig. 8, 9—*Ginkgocycadophytus nitidus* (Balme). 8, Distal focus; Robe Bore No. 1 at 3,500 ft, D261/2 54·2 119·0 (P22155). 9, Sectional focus; Robe Bore No. 1 at 3,500 ft, D244/1 34·8 124·3 (P22575).

Fig. 10-14—*Classopollis* cf. *C. classoides* Pflug. 10, Distal focus showing distal, polar, aperturoid area; Wonthaggi, No. 20 shaft, sample P22593, D141/2 50·7 126·7 (P22576). 11, 12, Specimen from Cootabarlow Bore No. 2 at 1,469-70 ft, D336/1 39·8 111·0 (P22113); 11, proximal focus; 12, × 1,000 sectional (left) and proximal (right) foci showing proximal, polar, exinal elements. 13, Lateral view, × 1,000, high focus showing surface pattern of equatorial exine; Cootabarlow Bore No. 2 at 1,471-72 ft, D304/1 58·8 127·5 (P22153). 14, Lateral view, × 1,000, sectional focus showing proximal, polar, exinal elements and equatorially thickened exine; Cootabarlow Bore No. 2 at 1,469-70 ft, D302/1 50·6 109·3 (P22002).

Fig. 15—*Araucariacites australis* Cookson. Robe Bore No. 1 at 2,325 ft, D256/2 36·8 111·0 (P22577).

Fig. 16, 17—*Spheripollenites psilatus* Couper. 16, Ruptured specimen × 1,000; Wonthaggi, sample P22589, D239/2 46·0 115·1 (P21962). 17, Ruptured specimen × 750; Robe Bore No. 1 at 2,630 ft, D225/2 28·4 123·7 (P22119).

Fig. 18, 19—*Schizosporis parvus* Cookson & Dettmann. Lateral view, high and sectional foci showing equatorial 'furrow'; Penola Bore No. 1 at 1,610-20 ft, D295/1 28·7 113·0 (P21968).

Fig. 20, 21—*Schizosporis reticulatus* Cookson & Dettmann. 20, Polar view × 250; Penola Bore No. 1 at 3,715-21 ft, D348/8 38·3 120·4 (P22578). 21, Polar view × 250; Loxton Bore at 1,465-70 ft, D365/2 39·7 118·6 (P22579).

Fig. 22, 23—*Schizosporis rugulatus* Cookson & Dettmann. 22, Polar view × 250; Robe Bore No. 1 at 1,400 ft, D217/24 44·0 116·0 (P22580). 23, Lateral view × 250, showing equatorial 'furrow'; Haddon Downs Bore No. 5 at 465 ft, Cookson and Dettmann's (1959b) slide 8 54·6 115·9 (P22581).

Fig. 24—*Schizosporis spriggi* Cookson & Dettmann. Lateral view, × 250, showing equatorial 'furrow'; Penola Bore No. 1 at 2,990-3000 ft, D349/2 51·5 126·8 (P22582).

PLATE XXVII

All figures × 500 unless otherwise specified; from unretouched negatives.

Fig. 1-3—*Sestrosporites irregulatus* (Couper). Holotype; proximal, sectional, and distal foci showing interradially thickened, equatorial exine.

Fig. 4, 5—*Trilites tuberculiformis* Cookson. Holotype (P22726); proximal and distal foci showing radially thickened, equatorial exine. Waterfall Gorge, Kerguelen (sample 81a).

Fig. 6-8—*Trilites tuberculiformis* Cookson. All from Cumberland Bay, Kerguelen; British Museum (Natural History) sample 75139 (102). 6, Distal focus; D358/1 46·2 119·3 (P22727). 7, Sectional focus; D350/2 21·3 120·7 (P22728). 8, Oblique lateral view, high focus; D350/7 42·1 118·2 (P22729).

Fig. 9-11—Spores of *Naiadita lanceolata* Buckman. All from Somerset (*Naiadita* beds), Upper Rhaetic. 9, Lateral view; British Museum (Natural History) slide V25312 39·9 120·1. 10, 11, Proximal and distal foci; British Museum (Natural History) slide V25310 40·5 117·1.

Fig. 12-16—Spores of *Nothylas breutelli* Gottsche. Cuba, coll. C. Wright; ex Herb. Hort. Bot. Reg. Kew. 12, 13, Proximal and distal foci of a specimen with spinules; R929/2 28·2 121·8 (P22730). 14, Lateral view, sectional focus of a spinulate specimen; R929/1 37·3 121·9 (P22731). 15, 16, Proximal and distal foci of a distally verrucate and granulate specimen; R929/2 32·3 122·6 (P22730).

Fig. 17, 18—Spores of *Phaeoceros bulbiculosus* (Brotero). Coimbra, Portugal, coll. Fernandes et al.; ex Herb. Hort. Bot. Reg. Kew. Proximal and distal foci; R930/1 24·5 115·7 (P22732).

2

STRUCTURAL ANALYSIS OF THE HARCOURT BATHOLITH CONTACT AUREOLE

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Abstract

Mapping and analysis of structural elements in the Ordovician greywackes and slates about the Harcourt Batholith have demonstrated the superposition of small folds, and a strain slip cleavage, on the previously folded sediments. The superposed structures, developed during and as a result of intrusion, imply an outward, horizontally directed compression by the magma on the chamber walls. There is no evidence of vertical stresses. Later stresses caused jointing of the granodiorite, as well as faulting.

Introduction

Mapping of Central Victoria by early workers of the Geological Survey of Victoria produced data which suggested an intimate relationship between the structure of the Lower Ordovician sediments and the form of the Harcourt granodiorite batholith. The present work sought, by using the methods of structural analysis, to determine this relationship, and hence the intrusion tectonics. The project was simplified because the early work of the Survey and the later detailed stratigraphic mapping of W. J. Harris and D. E. Thomas had clearly defined the major structural features.

Field work for the current research was restricted to an examination of all the available exposures, where the structural elements were recorded as data for the statistical analysis. Exposures are poor over much of the area so that some gaps remain in the data. Even where good exposures occurred, weathering tended to obscure some of the critical structures, and in many cases, fresh faces had to be cut.

The help of Mr K. Horwood in the translation of German references, and of my wife, both in the field work and in the translation of Italian references, is gratefully acknowledged. The cost of the field work was covered by research grants from the University of Melbourne.

General Geology

The central part of the area studied is occupied by the arcuate batholith of the Harcourt granodiorite. Although no petrological studies were made, it is apparent that the batholith does not represent a single intrusion; rather, it is made up of several small, related intrusions, each with some unique aspects of texture, composition, and structure. The batholith intruded Lower Ordovician greywackes and slates on which it imposed a thermal metamorphism (Beavis 1962). The aureole is continuous around the whole of the batholith, and although locally covered by alluvium, for the most part it stands out as a low but well defined ridge. Except in the Maldon area, and about the Coliban lobe of the batholith, the aureole is about ½ mile wide, with relatively high grade cordierite hornfels at the contact, grading to spotted slates at the outer margin. At Maldon, the aureole, consisting of very high grade and metasomatised hornfels, is over 1 mile wide. On the Coliban lobe, the aureole is frequently less than ¼ mile wide, and even at the contact the grade of metamorphism is extremely low. This is of some significance in the assessment of the intrusion tectonics.

Small masses of grandodiorite, separated from the main mass by alluvial flats, occur in the NW. near Lockwood. While these are obviously related to the main batholith, they are not continuous with it below the alluvium, since hornfels has been observed around each.

Intense intrusion of dykes has occurred into both the granodiorite and the sediments. Although the dykes, which range in composition from acid pegmatites and aplites to ultrabasic monchiquites, represent more than one period of intrusive activity, their structural relations with the sediments are uniform; they are almost invariably parallel to the axial planes of folds, and frequently they have been intruded along these planes. The dykes are normally thin, but in the Big Hill-Mt Lockwood sections of the contact, the margin of the batholith is locally occupied by aplite dykes over 500 ft thick, and outcropping over a length of more than 1 mile.

Regional Analysis

FOLDING

The broad-scale regional analysis has been based largely on the mapping of Harris and Thomas, summarized by Thomas (1939). The Ordovician sediments have been folded into a series of domes and basins; the folds are large anticlinoria and synclinoria, with varying axial plunge. In the vicinity of the Harcourt batholith there is a regional reversal of plunge: N. of the batholith the folds plunge S. at

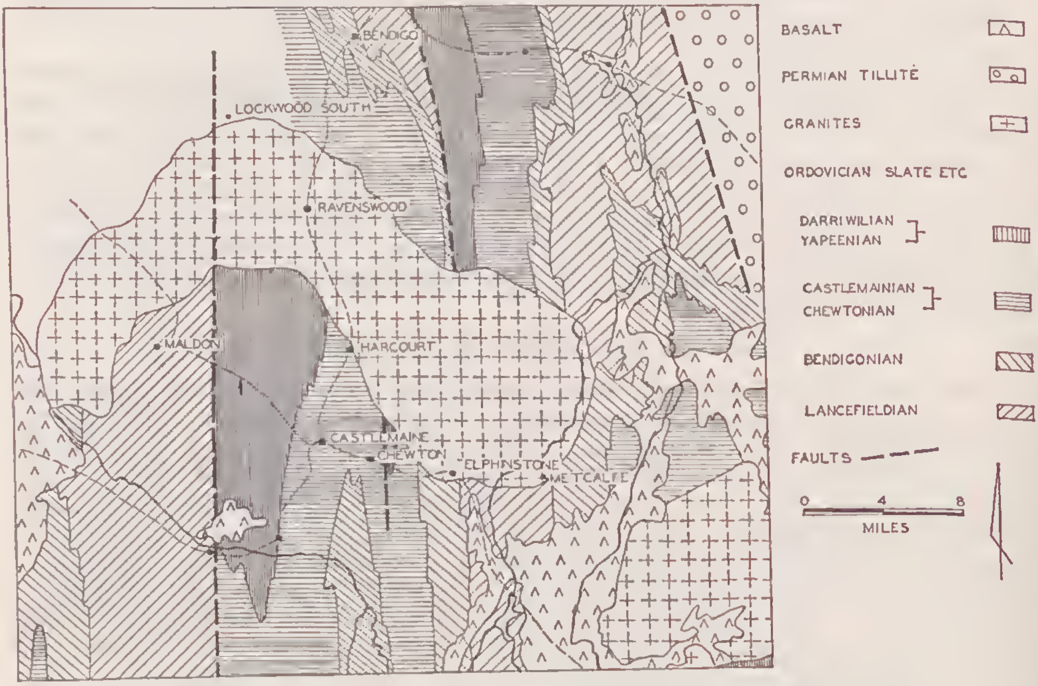

FIG. 1—Regional geological map of Central Victoria, after Harris 1916, and Thomas 1939.

10°-15°, while to the S. of the batholith, plunge is to the N. The batholith therefore occupies an E.-W. axis of plunge reversal, i.e., an open basin structure (which may indicate late collapse of the intrusion). This relationship is comparable to that observed by Stewart (1962) for the Cobaw batholith, which was intruded on the Riddell axis.

FAULTS AND LINEAMENTS

Although many minor faults were recorded, and some evidence of several large faults was observed, only two faults with significance so far as the present research is concerned, occur in the area studied: the Whitelaw Fault, and the Muckleford Fault. The work of Harris (1934) on the former, and of Thomas (1935) on the latter, has shown that while these structures are very old, renewed movement has taken place along them as recently as post-Pliocene times.

Where these faults cut the Ordovician sediments, lithological, palaeontological, and physiographic evidence of movement are clear. In the granodiorite, however, evidence of faulting is much more difficult to find. The E.-facing escarpment on the Whitelaw Fault (due as much to a more resistant lithology as to direct fault displacement) can be traced S. from Bendigo East until it merges with the high terrain of the contact aureole in the Parish of Sedgwick. No equivalent of this escarpment has been observed in the granodiorite; the elevated area about Mt Alexander is the effect of a more resistant granodiorite and has no association with faulting.

Within the batholith there are virtually no exposures on the line of the Whitelaw Fault, but there is a lineament, weakly defined by Myrtle Ck. At the head of this creek, the granodiorite is well exposed in a belt extending from Granite Hill to Mt Alexander. Within this belt there is no evidence of faulting, and it has been concluded that the Whitelaw Fault does not transect the batholith.

In the Chewton area, Harris (1916) postulated faulting from palaeontological evidence. Assessment of the evidence, reinterpreted in the light of the later, more detailed study of the graptolite zones by Harris and Thomas (1938) and the detailed mapping of Chewton by Thomas, raises doubts as to the validity of this structure, which possibly could have been regarded as a southerly continuation of the Whitelaw Fault. It can be stated with some certainty that the Whitelaw Fault pre-dated the intrusion of the batholith; later movement on this fault was the result of stresses with insufficient strength to cause rupture of the granodiorite.

By contrast, considerable evidence that the Muckleford Fault disrupted the granodiorite is available. The physiographic evidence of this fault in the granodiorite is seen in a lineament defined by the headwaters of Muckleford Ck and Spring Ck, and by a low, W.-facing escarpment across which there is a difference in altitude of 200 ft, developed on this lineament, near the Spring Vale Estate. The geological evidence is more impressive. While exposures of granodiorite are poor along the line of the Muckleford Fault, those near Spring Vale are excellent. Here, a very prominent set of N.-S. joints, strongly slickensided, has been developed, and in Spring Ck the granodiorite is locally brecciated. To the N., near Mt Lockwood, the Muckleford Fault locally forms a boundary of the batholith, with low grade brecciated hornfels abutting against the granodiorite, and a thick marginal aplite terminating on the fault. The evidence here indicates a lateral sinistral displacement of 1½ miles. In the S., near Porcupine Flat, a comparable displacement of the contact and of the aureole has been recorded.

The Muckleford Fault transects the batholith; whether or not the initial movement predated intrusion is not clear, but certainly post-intrusive stresses were adequate to disrupt the granodiorite. Harris and Thomas (1934) and Thomas (1935) have described the Muckleford Fault as a high angle thrust. While no evidence has been found to suggest that this is not so, it is clear that at some stage in the history of the fault there has been a considerable horizontal movement.

Observations in the field, combined with the study of topographic maps of the region, indicate two distinct elements in the stream pattern: a rectilinear element and a curvilinear element. The structural significance of these lineaments might be considerable; Hills (1959), e.g., has suggested that the curvilineament formed by the Coliban R. might reflect ring fracturing. Many of the lineaments are parallel both to the margin of the batholith and to major joint sets. This may be their sole significance, but often there is other evidence that they reflect important structures.

Fig. 2—Lineaments developed on the Harcourt Batholith. The inset shows the distribution of trends of the rectilineaments.

One noteworthy aspect of the streams developed on the granodiorite is that, almost invariably, these streams leave the batholith, and cross the aureole ridge on one of the lineaments. In some cases, as at Lockwood South, Expedition Pass, and Muckleford Ck, the lineament has been proved to represent a fault; in other cases the true nature of the lineament is uncertain or unknown. Some of the lineaments, e.g. that on Bullock Ck, mark important topographic boundaries. E. of Bullock Ck bold continuous outcrops form a rugged landscape, while to the W., the terrain is gently rounded, and exposures are limited to a few isolated boulders. There is some evidence that the Bullock Ck lineament does in fact represent a fault, but this evidence is by no means conclusive.

Mesoscopic Study and Macroscopic Analysis

GRANODIORITE

FOLIATION AND LINEATION

Foliation in the granodiorite is expressed by the preferred orientation of biotite flakes, and is seen in the field as linear traces on joints and other exposed planes. With two exceptions, foliation was observed only in the marginal zone of the batholith, and then only in restricted areas at Ravenswood, Emu Ck, and Porcupine Flat. The foliation observed in the marginal zone was invariably parallel or sub-parallel to the contact; the foliation is to be regarded as a primary flow structure since no evidence of post-crystallization stressing which could develop a foliation in the granodiorite has been obtained. Lineation, also regarded as a primary flow feature, is, with one exception, defined by the orientation of pod-shaped melanocratic schlieren. The exceptional case is the linear arrangement of felspar phenocrysts in a porphyritic phase of the granodiorite near Maldon cemetery. Lineation has an even more restricted development than foliation, only 15 lineations having been recorded for the whole batholith.

JOINTS

Joints are the most prominent structural elements in the granodiorite. The primary nature of some of the joints is suggested by the occurrence on them of dykes and veins of aplite and pegmatite. Other joints are demonstrably secondary, and the result of shearing stresses, but for most of the joints it is impossible to determine their origin; hence any analysis of the joint pattern must be restricted by this uncertainty.

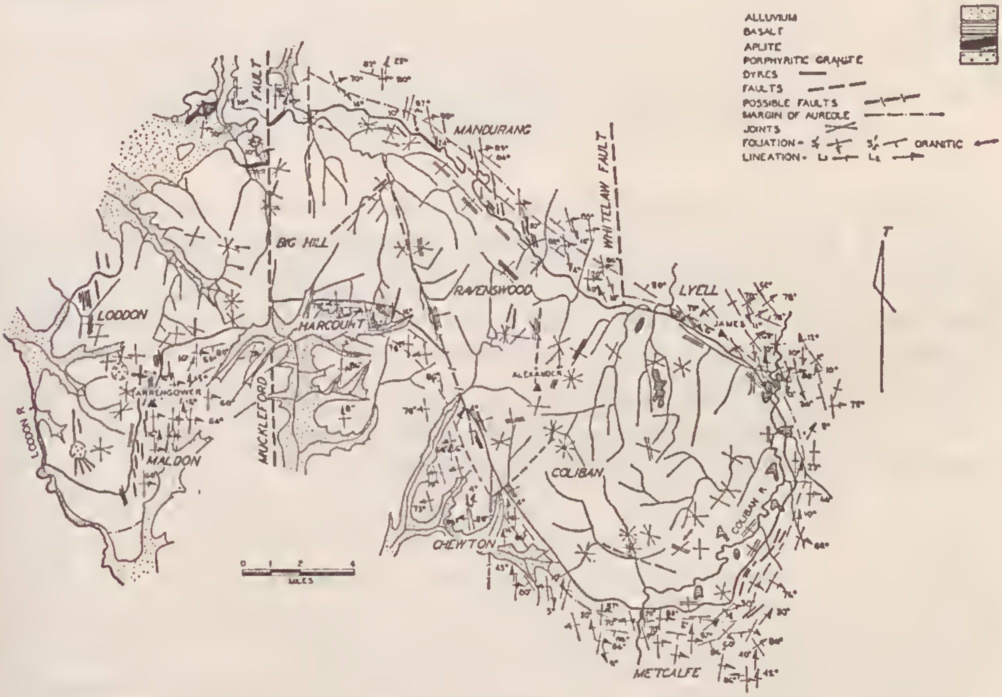

FIG. 3—Structural map of the Harcourt Batholith.

At each exposure examined, vertical joints dominated. Some flat joints occurred, and while many of these are considered to be exfoliation features, some are essential sets of the system. Typical joint systems for most of the exposures are shown on Fig. 3. Many of the joints could be traced only for 20 or 30 ft, others, usually two orthogonal sets, could often be traced for distances of 1 mile or more.

Where quarries have been excavated it was of interest to note that whereas the joint system recorded on the natural surface showed complexity, that exposed in the quarry was usually simple, with two vertical sets. It is most probable that the multiplicity of joints seen in the weathered rock is also a feature of the fresh rock, but that the joints become visible only as a result of weathering and the stress redistribution which would accompany erosional unloading. This relation is shown on Fig. 4b.

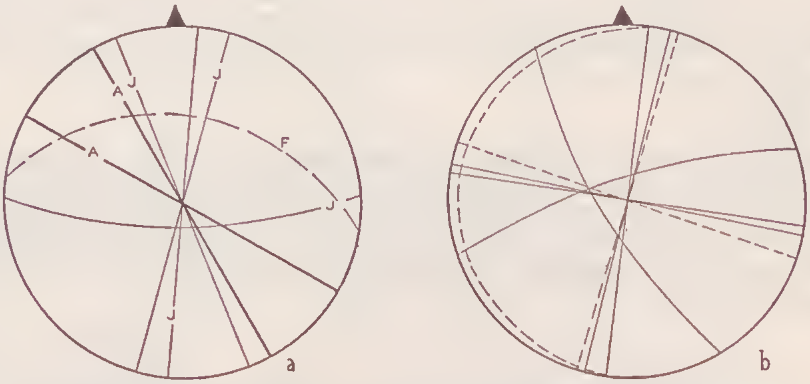

Fig. 4—a. Joints, foliation, and dykes in granodiorite, Belvoir Park. b. Joints at Mt Alexander. Broken lines are joints exposed in the Koala Park quarry; solid lines are joints exposed on the natural surface.

Fig. 4a illustrates a typical joint system. It can be seen that aplite dykes occur on two sets (A). The foliation (F) shows no relationship, apparently, to the jointing. The typical development of steeply dipping joints is seen clearly. One unusual joint system calls for some comment. A flat face of granodiorite, exposed about 1 mile W. from Mt Tarrengower, is broken into polygonal columns by joints, a structure unique in the batholith. It is most likely that this jointing is the result of weathering of a large exfoliated slab.

A multiplicity of joint systems exists within the batholith; however, there is both a local and regional homogeneity of the joint patterns. One of the most outstanding features is the parallelism to the contact of the major joints developed in the marginal zone right around the periphery. This is particularly so between Big Hill and Mt James, and for the full length of the contact of the Coliban lobe. Within the batholith it is possible sometimes to trace major, continuous joints about higher terrain, e.g., Mt Alexander. The high-level, xenolith-free granodiorite of this area has a pronounced set of joints parallel to its margin, suggesting that Mt Alexander comprises a distinct intrusion—an hypothesis which receives some support from petrological evidence (Dr R. J. McLaughlin pers. comm.).

Geometric and kinematic analysis of the granodiorite joint systems is limited by the inability to distinguish certainly between primary structures, and those due to post-crystallization stresses. Nonetheless, the geometry at almost all of the exposures tends to a uniform four sets, two of which intersect at right angles, and the other two intersecting at 55° to 60°: a typical pattern of fractures due to shearing stress. It is important to note that the two orthogonal sets are the most highly developed.

The joint patterns for the several sectors into which the batholith was somewhat arbitrarily divided for analysis are shown on Fig. 5. It is clear that, throughout, vertical joints predominate, and that the two main sets are those with N./S. and E./W. strike.

SEDIMENTARY ROCKS

FOLIATION

Foliation is used here in a non-genetic sense, and is applied to all planar, penetrative structures. Within the contact aureole, three types of foliation have been formed: bedding (S), slaty cleavage (S^1_1) and strain-slip cleavage (S^1_2). Bedding is the most prominent foliation, with slaty cleavage, restricted to the more incompetent sediments, next in importance. The strain-slip cleavage, too, tends to be restricted to the slates, but the fissuring of sandstones, described by Hills and Thomas (1945) appears in some cases to be a form of this cleavage developed on the hinges of folds during the first deformation, while it has formed also the puckering of slates and the rudimentary boudinage seen in the greywackes. In extreme cases, disruption of puckered laminae by the strain-slip cleavage has produced the cleavage boudinage described by Charlesworth and Evans (1962). Both the slaty and strain-slip cleavages show curvature locally, and on a macroscopic scale. The local curvature is associated with textural gradations in the complexly graded greywackes, as well as with structural discontinuities such as bedding. This is to be regarded as due both to variation in the orientation of the maximum principal stress resulting from inhomogeneities in the rocks, and to drag effects from slip along bedding planes during flexural folding. The more general, macroscopic curvature is a reflection of the geometry of the folds.

LINEATION

Lineation, parallel to fold axes, is developed in the slates. It is only rarely to be observed in normal exposures, and for the present work most observations were made on freshly cleared faces. The most consistently developed lineation is that due to the intersection of bedding and slaty cleavage. Microcrenulations on bedding planes were less frequent forms. In areas where strain-slip cleavage occurs, quite complex lineations can be seen. Where the bed is planar, with bedding and both strain-slip and slaty cleavages present, three lineations are developed: L1, the intersection of S and S^1_1; L2, the intersection of S and S^1_2; and L2′, the intersection of S^1_1 and S^1_2. Where the superposed deformation is represented by folds as well as strain-slip cleavage, the lineations are complex, and can be interpreted only after the most thorough study (Fig. 6).

FOLDS

On the mesoscopic scale, the folds are small plunging structures, usually asymmetric, and frequently overturned. The axial planes are almost invariably inclined and curved. The hinge lines may also show some curvature, but this is apparent only on the macroscopic scale; mesoscopically, the hinge lines may be regarded as rectilinear. Geometrically, the folds may be described as plunging, inclined, non-

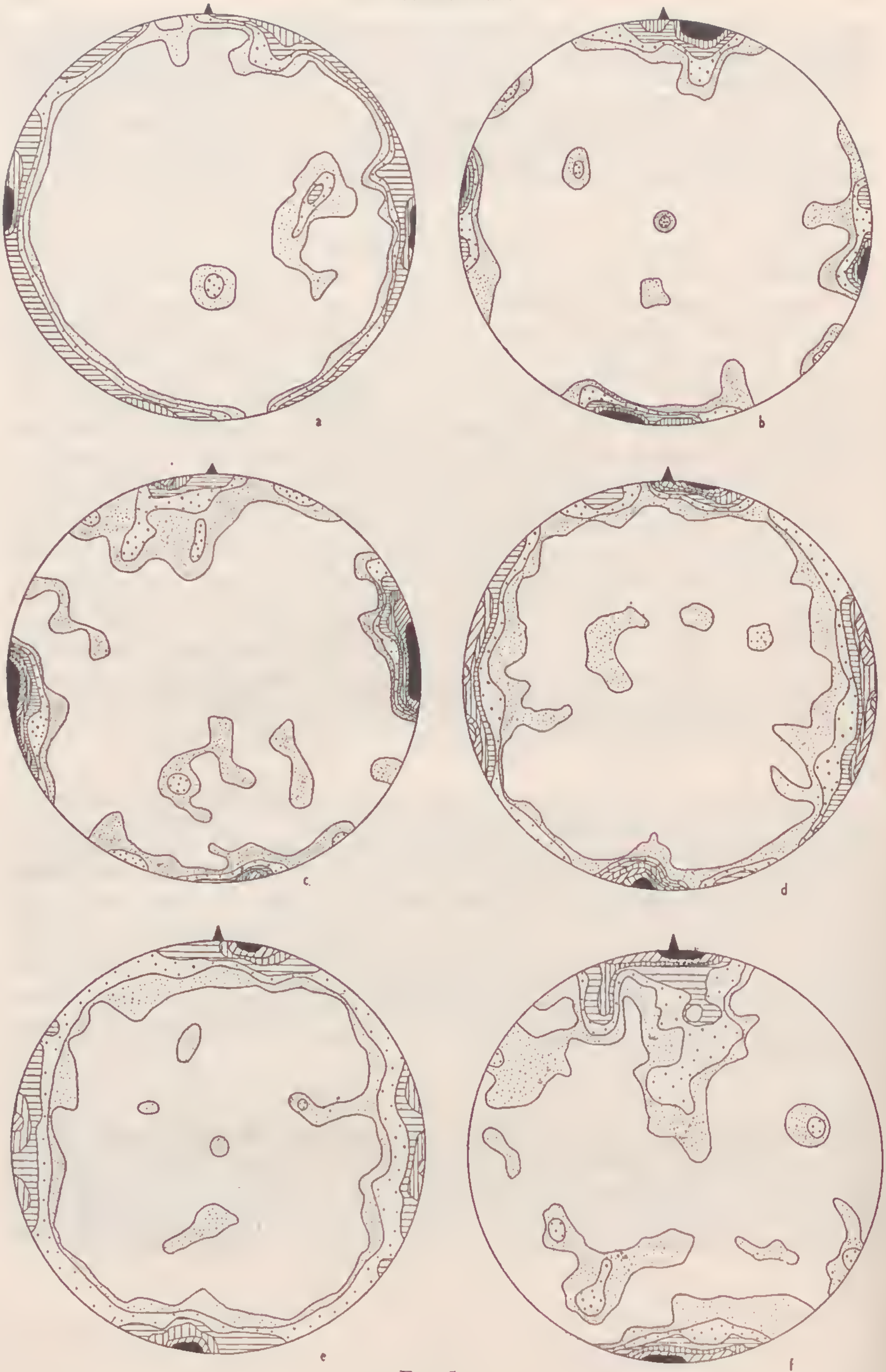

FIG. 5

plane, cylindrical structures. The strike of the axial plane is rarely parallel to the trend of the axis.

The style of folding is similar. Slate beds show marked thinning on the limbs of the folds, and the folding of these beds has been of the shear type. The greywackes show little or no thinning on the limbs. The folding of these beds has been by flexure, modified to some extent, particularly where complexly graded greywackes have been involved, by shearing. Here the slight thinning of beds on the limbs is the effect of flattening due to shear (Ramsay 1962). The folding of the sediments, from the mesoscopic evidence, has been flexural-shear type; slip along bedding planes has also been a significant feature. While these remarks apply to the first-generation folds, it will be seen that the superposed folds are of the same type, although with much smaller dimensions.

The deformed sediments cannot be described either as B tectonites or as S tectonites, since they have features of each. However, the S tectonite characteristics are dominant. The low degree of metamorphism associated with the folding, and the nature of the tectonite structures developed, suggest deformation at only a moderate tectonic level.

JOINTS

Because joints are non-penetrative, discrete structural elements, their analysis must be attended by some uncertainty. Various workers, e.g., Turner and Verhoogen (1960) and Price (1959) have suggested that, since folding has occurred while rocks are in a plastic condition, they cannot be ruptured. However, residual stresses, effective still when the rocks become brittle, would be expected to have the same effects as the original stress; relief of the residual stresses would be marked by the formation of joints. As pointed out by Weiss (1954) and others, it is significant that, in tectonites, the geometrical relationship of joints to penetrative elements of folds is too consistent to be fortuitous.

Of the joints present in the rocks of the Harcourt aureole, the *ac* set are the most important. These joints, interpreted as tension fractures, were rarely truly normal to the B1 lineation. This behaviour has been observed consistently by other workers in other areas. In the Turoka region of Kenya, Weiss (1958) noted a consistent angular relationship between the B axes of folds and the *ac* joints. In the area discussed in the present paper this was also found to be the case statistically, although at individual exposures there is a very wide range. The statistically consistent relationship, combined with the departure of the *ac* joints from truly normal to B, can possibly be explained by the development of a non-uniform stress field late in the deformation history, and the consequent formation of joints normal to variable axes of elastic strain at slight angles to the B axis of the main deformation (Weiss 1958). One interesting aspect of the Harcourt aureole is the fact that the *ac* joints of the sediments are parallel to the major set of the granodiorite.

FIG. 5—Equal area projection of joints in the Harcourt Batholith.
a. Coliban lobe, 200 joints, contours 5-4-3-2-1%.
b. Ravenswood area, 110 joints, contours 5-4-3-2-1%.
c. Big Hill area, 278 joints, contours 7-5-4-3-2-1%.
d. Loddon lobe, 300 joints, contours 7-6-5-4-3-2-1%.
e. Composite diagram for batholith, 888 joints, contours 5-4-3-2-1-½%.
f. Composite diagram for joints in sedimentary rocks about the batholith, 974 joints, contours 4-3-2-1-¾-½%.

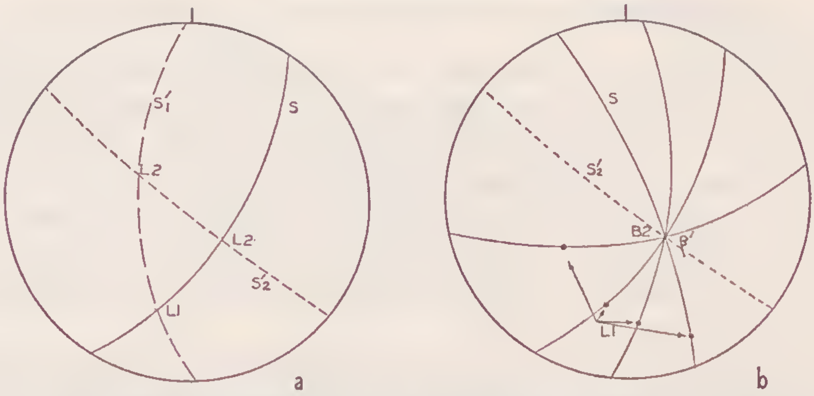

FIG. 6—Lineations developed in tectonites in the Harcourt Aureole.
a. Lineations in planar bed, Coliban R.
b. Lineations in folded bed, Mt James.

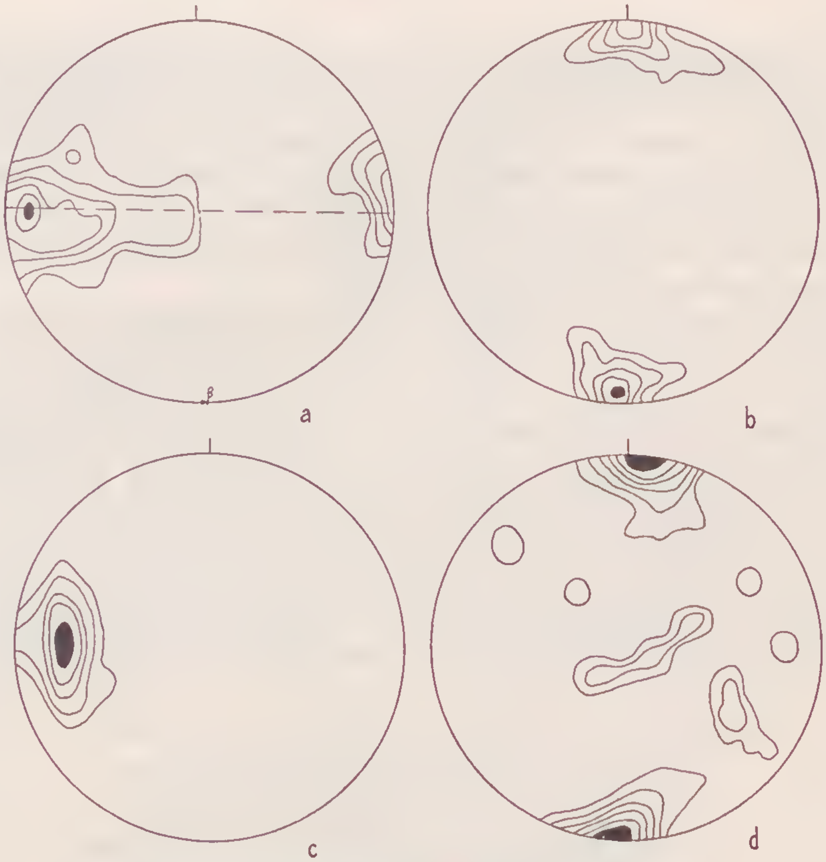

FIG. 7—Geometry of folding, Maldon sub area.
a. 98 π S, contours 6-5-4-3-2-1%.
b. 51B lineations, contours 10-8-6-4-2%.
c. 103 πS_1^1, contours 5-4-3-2-1%.
d. Poles to 175 joints, contours 6-5-4-3-2-1%.

Whereas the *ac* joints cut both the greywackes and slates, *hOl* joints tend to be restricted to the arenaceous sediments. These joints intersect in B of the first deformation, but there is some doubt that all are the result of this deformation since, in the Chewton sub area, these joints in the greywackes pass into strain-slip cleavage in the slates. *hkO* joints are rare, but *Okl* joints are frequently as prominent as the *ac* types. The *Okl* joints intersect in an acute angle which is bisected by the *ac* joint of the system they intersect in *a* and are regarded as shear fractures. *hkl* shear joints were recorded, but are rare.

Macroscopic Analysis

For the purpose of structural analysis, the aureole was divided into sub areas. As analysis proceeded, it became apparent that the folding was not always cylindrical; however, because of the nature of the geometry, this did not affect the validity of the analysis. W. of the batholith, and in the central part of the Barfold Ra., analysis was not possible because of lack of exposures, while to the S. of the Maldon lobe, flooding by the Cairn Curran reservoir prevented any study.

MALDON SUB AREA

The folds, previously described by Bradford (1904) and Moon (1897), are cylindrical both on the mesoscopic and macroscopic scales; they are almost invariably asymmetric, and overturned to the W. This is shown in Fig. 7a and 7c where poles to S and S_1^1 form maxima for E.-dipping structures. The geometry has a monoclinic symmetry: there is a single β tautozonal axis parallel to B (Fig. 7b). Strain-slip cleavage is developed, but is invariably parallel to the slaty cleavage. The most striking aspect of the geometry is the parallelism of the fold axial planes to the margin of the batholith.

The joint diagram shows the dominance of *ac* joints, which, statistically, are normal to the B axes. Other joints are only weakly developed.

HARCOURT SUB AREA

Strain-slip cleavage is strongly developed, with an E.-W. strike and a steep southerly dip, parallel to the margin of the batholith in this area (Fig. 8d). Two quite distinct lineations were observed: one has a maximum for gentle northerly plunge (Fig. 8b) and is coincident with β; the second is formed by the intersection of S_2^1 with S and S_1^1. The geometry is apparently monoclinic, but when all elements are considered, the symmetry is in fact triclinic. The folds tend to be symmetrical, are rarely overturned, and have near vertical axial planes. In this area the *ac* joints, normal to B1, are again the dominant set.

CHEWTON SUB AREA

The S diagram shows a single β, but there is a tendency towards the formation of a second girdle; the symmetry is monoclinic, but has triclinic aspects. In this sub area the slaty cleavage and strain-slip cleavage are sub-parallel, and it was frequently difficult to distinguish between B1 and B2 lineations. The geometry is made more complex by the presence of strain-slip cleavage of two generations. This certainly accounts for the spread in the B1 diagram (Fig. 9b). The B2 lineations are often complex, particularly near the hinges of folds, and where the slaty cleavage is curved. The strain-slip cleavage of the second deformation is once more parallel to the margin of the batholith, but the fold axes and axial planes of the first generation, in contrast to Maldon, are only sub-parallel to the batholith.

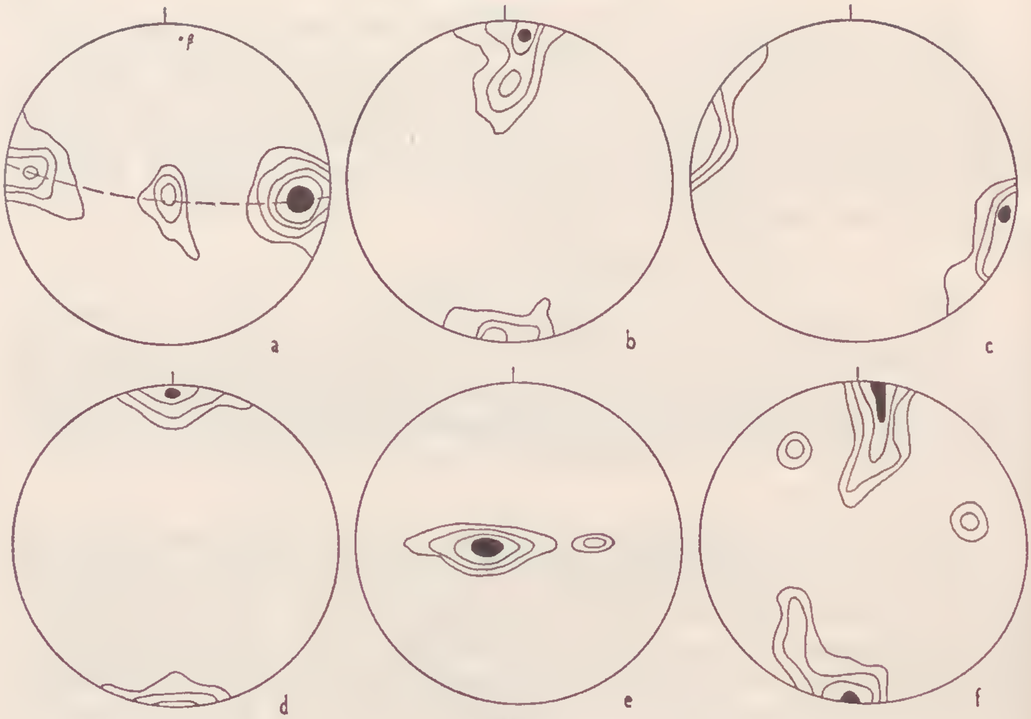

Fig. 8

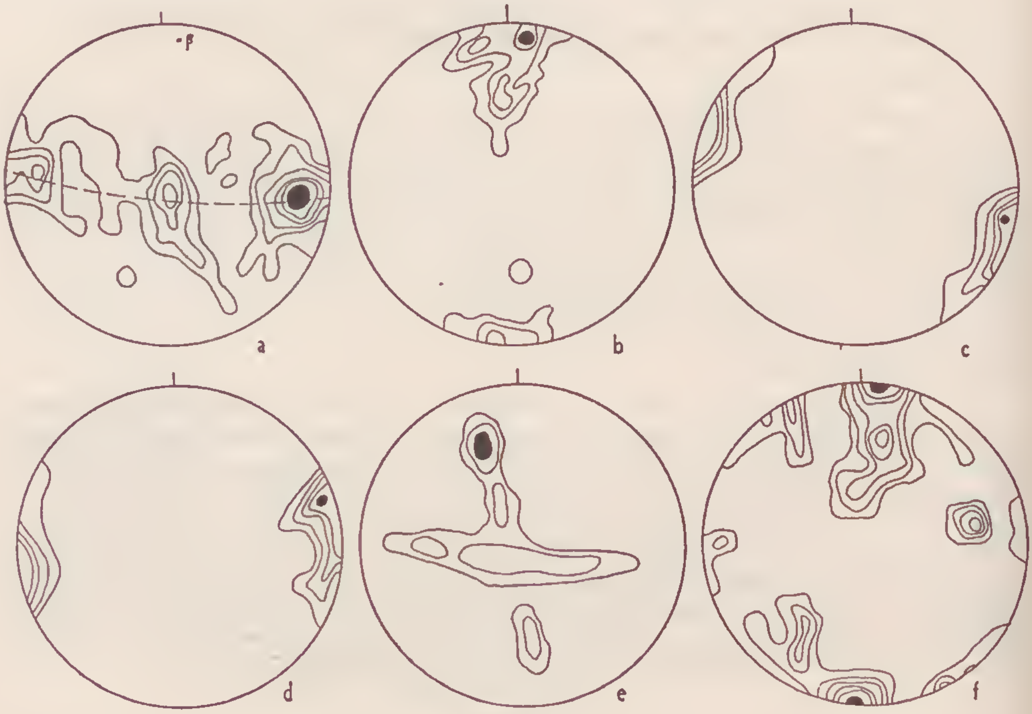

Fig. 9

Folds here, as noted by Thomas (1939, 1940, 1941), Baragwanath (1903) and Dickenson (1941), are uniformly overturned to the E., and overturned isoclinal folding is not uncommon. *ac* joints are still dominant, but in this area, other joints show an increasing importance. In general it was observed near Chewton that fissuring of sandstone was intimately associated with the strain-slip cleavage.

MANDURANG SUB AREA

The symmetry is apparently monoclinic, but consideration of all the elements again shows triclinicity. There is a single β parallel to B1 (Fig. 10a), which has a gentle plunge to the S. Strain-slip cleavage is parallel to the granodiorite contact, and is vertical. B2 lineations, with near vertical plunge, were clearly distinguishable in the field from B1 lineations. Small folds with axes B2 are commonly observed.

Slaty cleavage, parallel to the axial planes of the folds of the first generation, has a steep easterly dip. The folds are only slightly asymmetric, and are rarely overturned.

LYELL SUB AREA

In the contact zone, the metasediments are frequently crumpled and shattered. Here too, superposed folds show the highest development observed in the aureole. These folds are small, with amplitude rarely exceeding 12 inches; the axial planes, defined by strain-slip cleavage, are parallel to the batholith margin. Slaty cleavage shows a more westerly trend than is usual for the region; the two cleavages are sub-parallel, although in some places they intersect in angles as high as 75°. As in most of the other sub areas, the symmetry of S is statistically monoclinic, but that of the fabric as a whole is triclinic.

METCALFE SUB AREA

Between the Lyell and Metcalfe sub areas, too few observations were available for analysis to be attempted. In this intervening region, however, it would seem (Fig. 3) that bedding, slaty cleavage and strain-slip cleavage are all approximately parallel to the granodiorite margin. In the Metcalfe sub area itself, crumpling and shattering of the sediments was again noted near the contact, particularly near the township of Metcalfe. Both bedding and slaty cleavage show a concordance with the batholith: the spread in the diagrams (Fig. 12a, c) is due to the swing in

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FIG. 8—Geometry of folding, Harcourt sub area.
a. III π S, contours 5-4-3-2-1%.
b. 48 B1 lineations, contours 8-6-4-2%.
c. 52 πS_1^1, contours 8-6-4-2%.
d. 43 πS_2^1, contours 8-6-4-2%.
e. 46 B2 lineations, contours 8-6-4-2%.
f. Poles to 96 joints, contours 4-3-2-1%.

FIG. 9—Geometry of folding, Chewton sub area.
a. 142 π S, contours 6-5-4-3-2-1%.
b. 78 B1 lineations, contours 8-3-2-1%.
c. 97 πS_1^1, contours 5-4-3-2-1%.
d. 73 πS_2^1, contours 5-4-3-2-1%.
e. 54 B2 lineations, contours 8-6-4-2%.
f. Poles to 193 joints, contours 6-5-4-3-2-1%.

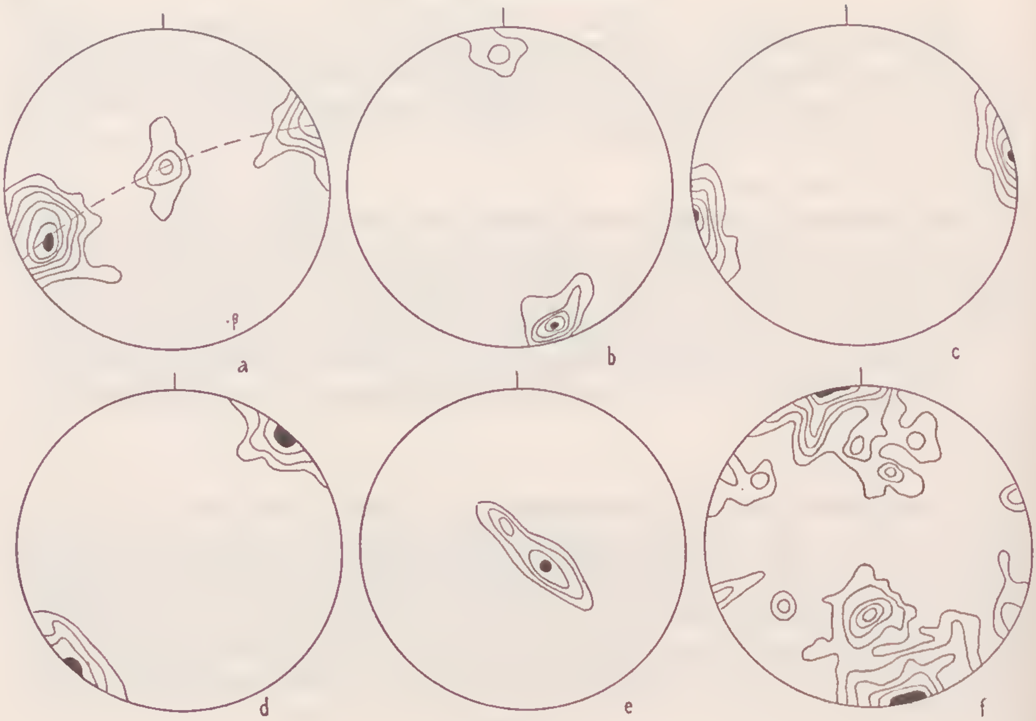

Fig. 10

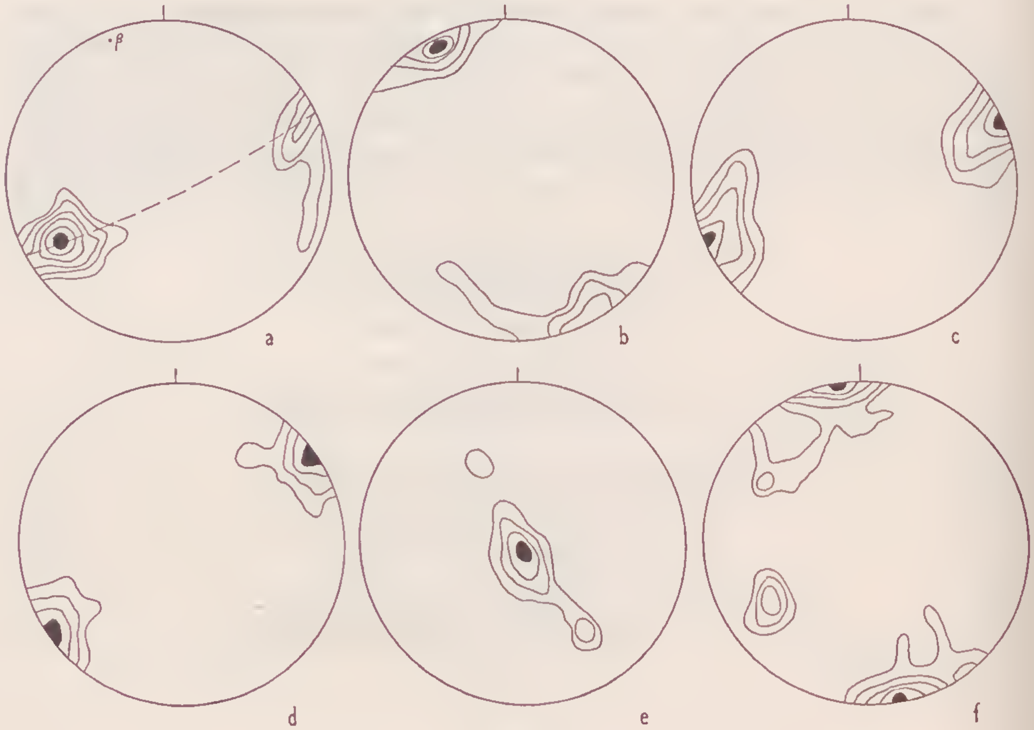

Fig. 11

attitude of these surfaces in the section between Metcalfe and Taradale. In the Metcalfe township area, strain-slip cleavage was not observed, but it is highly developed both south and west of the town, and is parallel to the contact. In this sub-area, a true *a* (of the B1 folds) lineation has been developed in shale beds. This is unique in the aureole.

QUARTZ REEFS

Fig. 13 shows the orientation of quartz reefs in the contact aureole. These are invariably parallel to the axial planes of the first folds. Some of the reefs show deformation, but this is not typical. The control of emplacement of the reefs was obviously S_1; the strain-slip cleavage has had no apparent influence.

Microscopic Analysis

GRANODIORITE

Mesoscopic foliation is present in the granodiorite only in the contact zone; elsewhere in the batholith there has been no apparent development of penetrative planar structures. Of the specimens analysed on the microscopic scale, two may be taken as typical. Specimen 1 (Fig. 14a) is a strongly foliated granodiorite from the contact zone at Big Hill. The poles to {001} of biotite form a single maximum normal to the mesoscopic foliation. By contrast, specimen 2 (Fig. 14b) represents a sample of non-foliated granodiorite from Mt Alexander. Three maxima were found for the biotite {001} orientation; this may be due to influences other than flow. There is no evidence of post-crystallization deformation in this rock, and the critical factor would seem to be the homogeneity of the biotite fabric. Three sections cut from the hand sample of specimen 2 gave three distinct orientation patterns for biotite. Homogeneity of fabric does not exist here, and fabric analyses are therefore of no value.

SEDIMENTARY ROCKS

Of this group, only the quartz-rich types such as greywacke and quartzite were suitable for microscopic analysis. Attempts were made to determine both quartz and biotite fabrics, but normally biotite was insufficient for reliable study. Most detailed work was therefore carried out on the quartz.

Fig. 15 illustrates biotite {001} fabric in two metagreywackes. These are representative of the two types of biotite fabric found. The symmetry of these fabrics was

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FIG. 10—Geometry of folding, Mandurang sub area.
a. $209\ \pi\, S$, contours 7-6-5-4-3-2-1%.
b. 96 B1 lineations, contours 5-4-3-2-1%.
c. $103\ \pi\, S_1^1$, contours 5-4-3-2-1%.
d. $56\ \pi\, S_2^1$, contours 8-6-4-2%.
e. 66 B2 lineations, contours 8-6-4-2%.
f. Poles to 201 joints, contours 6-5-4-3-2-1%.

FIG. 11—Geometry of folding, Lyell sub area.
a. $103\ \pi\, S$, contours 6-5-4-3-2-1%.
b. 54 B1 lineations, contours 10-8-6-4-2%.
c. $87\ \pi\, S_1^1$, contours 6-4-3-2-1%.
d. $75\ \pi\, S_2^1$, contours 5-4-3-2%.
e. 46 B2 lineations, contours 8-6-4-2%.
f. Poles to 121 joints, contours 5-4-3-2-1%.

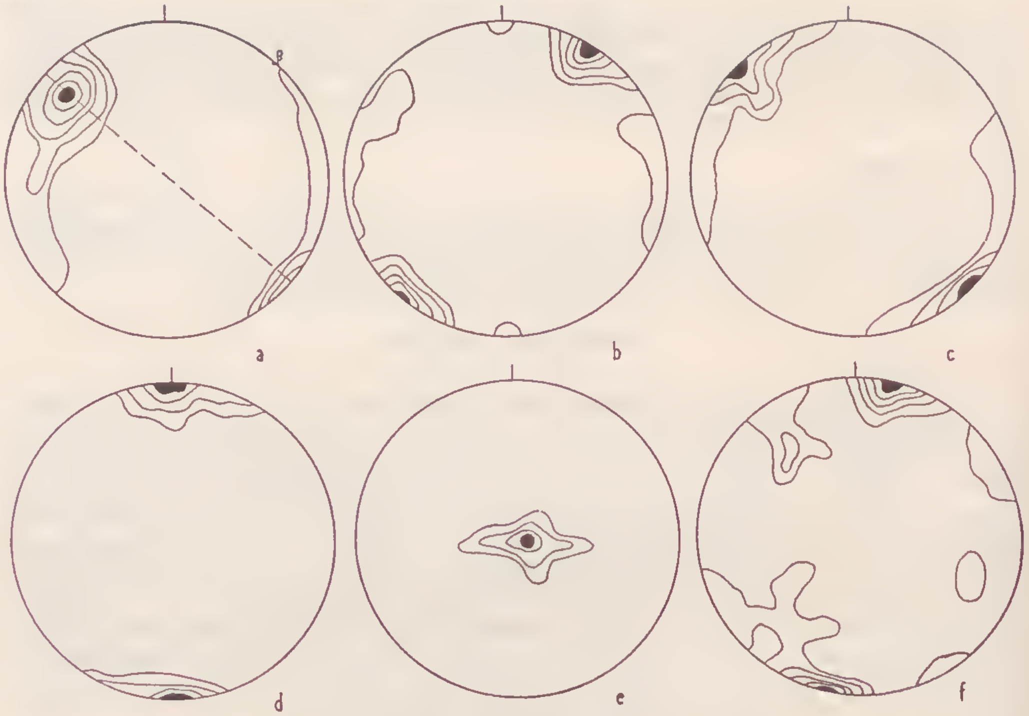

FIG. 12—Geometry of folding, Metcalfe sub area.
a. III S, contours 6-5-4-3-2-1%.
b. 89 B1 lineations, contours 5-4-3-2-1%.
c. 53 S^1_1, contours 8-6-4-2%.
d. 48 S^1_2, contours 8-6-4-2%.
e. 46 B2 lineations, contours 8-6-4-2%.
f. Poles to 178 joints, contours 5-4-3-2-1%.

invariably triclinic; within the fields of both a thin section and a hand specimen, fabric homogeneity was of a high order. Specimen 3 shows one very strong maximum, with two less well developed maxima. The strongest is normal to the mesoscopically visible S^1, while of the two weaker, one is normal to S and the other to S^1_2. Specimen 4 shows one strong maximum which is normal to S^1_2, and one weak maximum normal to S^1_1. There is no apparent parallelism of biotites to S.

The biotite fabrics then give microscopic evidence of the formation of two deformational *s* planes within the sedimentary rocks about the batholith. The biotite fabric appears as the result of two distinct deforming stresses which produced, as inferred from the mesoscopic data, $B \wedge B'$ tectonites.

The quartz fabrics invariably display a triclinic symmetry. The degree of homogeneity of these fabrics varies with scale: it is high on the scale of a thin section (see example Fig. 16). Similarly, for samples taken from a single bed at Lockwood South, a high degree of homogeneity was found. On a regional scale, it would be difficult to assess this feature unless some hundreds of specimens were examined:

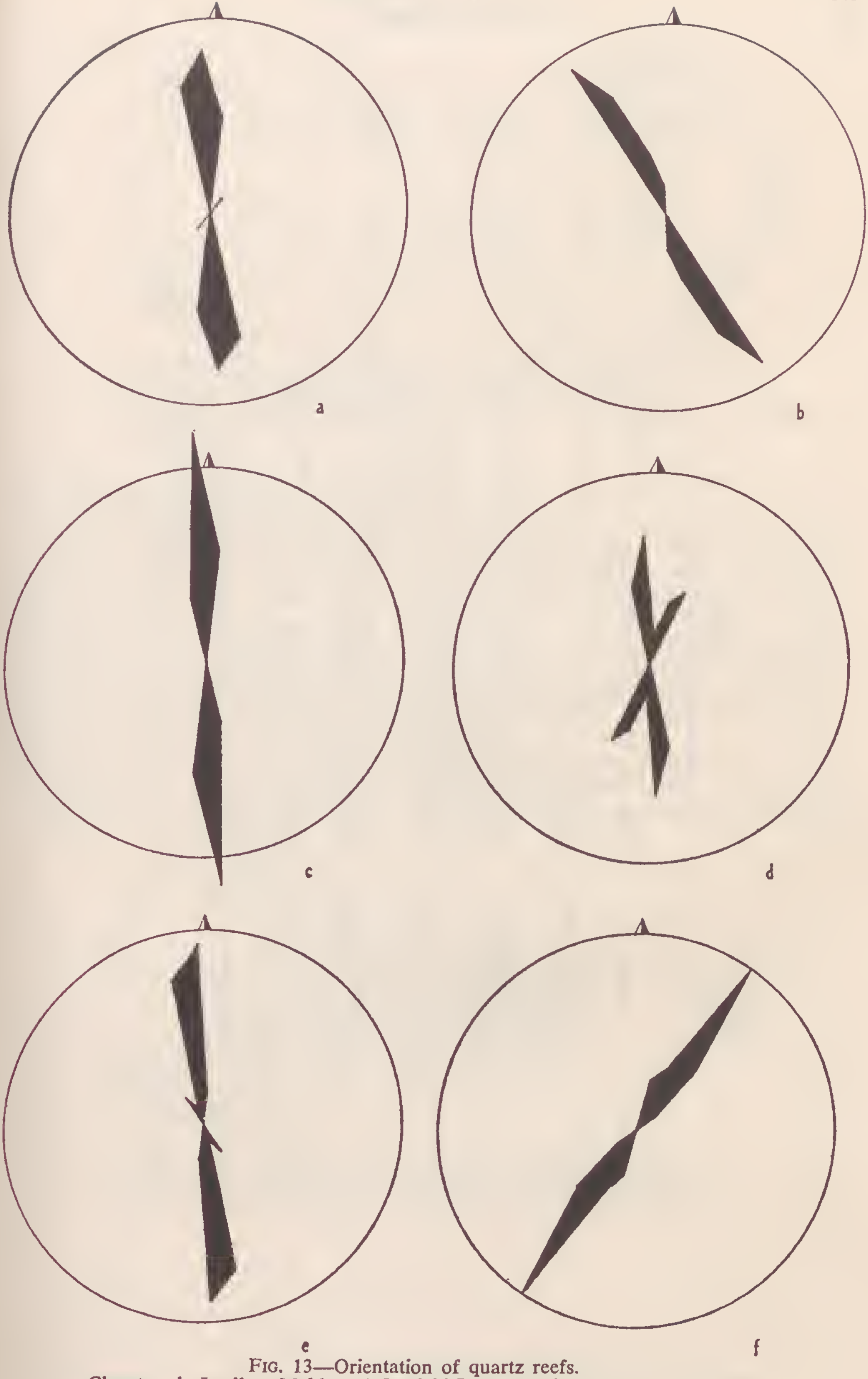

Fig. 13—Orientation of quartz reefs.
a. Chewton, b. Lyell, c. Maldon, d. Barfold Ranges, e. Mandurang f. Metcalfe.

TABLE 1

Summary of Macroscopic Geometry

Sub Area	Bedding, S	Cleavage S_1^1	Cleavage S_2^1	Lineations	Total Symmetry	Trend of margin of Batholith
Maldon	Cylindrically folded; β plunges 0°/N. Monoclinic	Dip 62°E. Strike N.-S.	—	B1 plunges 8°S.	Monoclinic	N.10°E.
Harcourt	Cylindrically folded; β plunges 8°/N.6° E. Monoclinic	Dip 78°W. Strike N.11°E.	Dip 85°S. Strike E.-W.	B1 plunges 10°N.8°E. B2 plunges 75°W.	Triclinic	E.-W.
Chewton	Cylindrically folded; β plunges 10°/N.60°E. Monoclinic-Triclinic	Dip 80°W. Strike N.12°E.	Dip 80°W. Strike N.17°W.	B1 dispersed 10° plunge, N.6°E. B2 dispersed 32° plunge N.20°W.	Triclinic	N.25°W.
Lyell	Cylindrically folded; β plunges 6°/N.20°W. Monoclinic	Dip 90° Strike N.22°W.	Dip 90° Strike N.32°W.	B1 plunges 10°N.20°W. B2 plunges 85°S.45°E.	Triclinic	N.40°W.
Metcalfe	Cylindrically folded; β plunges 0°/N.43°E. Monoclinic	Dip 90° Strike N.43°E.	Dip 90° Strike E.-W.	B1 plunges 0°N.43°E. B2 plunges 85°E.	Triclinic	E.-W.
Mandurang	Cylindrically folded; β plunges 11°/S.24°E. Monoclinic	Dip 90° Strike N.10°W.	Dip 90° Strike N.46°W.	B1 plunges 10°S.24°E. B2 plunges (i) 75°/S.48°E. (ii) 75°/N.42°W.	Triclinic	N.45°W.

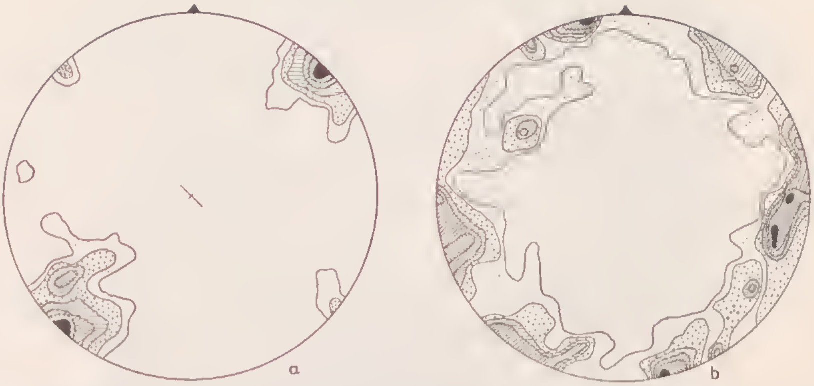

FIG. 14—Poles to {001} of biotite in granodiorite.
a. Big Hill contact zone, foliated granodiorite, 300 poles, contours 6-5-4-3-2-1%.
b. Non-foliated granodiorite, Mt Alexander Koala Park quarry. 300 poles, contours 6-5-4-3-2-1%.

in the region studied, the few samples suggest that the quartz [0001] fabric is regionally inhomogeneous.

Axial distribution analyses (A.V.A.) were carried out on three specimens. A.V.A. are used to distinguish between orientation patterns which are due to inhomogeneities in the fabric field as a whole, and those which are due to inhomogeneities between individual grains without reference to the complete fabric field (Case I and Case II, respectively of Sander 1950). Orientation patterns of case I show maxima in the diagrams which may be referred to specific S planes within the rock, since the orientation pattern is determined by the mechanical behaviour of the whole rock. For case II, the grains may show a strong preferred orientation, but grains with a given orientation are not spatially related to definite S planes in the fabric: this is known as direction homogeneity.

Of the three specimens analysed in this way, No. 5 is a metagreywacke from Mt Herbert; No. 6, a metaquartzite from Lockwood South; and No. 7, a metaquartzite from S. of Harcourt. Each of these rocks differs in the proportion of quartz

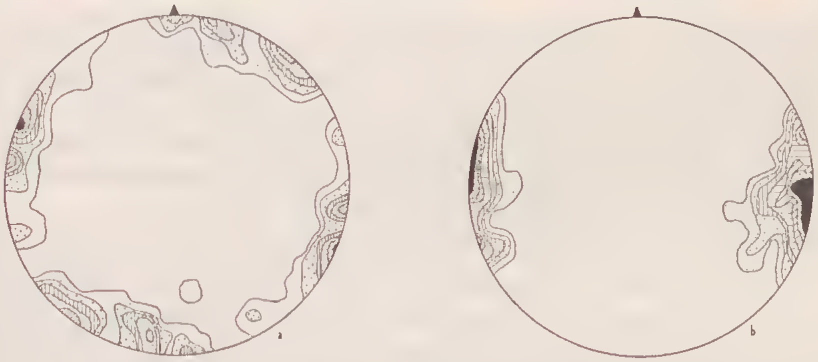

FIG. 15—Poles to {001} of biotite in two metagreywackes.
a. Specimen 3, Big Hill Tunnel, 300 poles, contours 6-5-4-3-2-1%.
b. Specimen 4, Barfold Ra., 300 poles, contours 7-6-5-4-3-2-1%,

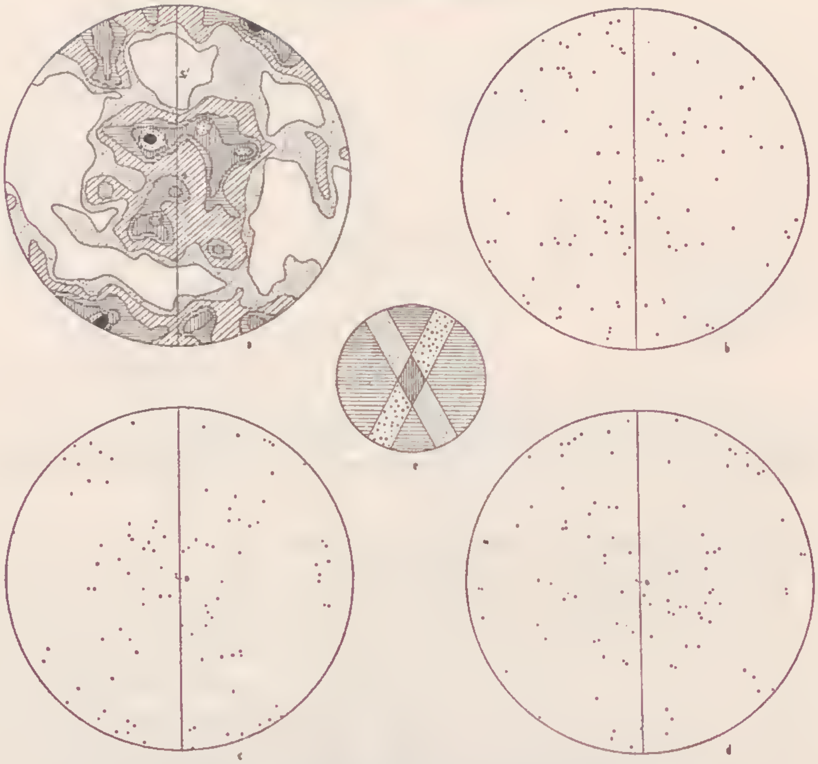

FIG. 16—A.V.A. of metagreywacke, Mt Herbert Specimen 5.
a. 491 [0001] quartz. Contours 5-4-3-2-1-½%.
b, c, d. Partial diagrams for [0001] of 100 grains.
e. Key to shading of grains in figure 17.

present, and together represents the main types of quartz-rich metasediments in the aureole.

Examinations of faces cut on a hand specimen of the metagreywacke (No. 5) suggested the existence of three sets of planes: the mesoscopic S_1^1 (aB1), and two *hOl s* planes which intersected in B1, and symmetrically disposed about S$\sim$. The [0001] quartz orientation diagram (Fig. 16a) measured in the *ac* plane of the fabric, shows a strong maximum in *b* (B1), and an equally strong maximum near *a* (possibly to be regarded as B2) of the fabric. Minor maxima also occur, the overall diagram suggesting *hOl* girdles. The symmetry is triclinic.

Partial diagrams, prepared for different areas of the thin section, confirm the homogeneity of the quartz fabric. Fig. 17a, a tracing of the photomicrograph of the section, shows that grains contributing to each of the maxima of the orientation diagram (direction groups) show no obvious mutual differences in spatial relationships. There seems to be a slight tendency for the grains to be aligned in the *hOl* planes, but it is possible that this alignment is fortuitous, and direction homogeneity may be inferred. It is clear also that grains forming each of the direction groups show no mutual differences in dimensions.

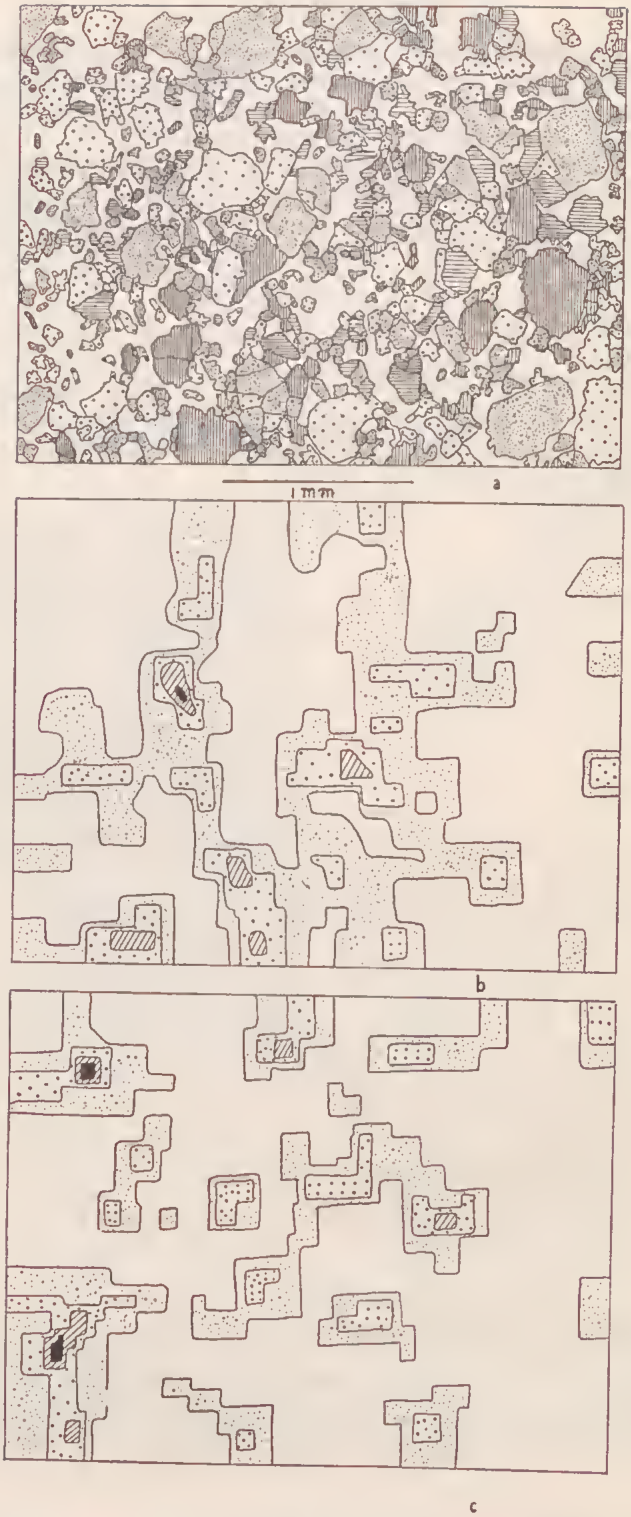

Fig. 17

a. Tracing of photomicrograph of specimen No. 5, showing distribution of grains.
b. Distribution of 168 grains shown by coarse stippling in a.
c. Distribution of grains shown by fine stippling in a. Contours for both b and c, 4-3-2-1% per sq. cm of area.

As a further investigation of direction homogeneity, the centres of the grains of each direction group were plotted as points; the distribution of points was measured, and the diagrams contoured (Fig. 17b, c). These show that while direction homogeneity is not perfectly achieved, it is closely approximated.

In specimen 6, a metaquartzite, with quartz constituting 93 per cent of the rock, bedding was visible as colour bands; two well developed sets of shear planes were also visible. Tests similar to those for No. 5 proved homogeneity of the [0001] quartz fabric. The symmetry of this fabric is triclinic. The [0001] quartz orienta-

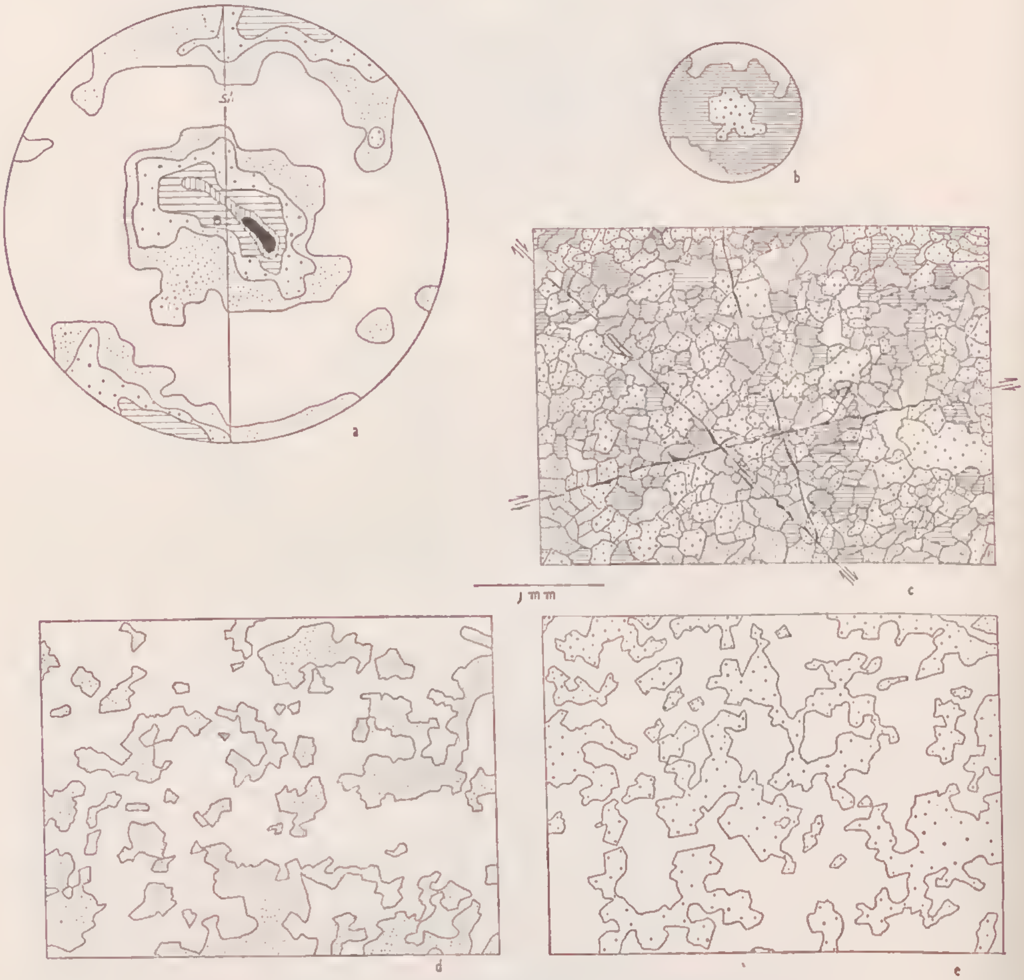

FIG. 18—A.V.A. metaquartzite, specimen 6.

- a. 473 [0001] quartz. Contours 5-4-3-2-1%.
- b. Key to grains in Fig. 18c.
- c. Tracing of photomicrograph of specimen 6, with grains shaded according to orientation.
- d. Domains of grains of the direction group indicated by fine stippling in 18c.
- e. Domains of grains of the direction group indicated by coarse stippling in 18c.

tion diagram (Fig. 18a) measured in the *ac* plane of the fabric, has a strong maximum in B1, but in contrast to No. 5, there is no development of *hOl* girdles, nor of a maximum in or near *a*.

In Fig. 18c it can be seen that the grains show some tendency to lie in planes, but as in specimen 5, direction homogeneity appears to be approximated. For this analysis, the grains forming the two main direction groups were separated by tracing from Fig. 18c. In both cases, the grains form large, somewhat irregular domains which clearly define the *hOl* planes. Direction homogeneity is less than in No. 5. The shear planes are clearly expressions of post-recrystallization deformation; while there is a tendency for these planes to follow grain boundaries, they frequently cut through grains. Displacement, the direction and amount of which are measurable, has occurred along these planes, but there has not been a significant rotation. The three sets apparently developed synchronously.

Specimen 7 is a metaquartzite in which quartz constitutes 75 per cent of the rock. Neither the thin section nor the hand specimen shows clearly any planar dis-

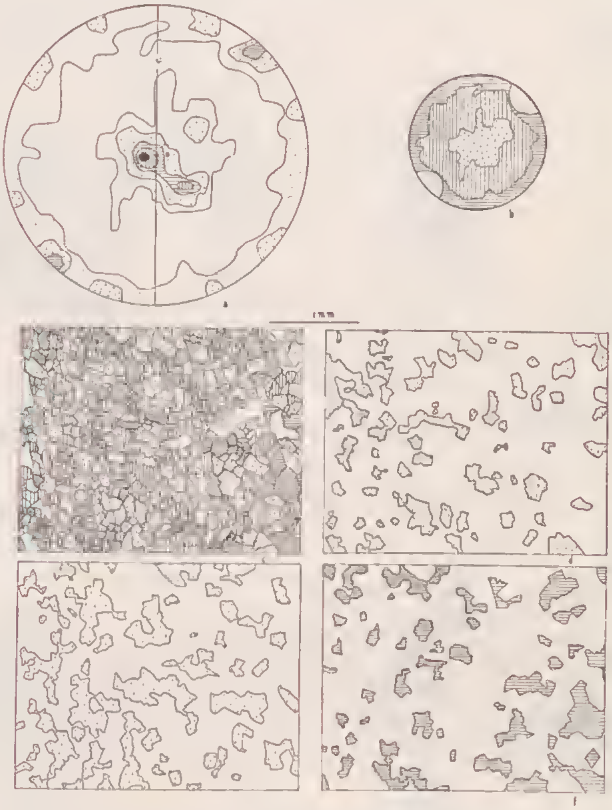

FIG. 19—A.V.A. of metaquartzite, specimen 7.
a. 565 [0001] quartz. Contours 5-4-3-2-1%.
b. Key to shading Fig. 19c-19f.
c. Tracing of photomicrograph of specimen 7.
d. Domains of direction group shown by fine stippling in (c).
e. Domains of grains shown by coarse stippling in (c).
f. Domains of grains shown by horizontal lines in (c).

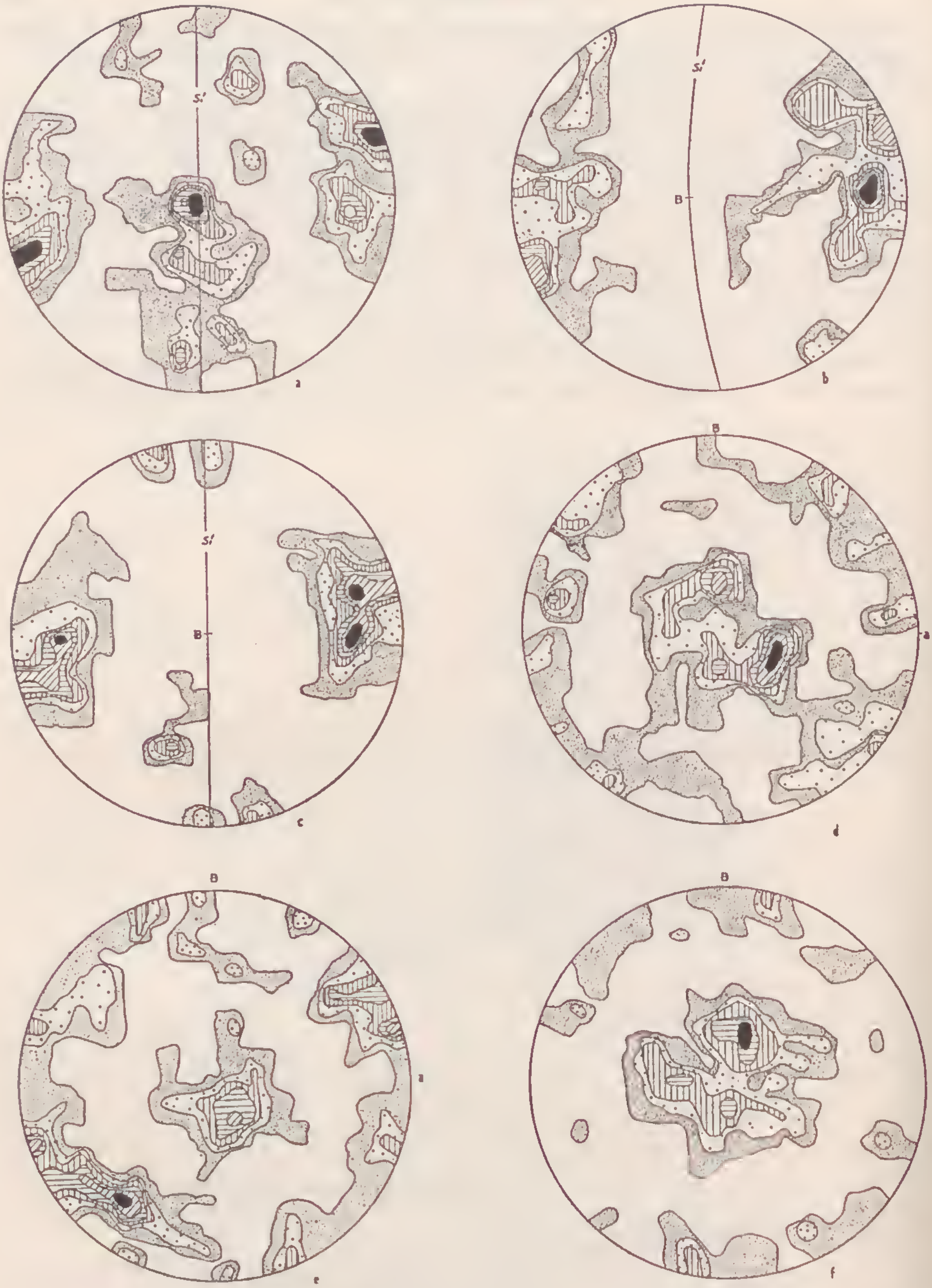

FIG. 20—[0001] quartz diagrams.
a. Specimen 8, Chewton. *ac* plane, 300 [0001] quartz contours 5-4-3-2-1%.
b. Specimen 9, Barfold Ra. *ac* plane, 300 [0001] quartz contours 6-5-4-3-2-1%.
c. Specimen 10, Big Hill. *ac* plane, 300 [000] quartz, contours 6-5-4-3-2-1%.
d. Specimen 11, Lockwood South, *aB*1 plane, 300 [0001] quartz, contours 6-5-4-3-2-1%.
e. Specimen 12, Maldon, *aB*1 plane, 300 [0001] quartz, contours 6-5-4-3-2-1%.
f. Specimen 13, Fogarty's Gap, *aB*1 plane, 300 [0001] quartz, contours 5-4-3-2-1%.

continuity, although Fig. 19c suggests some orientation of the grains in aB1 and *hOl* shears. The [0001] orientation diagram shows features intermediate between those of the two previous specimens. In common with these, a strong maximum is present near B, and as in No. 5 there is an *ac* girdle, although this lacks the maximal concentration in *a* shown by No. 5. Fabric homogeneity was established by partial diagrams; the symmetry of this fabric is triclinic.

The separation of the domains of each of the three direction groups suggests that direction homogeneity is of a low order, and that this specimen approaches case I of Sander. The grains form small irregular domains, which for each group tend to define planar discontinuities of a particular set.

Six specimens were analysed to establish the [0001] quartz fabric without recourse to the detailed A.V.A.

The diagram for specimen 8 (Fig. 20a), a greywacke, shows a maximum in B (B1), with weaker maxima in *c*. *hkO* girdles show some development. Specimen 9 is a slightly sheared metagreywacke, and specimen 10, an intensely sheared metagreywacke. The fabric of these specimens (Fig. 20b, c) differs from that of others already discussed in that the maximum in B is absent. In No. 9 there is a maximum in *c* and a tendency to an *ac* girdle; in specimen 10 two maxima of equal intensity occur symmetrically disposed with respect to aB, and lie on *hOl* planes defined by partial girdles, an orientation reflecting the influence of flattening.

In specimen 11 (Fig. 20d), a metaquartzite, *hkl* girdles and maxima near *c* have been developed. There is also some evidence of an aB girdle comparable to that of No. 8. A quartzite from near Maldon, specimen 12 (Fig. 20e) shows an aB girdle, with maximal concentrations near *c* and in a partial *hkl* girdle. A similar rock at Fogarty's Gap, No. 13 shows a concentration of [0001] about *c*, with only partial *hkl* and aB girdles.

In all of the rocks examined, the quartz grains were notably free of deformation features: undulatory extinction was noted only occasionally, and deformation lamellae in only 6 grains. In general, it is clear that both the quartz and biotite fabrics are due to more than one set of stresses. Post-folding deformation, which imposed a strain-slip cleavage on the slates, has clearly influenced the orientation of both the biotite and quartz in the arenaceous rocks. Post-recrystallization deformation is indicated by shear planes, but this deformation does not appear substantially to have influenced the microfabric except in a few rare cases. One of the most significant facts is that the microfabric, like the macrofabric, has a markedly triclinic symmetry.

Discussion

In the region surrounding the Harcourt batholith the rocks are clearly $B \wedge B'$ tectonites, the geometry of which is triclinic. The original folding of the sediments, which predated the emplacement of the batholith, produced, in a very general manner, monoclinic $B \perp B'$ fabrics; on this has been overprinted the fabric of a later deformation. The following is a summary of the results of analysis at all scales.

1. The axis of the batholith is arcuate, and has a general E.-W. trend, convex to the N. The E. lobe of the batholith has a circular margin; around this lobe the aureole is much thinner than elsewhere, and the grade of the contact rocks is much lower.
2. The arcuate axis of the batholith more or less coincides with an E.-W. axis

of downfolding in the Ordovician sediments, i.e. the batholith may be associated with a collapse structure.

3. Where the margin of the batholith is meridional or sub-meridional, the bedding is parallel to the contact (Maldon, Barfold Ra.) or subparallel to the contact (Chewton). In the Barfold Ra. sharp departures occur from the regional trend.

4. Regionally, the axial planes of folds (S_1^1) have a NNW. trend with steep easterly dip. In the region between Maldon and Chewton, polyclinal folding has been developed: in the Chewton area axial planes S_1^1 dip 70°-80°W., in the Maldon area they dip 60°-70°E., while in the intervening area they tend to be vertical.

5. Everywhere the sediments were studied in the aureole, a strain-slip cleavage, parallel to the margin of the batholith, and locally, superposed folds with axial planes defined by the strain-slip cleavage, have been developed.

6. Petrofabric data give evidence of multiple deformation.

7. Petrological studies (Beavis 1962) showed a retrograde aspect of the contact metamorphism, suggesting the development of stresses during or, less probably, after recrystallization.

It may be concluded that two main deformations have been responsible for the development of the present structure of the metasediments in the Harcourt aureole. The first was a tangential E.-W. compression, affecting the whole of Central Victoria, and predating intrusion; the second was effective only about the batholith. Because of the orientation of the structures resulting from this later deformation, it is to be concluded that the stress was everywhere normal to the margin of the batholith, and hence that intrusion was markedly an outward acting compression by the magma. That this deformation was synchronous with the intrusion is demonstrated by the nature of the thermal metamorphism (Beavis op. cit.); the metasediments show aspects of stressing, but there is no evidence of post-recrystallization deformation of intensity sufficient to lead to mineralogical changes. Such a stress field would account not only for the mesoscopic superposed structures noted, but also for the macroscopic polyclinal folding developed between the two lobes of the batholith, where opposing stresses would have acted. It would also account for curvature of beds and axial planes on the east margin of the Coliban lobe. It is important to note that no evidence of vertical stresses was obtained. This is somewhat puzzling, since such stresses would be expected.

The mechanics of intrusion were possibly more complex than has been determined here. It is likely that the batholith consists of a number of intrusions, and for the Coliban lobe at least, some ring fracturing and collapse may have occurred. This is suggested both by the circular form of the contact, and the thinness and low grade of the aureole here. If collapse of the magma occurred it is not unlikely that the inner part of the aureole was involved.

One important aspect remains to be considered: the jointing both of the sediments and of the granodiorite. Analysis of the former shows that these were the result of stresses of the first deformation, and appear to have been only slightly modified by the second deformation. Some anomalous joints in the sediments may have formed during the later stressing, but these are rare. Many of the joints in the granodiorite are certainly primary, but, as was pointed out, some are clearly secondary, and the result of shear stresses. If the assumption that the joint pattern of the granodiorite is due to shearing is valid, then an E.-W. tangential compression, post dating intrusion, must have occurred. Microfabric data give some evidence of this, while such a stress would be necessary for the fracturing of the granodiorite along the Muckleford Fault. Such a stress, since it would be parallel to the original folding stress, would have little influence on the jointing of the metasediments.

References

BARAGWANATH, W., 1903. The Castlemaine goldfield. *Mem. Geol. Surv. Vict.* 2.
BEAVIS, F. C., 1962. Contact metamorphism at Big Hill. *Proc. Roy. Soc. Vict.* 75 (1): 89-100.
BRADFORD, W., 1904. The Maldon goldfield. *Bull. Geol. Surv. Vict.* 14: 1-28.
CHARLESWORTH, H. A. K., and EVANS, C. K., 1962. Cleavage boudinage. *Geol. Mijn.* 41 (8): 356-362.
DICKENSON, D. R., 1941. Structural conditions at the Nimrod workings. *Min. Geol. J. Vict.* 4 (2): 225-227.
HARRIS, W. J., 1916. The palaeontological sequence in the Castlemaine district. *Proc. Roy. Soc. Vict.* 29 (1): 50-74.
————, 1934. The eastern boundary of the Bendigo goldfield. ibid. 46 (2): 200-206.
HARRIS, W. J., and THOMAS, D. E., 1933. The geological structure of Eastern Talbot. ibid. 46 (2): 153-178.
————, — ————, 1938. A revised classification . . . of the Ordovician rocks. *Min. Geol. J. Vict.* 1 (3): 62-72.
HILLS, E. S., 1959. Cauldron subsidences. *Geol. Runds.* B57H3: 543-561.
HILLS, E. S., and THOMAS, D. E., 1945. Fissuring in sandstones. *Econ. Geol.* 40: 51-61.
MOON, R. A., 1897. Report on the Maldon goldfield. *Mines Dept. Vict. Special Report.*
PRICE, N. J., 1959. Mechanics of jointing. *Geol. Mag.* 96: 149-167.
RAMSAY, J. G., 1962. The geometry . . . of similar type folds. *J. Geol.* 70 (3): 309-327.
SANDER, B., 1950. *Einfuhrung in die Gefugekunde.* J. Springer, Wien. II: 161-217.
STEWART, A., 1960. Unpublished thesis, University of Melbourne.
THOMAS, D. E., 1935. The Muckleford Fault. *Proc. Roy. Soc. Vict.* 47 (2): 213-229.
————, 1939. The Chewton Mine. *Min. Geol. J. Vict.* 2 (1): 11-14.
————, 1939. The structure of Victoria. ibid. 1 (4): 59-64.
————, 1940. Notes on the Chewton goldfield. ibid. 2 (2): 91-97.
————, 1941. Reefs at Wattle Gully. ibid. 2 (4): 219-224.
WEISS, L. E., 1954. A study of tectonic style. *Univ. Calif. Publ. Geol. Sci.* 30 (1): 1-102.
————, 1958. Structural analysis at Turoka, Kenya. *Overseas Geol. and Min. Res.* 7 (1): 3-35; 7 (2): 123-153.

3

EVOLUTION OF THE ZENATIINAE (MACTRIDAE: LAMELLIBRANCHIATA)

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Abstract

The Zenatiinae are herein defined as comprising three closely related genera confined to Australasia, viz. *Zenatia* (Oligocene to present, New Zealand), *Zenatiopsis* (Oligocene to Pleistocene, Australia), and *Zenatina* gen. nov. (Lower Pliocene to present, Australia). A new species *Zenatiopsis phorca* is described. The zenatiins are elongate, thin-shelled mactrids with gaping valves and anterior hingeplates specialized probably for burrowing.

Introduction

Mactrid lamellibranchs are common in occurrence and cosmopolitan in distribution, but the subfamily Zenatiinae (*Zenatia, Zenatiopsis, Zenatina* gen. nov.) are comparatively rare in collections, and in distribution are limited. This subfamily has been studied evolutionally, and this has shown the need for a new genus to represent the line of molluscs ending with the form living in Australia at present. The study began as a contribution to the elucidation of the Pliocene-Pleistocene boundary. Although the morphological changes in zenatiins with time are not great, they are nevertheless useful for stratigraphic purposes. Thus even a very conservative group of organisms, if studied in detail, can be stratigraphically useful. A similar evolutional study of the genus *Placamen* has been reported in outline (Gill 1962). Fleming's (1962) study of *Bassina* is an excellent example of this approach.

Evolution

The evolution of the subfamily has resulted in the alteration of the typical subtriangular, thick-shelled mactrid stock with its more or less central hingeplate and short pallial sinus associated with a lack of gape between its valves into an elongate-oblate, commonly thin-shelled type of mactrid with an anterior hingeplate, long pallial sinus, and gape of the valves at both ends. This change of skeleton and soft parts is an accommodation to a different mode of life. The typical mactrids are found round the world as shallow burrowers in the sand of open beaches. The living zenatiins are not worldwide but limited to Australasia, and do not belong to the sandy open ocean beaches so much as to the muddy sand of bays and inlets or ocean sites protected by reefs. Ecological information is very limited, but it is understood they live in vertical burrows. The anterior gape of the valve apparently accommodates the strong burrowing foot, while the posterior gape allows space for the large siphons. If this be correct, then it would explain the shift of hinge structures to the anterior end where most leverage is exerted. This part of the shell is further strengthened by the presence of ridge and or callus structures on the valve walls. Also the resilifer has dropped from the plane of the hinge. The development of an internal ridge and similar structures has happened a number of times in lamellibranch history. The internal buttress of the Palaeozoic *Nuculites* (family Nuculidae) appears to fulfil this function. Among Cainozoic shells *Leptosolen siliqua* (Solenidae), *Laternula* (Laternulidae), *Capistrocardia* (Saxicavidae), and *Cleidophorus* (Ledidae) may be quoted as examples of genera developing internal ridges.

Distribution in Time

The earliest known zenatiins are from the Duntroonian and Awamoan (Lower and Upper Oligocene respectively) of New Zealand, and from the Janjukian (Upper Oligocene) of N. Tasmania. All the sub-family characters were fully developed by this time, and so must have emerged earlier still. Many indigenous genera first appear in the early Tertiary. The New Zealand genus *Zenatia* has a known range in time of Oligocene to the present, while the Australian genus *Zenatiopsis* lasted from the Oligocene to the Pleistocene, and *Zenatina* gen. nov. from Lower Pliocene to the present. These genera are all very conservative, so that the fossil forms are quite like the living or recently living ones. They exhibit no convergence that might throw light on the origins of the genera, but maintain their distinctive morphologies throughout their known occurrence.

The ages attributed to Tertiary formations in Australia follow Glaessner (1959), except as modified by Wilkins (1963), and the Pliocene-Pleistocene boundary is that defined by Gill (1957a, 1961a).

Geographical Distribution

Iredale (1930, p. 401) and Joyce Allan (1950, p. 350) state that living *Zenatina victoriae* occur in E. Australia from S. Queensland to Victoria. The writers have seen specimens from Noosa R., N. of Brisbane in Queensland, to Port Albert in Victoria. The holotype thus comes from the S. limit of the range. The shells of this genus are comparatively rare as fossils which is not surprising in view of their delicate structure and their facies limitations. At present it has been collected from only two Pliocene localities—Muddy Ck near Hamilton in W. Victoria, and the uppermost shell bed in the Bunga Ck road cuttings on the Princes Highway NE. of Lakes Entrance, Victoria (Wilkins 1963). The species has also been collected from a Quaternary coquina at Seaspray, Gippsland, Victoria.

The only other living zenatiin is *Zenatia acinaces* in New Zealand, of which Suter (1913, p. 972) says, 'Habitat: North and South Islands from below low water mark to about 30 fathoms. In some places like New Brighton it is evidently common in a depth of from 3 to 5 fathoms'.

Zenatiopsis, now extinct, is known from Adelaide, S.A., in the N., to Wynyard, Tasmania, in the S., where it lived in a time of warmer climate (Gill 1961b, c).

Palaeoecology

Zenatiins appear to favour a habitat of muddy or marly sand, and not to favour an environment of turbulent waters. As far as we are aware, no fossil zenatiins have been found in strata which contain pebbles, gravel or other evidences of strongly moving waters. Thus *Zenatiopsis phorca* has not been found by us in the pebble-bearing 'upper shell bed' (Singleton 1941, p. 41-2) at Lakes Entrance, but this species is not uncommon in the same bed in the road cutting on the Princes Highway at Bunga Ck, NE. of Lakes Entrance where this shell bed is not conglomeratic. *Zenatiopsis phorca* and *Zenatina victoriae* occur in the Hamilton district in marly beds. At Minhamite, 25 miles SE. of Hamilton, *Zenatiopsis phorca* is present in a marly sand, but was not found in the underlying pebbly coquina. *Zenatiopsis fragilis* occurs in marly sandstone at Fossil Bluff near Table Cape in

N. Tasmania, but it appears to be absent from the underlying shelly conglomerate. *Zenatiopsis angustata* s.s. comes from the Cadell Marl Lens, Murray R. Cliffs.

Zenatiopsis sp. nov. is present in a marly sand in the Maretimo beds at Portland (but appears to be absent from the overlying oyster bed), and in the sandy coquina of Limestone Ck, a tributary of the Glenelg R. The living *Zenatina victoriae* is found in the muddy sands of the large inlet leading to Port Albert, and is known from other similar habitats up the E. coast of Australia. However, it must be stressed that only the most general information is available concerning the occurrence of this species. Likewise little is known about the conditions of life of the New Zealand *Zenatia acinaces*, but the fossil forms from that country present in a matrix and examined by us were in marly or muddy sands.

Classification

Class LAMELLIBRANCHIATA

Family MACTRIDAE Gray 1853

Equivalve inequilateral mactracean lamellibranchs with a small posterior cardinal tooth (4b) and central bifid cardinal teeth (2a, 2b) in the left valve, with bifid cardinal (3a, 3b) only in the right; subtriangular resilifer.

TIME RANGE: Cretaceous to present.

DISTRIBUTION: Cosmopolitan.

Subfamily ZENATIINAE Dall 1895

Elongate mactrids, gaping both ends, with large deeply excavated resilifer bent out of the plane of the hingeplate and separate from the cardinal socket; internal ridge (*Zenatiopsis, Zenatina*) or imperfect ridge (*Zenatia*) extending across each valve from the hingeplate; umbo one-third to one-fifth length of shell from anterior end.

TIME RANGE: Oligocene to present.

DISTRIBUTION: Australia and New Zealand.

NOTE: As defined here, the subfamily excludes—

1. *Vanganella* (= *Resania*) where the resilifer is fused to an internal ridge, is not separate from the cardinal socket, and lies parallel to the plane of the hingeplate.
2. *Darina*, a South American mactrid with zenatiin-like shell but no internal ridge, or callus ridge as in *Zenatia*.
3. *Lutraria*, which possesses no internal ridge or imperfect ridge, and the resilifer is in the plane of the hingeplate.

The Zenatiinae, as now defined, comprise three Australasian evolutionary lines consisting of shells of very similar structure that point to a common origin.

Genus **Zenatia** Gray 1853

DIAGNOSIS: Zenatiins with callus forming an imperfect internal ridge; hingeplate not supported by this ridge; umbo about one-fifth of length of shell from anterior end.

TYPE SPECIES (monotypy): *Lutraria zelandica* Gray 1837 = *L. acinaces* Quoy and Gaimard 1835. Living and fossil.

TIME RANGE OF GENUS: Oligocene to present.

Distribution: New Zealand.

Other Species: *Z. flemingi* Marwick, Pliocene. *Zenatia* sp. nov. Oligocene to Miocene.

Note: Dr C. A. Fleming kindly lent to us a series of New Zealand fossil and living *Zenatia*. This New Zealand genus has a similar time range to the Australian *Zenatiopsis*, has a similar range of shell thickness (papery to solid), but overall the New Zealand shells are larger. Shells of the living Australian *Zenatina victoriae* approach nearest in size and thickness the large *Zenatia* specimens.

Genus **Zenatiopsis** Tate 1879

Diagnosis: Zenatiins with well-defined internal ridge rising under the cardinal socket but not fusing with its ventral margin; ridge extends more than half way obliquely across the valve; dorsal end of ridge is shaped round the contiguous part of the adductor muscle scar; hingeplate supported by pillar that forms umbonal end of ridge; umbo about one-fifth of length of shell from anterior end.

Type Species (original designation): *Zenatiopsis angustata* Tate.

Time Range of Genus: Upper Oligocene to Pleistocene.

Distribution: Australia.

Other Species: *Z. fragilis* Pritchard, Oligocene (Janjukian); *Z. phorca* sp. nov., Upper Miocene-Lower Pliocene (Cheltenhamian-Kalimnan); *Zenatiopsis* sp. nov., Werrikooian (Lower Pleistocene).

Genus **Zenatina** gen. nov.

Diagnosis: Zenatiins with internal ridge rising from the ventral edge of the tooth socket, and extending a small distance approximately normal to the hingeline, then flattening and widening to become a flat-topped rise on the wall of the valve; ridge extends under hingeplate providing support for it; umbo about one-third of length of shell from anterior end.

Type Species: *Zenatia victoriae* Pritchard and Gatliff, living and fossil.

Time Range: Lower Pliocene to present.

Distribution: Australia.

Systematic Descriptions

Zenatiopsis angustata Tate 1879

(Pl. XXIX, fig. 1, 3-4; Pl. XXXI, fig. 1-2, 6, 10)

Material Described: Pair of valves, believed to be a topotype (see below), from the Cadell Marl Lens of the Morgan Limestone, 4 miles S. of Morgan on the left bank of the Murray R., South Australia. Age: Batesfordian (Lower Miocene), Cudmore Coll. P22527-8, hypotype (numbers so given are in the palaeontological collection of the National Museum of Victoria).

Description: Shell thin, elongate oval, gaping at both ends, concentrically striated with very fine growth lines. Umbos small, raised orthogyral. Shell anterior to the umbo about one-fifth the length of the shell. Posterior to the umbo, shell attentuates slightly in height. Lunule hardly encroaching on the inner dorsal margin of the valve. Interior of valves porcellanous. Hinge narrow and short. Right valve with two cardinals (3a, 3b) of equal length united above, forming an inverted V; no posterior laterals. Left valve with two large cardinals (2a, 2b) united above, vertex directed slightly to posterior, a very thin cardinal (4b) between 2b and resilifer, a thin anterior lateral (LAII) parallel to 2a, no posterior laterals. Resilifer subtriangular, anterior side making an angle of about 40° with the dorsal margin. Ligament area raised, situated just above the vertex of the resilium; the dorsal raised edge of the resilifer forms this flat area on fusion with the dorsal side of the valve. Extending from under the hingeplate (under anterior cardinal) to more than half way across the interior surface of each valve is a narrow ridge making an angle of about 80° with the posterior dorsal margin. This ridge also curves round the posterior side of the muscle scar, forming part of the dorsal margin of the scar. Muscle scars subequal, the anterior one being situated close to the dorsal and anterior margins of the valves, while the posterior scar is close to the dorsal side and about one-third of the length of the shell from the posterior end. Pallial sinus deep, extending slightly beyond the middle of the valve.

COMMENT: These valves are not complete, but the shells are so fragile that it has not been possible to obtain a pair of complete valves; as they are incomplete, measurements are not given.

In *Zenatiopsis angustata* the internal ridge is narrower than is normal in *Z. phorca*, and closer to the anterior end, viz. it is under the anterior cardinal tooth. The internal ridge is also usually at a greater angle to the margin of the valve in *Z. angustata* than in *Z. phorca.* The teeth point very slightly posteriorly—not nearly as much as in *Z. phorca.* The shells are usually a little smaller and more slender, but this is not regarded as a character of much taxonomic significance. *Zenatiopsis angustata* s.s. is intermediate in both age and morphology between the Oligocene *Z. fragilis* and the Pliocene *Z. phorca.*

The hypotypes figured are from Cudmore's collection and labelled as being from 'Tate's locality of 4 miles below Morgan, Murray River' and from 'Tate's beds 6-8 (Tate 1885)'. These beds are now called the Cadell Marl Lens and their age is Batesfordian (Ludbrook 1961, p. 53).

In his description of *Z. angustata* as the type species of his new genus *Zenatiopsis,* Tate (1879) wrote 'Locality and horizon. The older Tertiary of Muddy Creek, Hamilton, Victoria, and the contemporaneous "Upper Murravian", near Morgan (North-West Bend), on the River Murray'. Through the kind co-operation of Dr M. F. Glaessner, we have examined Tate's types which are labelled 'Loc. R. Murray—Miocene. Muddy Creek. Gippsland Lakes'. The type specimens are in the Tate Collection in the Department of Geology, University of Adelaide (T1205). There are 8 specimens glued on to a plaque so that the reverse sides cannot be examined. The first specimen on the plaque in the top left hand corner is *Z. angustata* s.s., and is obviously figure 6b of Tate 1879; this is here chosen as the lectoholotype. The specimen beside the foregoing is figure 6a of Tate 1879. Some of the other specimens are *Z. angustata* s.s. while others are *Z. phorca* sp. nov.

At about the same time as he described the new genus *Zenatiopsis,* Tate (1878) listed the strata comprising the Murray R. Cliffs, stating that the 'Upper Marine Series' is about 50 ft thick. Seven years later, Tate (1885) gave a section of the Murray R. Cliffs 4 miles S. from Morgan, but reduced the thickness of the above series (Upper Murravian) from 50 ft to 12 ft (= the 'oyster bank'), while the Middle Murravian was extended from 40-45 ft to 157 ft 4 in. reaching river level. There is thus a change in definition of the Upper Murravian as Singleton (1941, p. 43) has already noticed. Tate lists *Zenatiopsis* (p. 36) among the fossils of the 'older Tertiary deposits', i.e. beds older than Upper Murravian as re-defined. On p. 35 the gasteropod bed is placed in the Middle Murravian. This is the bed with

Zenatiopsis (Tate 1887, p. 31) and is part of the Cadell Marl Lens. In the foregoing reference Tate gives the localities for *Z. angustata* as 'Gasteropod bed of the River Murray cliffs near Morgan, upper and lower beds at Muddy Creek, Table Cape'. He included in his one species the specimens that are now divided into three species.

Thus the gasteropod bed containing *Zenatiopsis* in the Murray R. Cliffs near Morgan was in 1878 included in the Upper Murravian but in 1885 removed to the Middle Murravian. This may account for the erroneous belief that the type of *Z. angustata* came from the Pliocene of Northwest Bend whereas it came from the Miocene of the Cadell Marl Lens. It should be noted that a well preserved delicate translucent shell like the lectoholotype could not be collected from the leached Northwest Bend formation where only phosphatic and calcitic shells are well preserved. In the original description Tate refers to the *Zenatiopsis* shells from the Murray R. Cliffs as being 'thin, fragile, semi-pellucid tests'. Such could not come from the oyster bed which is now called the Northwest Bend formation. The lectoholotype has a similar colour to our hypotypes collected by Cudmore from the Cadell Marl Lens, and the minute grains of matrix still adhering are of a similar orange colour.

On the foregoing evidence our hypotypes are topotypes.

DISTRIBUTION: The description given is of topotype material of the type species of the genus *Zenatiopsis*. This is *Z. angustata* s.s., which is not rare at the type locality, but appears to be rare elsewhere, probably because of lack of beds of suitable facies and age. However, a shell (P22608) referable to this species, although varying a little from the type, was found by Mr R. W. T. Wilkins in the Tambo River Formation at Cunningham's (Old Rosehill Farm), near Bairnsdale in Gippsland, Victoria. The top of the shell bed at Rosehill Farm is by definition the upper limit of the Mitchellian Stage as re-defined by Wilkins (1963). Another specimen (P21903) comes from the nearby locality of Underwood's which belongs to the same stage. This fossil was found in the Dennant Collection in the National Museum of Victoria.

Dr O. P. Singleton kindly allowed us to examine a left valve of *Zenatiopsis* from Balcombe Bay, Victoria, in his possession which appears to be the only specimen from there collected to date; it is referable to *Z. angustata*. Its rarity is accounted for in the notes on the ecology of *Zenatiopsis*. The Balcombe Bay deposit is a silt deposited in deep water. In the Cudmore Collection there is a specimen referable to *Zenatiopsis angustata* s.s. (P21836) from the Abattoirs Bore, Adelaide, South Australia. Cudmore (pers. comm. to E.D.G.) collected his specimens from the spoil heap of the bore and so the depth from which it came is unknown.

Specimens from the Abattoirs Bore, Adelaide, were examined by us in the collections of the Department of Geology, University of Adelaide. The shells possess a thin internal ridge with its dorsal end under cardinal tooth 2a as in *Zenatiopsis angustata*. There is no curving of the ridge round the muscle scar as in *Z. phorca*. While there is some variation from the type, we refer these shells to *Z. angustata*, which is a Miocene species elsewhere.

Zenatiopsis fragilis Pritchard 1896

(Pl. XXVIII, fig. 1-2; Pl. XXXI, fig. 3)

MATERIAL DESCRIBED: Hypotype and topotype P21900-1. Pair of valves from 'Table Cape', i.e. Fossil Bluff at Wynyard, N. Tasmania. From the 'Turritella Bed' (see Gill 1957 b, Fig. 2), i.e. Fossil Bluff Calcareous Sandstone (Banks 1957, p. 74-76); Oligocene. Coll. F. A. Cudmore.

DESCRIPTION: Shell thin, elongate oblong, gaping at both ends, equivalve, very inequilateral, concentrically striated with growth lines; dorsal and ventral margins slightly curved. Umbos small, pointed and very little raised, orthygyral; umbo to anterior end about one-fifth of shell length. Lunule small and only slightly encroaching on the inner dorsal margin. Interior of valves porcellanous. Hinge narrow and short. Left valve with two cardinals (2a, 2b) united above, vertex directed slightly anteriorly, a very thin cardinal (4b) between 2b and the resilifer, a thin anterior lateral LAII parallel to 2a, no posterior laterals; right valve with two cardinals (3a, 3b) of equal length forming an inverted V, no posterior laterals. Resilifer subtriangular, anterior side making an angle of about 35° with the dorsal margin. Ligament area raised, striated, immediately posterior to the vertex of the cardinals, and continuous with the raised anterior edge of the resilifer. Extending from under the hingeplate to past the midline of the shell in each valve is a ridge making an angle of 70° with the hingeline, forming the posterior side of the muscle scar, and curving anteriorly to form part of the dorsal side of the scar; under the anterior cardinal is a pillar supporting the hingeplate and fusing on its anterior side with the internal ridge (alternately it could be interpreted as part of the ridge). Anterior muscle scar close to dorsal and anterior margins of the valve; posterior scar close to dorsal side and about one-third length of shell beyond the midline.

MEASUREMENTS: Holotype (P3045) height 12 mm, length 33 mm, umbo to anterior end 6 mm. The same measurements respectively for other type specimens are: Paratype (P3044) 17 mm, 46 mm, 7 mm. Hypotype (P21900-1) 17 mm, 50 mm, 8 mm. Hypotype (P21902) 20 mm, 57 mm, 10 mm.

COMMENT: 11 specimens (mostly paired valves) were available for study. Pritchard based the species on three imperfect specimens from Fossil Bluff near Wynyard, Tasmania, whence all the known specimens come. The holotype (P3045) is a young specimen with paired valves. The outer surface of the right valve is all that is exposed, the shell is cracked over much of its surface, and part of the posterior end is missing. Paratype P3044, a larger specimen, consists of a pair of valves filled with matrix; both valves are covered with cracks. Paratype P3046 is a right valve, most of which is missing. It is of the same order of size as the holotype. None of the types has any internal structures visible. Pritchard erected *Z. fragilis* on external features only. Pritchard's specimens are too fragile to be dissected, and so topotype specimens from the Cudmore collection were used. Hypotype P21900-1 has both valves present. The surface of one of these was fully exposed, and then the specimen set in plaster of Paris with the exposed surface in the plaster. The matrix was then carefully removed until the other valve was exposed. Being cracked, like all the valves examined by us, and the carbonate of the shell being rather chalky, the removal of this valve to bring to view the internal structures was a problem. The exposed valve was held together with adhesive tape and then removed, but (as might be expected) the cardinal teeth of the right valve broke off, remaining in the left valve socket. However, this dissection made possible for the first time the study of the internal structures of *Z. fragilis*.

Zenatiopsis phorca sp. nov.

(Pl. XXVIII, fig. 3-4; Pl. XXIX, fig. 2, 5-6; Pl. XXXI, fig. 4, 7-8)

MATERIAL DESCRIBED: Syntypes, a right valve (P21899) and a left valve (P21898), not a pair, from the 'Upper beds, Muddy Creek', i.e. Grange Burn

Coquina (Gill 1957b) at MacDonald's Bank, Muddy Ck, about 4 miles W. of Hamilton, Western Victoria. Age: Kalimnan, Lower Pliocene. Dennant Coll. P21922 is a paratype from MacDonald's Bank, Hamilton, coll. T. S. Hall.

DESCRIPTION: Shell thin, elongate oval, gaping at both ends, very inequilateral, concentrically striated with growth lines. Umbos small, very little raised, orthogyral. Shell anterior to umbo about one-fifth the length of shell; shell posterior to umbo attenuates slightly in height. Lunule encroaching on the inner dorsal margins of the valves. Interior of valves porcellanous. Hinge narrow and short. Right valve with two cardinal teeth (3a, 3b) of equal length, united above, forming an inverted V; no posterior laterals. Left valve with two large cardinals (2a, 2b) united above, vertex directed posteriorly; a very thin cardinal 4b between 2b and the resilifer; a thin lateral LAII parallel to 2a; no posterior laterals. Resilifer subtriangular, anterior side making an angle of about 40° with the dorsal margin. Ligament area raised, striated, just above the vertex of the resilium; the dorsal raised edge of the resilifer forms this flat area on fusion with the dorsal side of the valve. Extending from under the hingeplate to more than half way across the interior surface of each valve is a ridge making an angle of about 70° with a line parallel to the hingeline at the umbo, although occasionally the angle varies up to 90°. This ridge also curves round the posterior side of the muscle scar towards the anterior end, forming part of the dorsal margin of the scar. Muscle scars subequal, the anterior situated close to the dorsal and anterior margins of the valve; posterior scar close to the dorsal side, and about a quarter of length of shell from posterior end. Pallial sinus deep, extending to slightly beyond the middle of the valve. A latex impression (P22573) has been made of steinkern P21904 from 'Cheltenham', (= Beaumaris) from the Dennant collection. It shows from the dorsal aspect the relationship of the articulating structures along the hingeline (Pl. XXIX, fig. 2).

MEASUREMENTS: P21898 height 18 mm, length 54 mm, umbo to anterior end 8 mm. The same measurements respectively for P21899 are 19 mm, 53 mm, and 10 mm; for P21922, 23 mm, 67 mm, and 10 mm.

COMMENT: This species is named after the sea god of Greek mythology. Lower Pliocene localities for *Z. phorca* are the various outcrops of the Grange Burn Coquina on Muddy Ck and Grange Burn, near Hamilton, under tuff on Spring Ck at Minhamite, SE. of Hamilton, Western Victoria, and at Nyerimalang (Cudmore locality), cliff at Kalimna Jetty, Jemmy's Point, Maringa Ck (about one half mile upstream from L. King), and the road cutting on the Princes Highway on the W. side of Bunga Ck, all near Lakes Entrance, Gippsland, Victoria. *Z. phorca* also occurs in the uppermost Miocene (Cheltenhamian) above the nodule bed at Beaumaris (Cudmore coll.) P21906, at Black Rock (Colliver coll.) P21905, and in the lowest shell bed in the road cutting on the Princes Highway just E. of Bunga Ck, (P22539-41) near Lakes Entrance, Victoria. A steinkern which may belong to this species comes from between the Brighton Cemetery and Red Bluff, i.e. Point Ormond, Melbourne (Dennant coll.) P22574. An indeterminable *Zenatiopsis* in ironstone from Shelford (P22605) is in the National Museum collection.

The following differences between *Z. angustata* (type species), *Z. fragilis*, and *Z. phorca* sp. nov. were noted. The time sequence of these species is *fragilis* (Oligocene)—*angustata* (Miocene)—*phorca* (upper Miocene-Lower Pliocene).

1. Teeth. Cardinal vertex directed slightly anteriorly in *fragilis*, but posteriorly in *angustata* and *phorca* (more so in *phorca*). The cardinal teeth diverge about 10° more in *angustata* than in the other two species.

2. Internal ridge. The dorsal end of the ridge is practically in front of the cardinal teeth in *fragilis*, under the anterior cardinal 2a in *angustata*, and between the cardinals or under 2b in *phorca*. With time the ridge has migrated posteriorly.
3. Muscle scars. The posterior scars are relatively closer to the midline in *fragilis* and *angustata* (i.e. about one-third of the shell length from the posterior end) than in *phorca* (about one quarter of the length from the posterior end). There has thus been a posterior migration of the scars.
4. Pallial sinus. The sinus extends further into the valve in *fragilis* and *angustata* than in *phorca*.
5. Shape of shell. *Z. fragilis* generally has slightly curved dorsal and ventral margins, whereas in *angustata* and *phorca* they are relatively straight. There are slight differences in the rounding of the ends of the shells. The *Z. phorca* from the lowest shell bed at Bunga Ck (Cheltenhamian) tend towards the *Z. angustata* found earlier in the Miocene. The latest *Z. angustata* known are in the Mitchellian (which immediately precedes the Cheltenhamian) and these tend towards the *Z. phorca* of the Cheltenhamian-Kalimnan. These facts suggest that *Z. angustata* evolved into *Z. phorca*, and that the latter is not a species from a different evolutionary line that migrated into the area. Where two species approach one another, there may be doubt in determining a single specimen, but where a few can be viewed, the species can be determined by using the key provided.

Zenatiopsis sp. nov.

MATERIAL DESCRIBED: From the Dennant collection a right valve P21841 and a left valve P21840, not a pair, and both incomplete, found at Limestone Ck on the W. bank of the Glenelg R., Western Victoria (see map, Singleton 1941). From the Pritchard collection a left valve P21957, incomplete, from the same locality. During a visit to Limestone Ck in 1962 a search was made for *Zenatiopsis*; only fragments were found, but four were determinable (P21958-9, P22607-8). Large scale slipping is present at this locality and we have not seen the beds yielding these fossils in situ, neither did Singleton (pers. comm.) nor Pritchard (pers. comm.). However, there is no reason to doubt that they are part of the Werrikoo Member of the Whaler's Bluff Formation, now given a Lower Pleistocene age (Gill 1957a, 1961a).

DESCRIPTION: This form is regarded as new, but a new species is not erected because there is not adequate type material.

The following features may be noted:

1. The cardinal teeth are relatively large and project more strongly than noted in other species.
2. The internal ridges are well developed but are somewhat irregular and less distinct, especially at their ventral ends. P21840 has a ridge with an asymmetrical profile, the posterior side tending to merge into the wall of the valve.
3. The hingeplate does not disappear into the dorsal margin of the valve, but swings around it and merges with it on the anterior end (as in *Zenatia*), so that the lunule is more prominent than in other species. This arrangement does occur elsewhere but is rare. A larger series of shells is needed to check this feature in the new species.
4. The shell is more solid than in the other species of *Zenatiopsis*.

COMMENT: Specimens of *Zenatiopsis* from the underlying Maretimo Member at Dutton Way, Portland, have been collected, but they are very poorly preserved and it has not been possible to determine them. Also specimens have been found in the calcareous sandstones overlying the Werrikoo Member, where they are preserved as casts and moulds. The Parr Collection contains a specimen from the Glenelg crossing at Dartmoor, and one of us (E.D.G.) collected four specimens (P21907-21910) from about 7 ft from the top of the cliff at Devil's Den near Myaring bridge on the Glenelg R. These fossils are not determinable either, but they represent, as far as is known, the end of the *Zenatiopsis* evolutionary line. No specimens of *Zenatiopsis* have been found in later Quaternary beds, and no species is still living.

Zenatina victoriae (Pritchard and Gatliff) 1903

(Pl. XXX, fig. 3-5; Pl. XXXI, fig. 5, 9)

MATERIAL DESCRIBED: Two valves of holotype from Port Albert, Victoria. National Museum of Victoria F440.

DESCRIPTION: Both valves thin, elongate oval, compressed, gaping at both ends but posterior gape greater than anterior, equivalve, very inequilateral, concentrically striated by growth lines. Umbos small, pointed, very little raised, orthogyral. Part of shell anterior to umbo one-third length of shell. Dorsal margin slopes from umbo at about the same declivity anteriorly and posteriorly, but as the posterior part is longer, the dorsal margin reaches a lower point posteriorly than anteriorly. Lunule encroaches on the inner dorsal margin. Interior of valves whitish and porcellanous. Hinge narrow and short. Right valve with two cardinal teeth (3a, 3b) united above, forming an inverted V. One poorly developed posterior lateral (LAI) subparallel to dorsal margin. Left valve with two large cardinals (2a, 2b) united above, vertex directed very slightly to the posterior end, a very thin cardinal (4b) between 2b and the resilifer. A thin anterior lateral (LAII) parallel to 2a. A long thin posterior lateral (LPII) subparallel to dorsal margin. Resilifer subtriangular, anterior side making an angle of about 30° with the dorsal margin. Ligament short, situated in a small furrow behind the umbo and above the posterior lateral. Prominent ridge fused to base of cardinal teeth and extending across valve for about 2·5 mm approximately normal to the hingeline, then continuing as a flat callus about 3 mm wide for another 4 mm. Adductor scars subequal, close to hingeline. Adductor scar separated from the 'umbonal ridge' by the pedal muscle impressions and associated callus. Posterior scar situated one-third of length of shell from posterior end. Pallial sinus deep, extending to the middle of the valve.

MEASUREMENTS: Height (line normal to hingeline to umbo) 31 mm. Length (maximum length normal to line of height) 73 mm. Thickness (maximum distance through both valves) 10 m. Position of umbo (distance of height line from most anterior part of margin) 24 mm. Maximum gape: anterior 4 mm, posterior 6 mm. Angle between hingeline and line formed by junction of resilifer with valve, approx. 30°.

COMMENT: Port Albert, whence the holotype comes, is an inlet with sandy mud and shallow waters. *Zenatina* is usually obtained by dredging and is apparently not common there. However, further N., shells of *Zenatina* can be collected on beaches in numbers (e.g. Boydtown, N.S.W.). The holotype comes from the S. extremity of the range of this species. In the National Museum of Victoria and the Australian Museum, Sydney, specimens of *Zenatina victoriae* have been seen from Snake I., Mallacoota and the Ninety Mile Beach (e.g. Seaspray) in Victoria, from Boydtown, Middle Harbour at Sydney, Fingal Bay near Port Stephens, L. Macquarie, Trial

Bay, Coff's Harbour, Sussex Inlet and Byron Bay in New South Wales, and from Noosa R. in Queensland.

In the fossil record, *Zenatina victoriae* is known from the Lower Pliocene (Kalimnan) of Macdonald's Bank, Muddy Ck, W. of Hamilton (5 specimens P21837-9, 22543-4) and from a bed of about the same age in the cuttings on the Princes Highway at Bunga Ck near Lakes Entrance, Victoria (numerous specimens including P22323-8, 22531-8, 22542). A Quaternary *Zenatina* was collected at Seaspray, Victoria (P22667). There are small differences between the Lower Pliocene shells and the living ones (e.g. in the resilifer) but we think they belong to the same species. *Zenatiopsis phorca* and *Zenatina victoriae* are sympatric at the above two Pliocene localities, the former being the more numerous, e.g. at Bunga Ck we have collected 91 valves of *Zenatiopsis* and 57 of *Zenatina*.

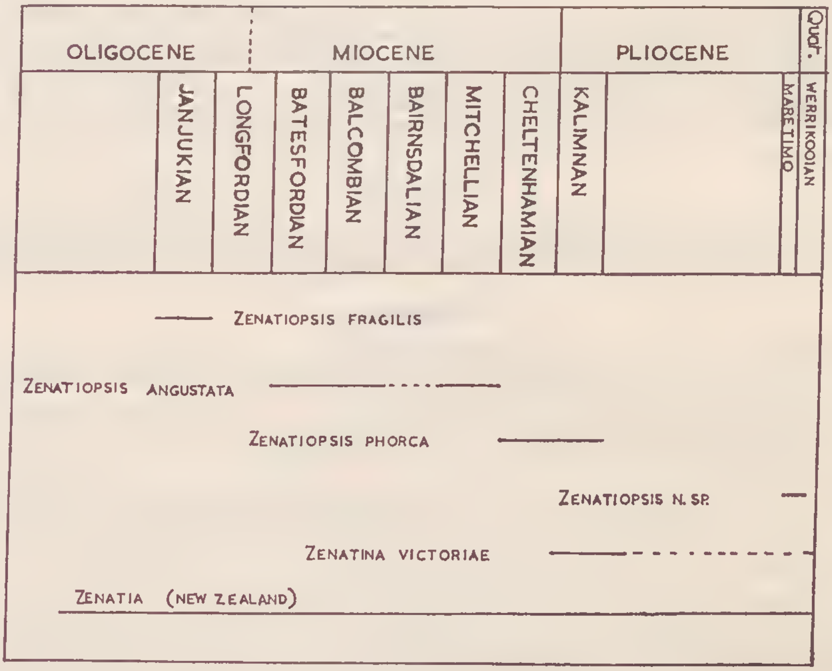


FIG. 1

Stratigraphy

The Zenatiinae are a particularly conservative group, and through the 30 million years of their known history, their morphological changes have been comparatively minute. However, careful study shows that these changes, though small, were sustained, and provide a sound basis for classification. On present knowledge *Zenatiopsis fragilis* is confined to the Upper Oligocene, *Z. angustata* to the Middle Miocene, *Z. phorca* to the uppermost Miocene and Lower Pliocene, and *Zenatiopsis* sp. nov. to the Pleistocene. *Zenatina victoriae* ranges from the Lower Pliocene to the present. The stratigraphical ranges of these evolutionary lines are indicated in Fig. 1.

The Zenatiinae are thus useful for stratigraphy in spite of their conservative nature.

Key to the Zenatiinae (using left valve only)

1. Zenatiinae with callus forming rise on inner shell surface beneath the hinge structure and sometimes forming distinct low ridge; umbo about one-fifth shell length from anterior end. *Zenatia*, New Zealand, Oligocene to present.
2. Zenatiinae with well-defined internal ridge extending more than halfway across valve; umbo about one-fifth shell length from anterior end. *Zenatiopsis*, Australia, Oligocene to Pleistocene (extinct).
   a. Dorsal end of thin ridge practically in front of cardinal teeth; vertex of cardinal teeth directed anteriorly. *Z. fragilis*, Oligocene.
   b. Dorsal end of thin ridge under cardinal tooth 2a; vertex of cardinal teeth directed normal to hingeline or slightly posteriorly. *Z. angustata*, Miocene (except Cheltenhamian).
   c. Dorsal end of thick ridge between cardinal teeth or under 2b; vertex of cardinal teeth directed posteriorly. *Z. phorca*, Uppermost Miocene (Cheltenhamian) and Lower Pliocene.
   d. Thick internal ridge tending to lose regularity; cardinal teeth very prominent and directed normal to hingeline or slightly anteriorly. This definition tentative because of inadequate material. *Zenatiopsis* sp. nov., Uppermost Pliocene (Maretimo member), Lower and Middle Pleistocene (extinct).
3. Zenatiinae with short internal ridge succeeded by wide flat callus; ridge fused to base of cardinal teeth; umbo about one-third shell length from anterior end. *Zenatina*, gen. nov. Australia, Lower Pliocene to present.

Addendum

Examination of complete specimens of *Zenatiopsis* sp. nov. from Minnie Ck, Glenelg R. (Allot. 27, parish of Myaring) kindly made available by the Bureau of Mineral Resources, Canberra, has confirmed the observations made on this species.

References

ALLAN, JOYCE, 1950. *Australian Shells.* 8vo, Melbourne.

BANKS, M. R., 1957. The stratigraphy of Tasmanian limestones. p. 39-85 in Hughes, T. D., Limestones of Tasmania, *Geol. Surv. Tas. Min. Res.* 10.

DALL, W. H., 1895. Synopsis of a review of the genera of Recent and Tertiary Mactridae and Mesodesmatidae. *Proc. Malac. Soc. Lond.* 1: 203-213.

————, 1898. Contributions to the Tertiary fauna of Florida. Pt. IV. *Trans. Wagner Free Inst. Sci. Phil.* 3 (4).

DENNANT, J., and KITSON, A. E., 1903. Catalogue of the described species of fossils (except Bryozoa and Foraminifera) in the Cainozoic fauna of Victoria, S.A. and Tasmania. *Rec. Geol. Surv. Vict.* 1 (2): 89-147.

FLEMING, C. A., 1962. Palaeontological evidence for speciation preceded by geographic isolation. *The Evolution of Living Organisms* (Melb. Univ. Press) p. 225-241.

FISCHER, P., 1887. *Manuel de Conchyliologique et de paléontologie conchyliologique ou histoire naturelle des mollusques vivants et fossiles.* 8vo, Paris.

GILL, E. D., 1957a. The Pliocene-Pleistocene boundary in Australia. *Aust. J. Sci.* 20 (3): 86-87.

————, 1957b. The stratigraphical occurrence and palaeoecology of some Australian Tertiary marsupials. *Mem. Nat. Mus. Vict.* 21: 135-203.

————, 1961a. The Pliocene-Pleistocene boundary in Australia. *Internat. Geol. Congr. 20th. Sess., Mexico 1956*, Sect. 7, p. 389-395.

————, 1961b. Cainozoic climates of Australia. *Ann. New York Acad. Sci.* 95: 461-464.

————, 1961c. The climates of Gondwanaland in Kainozoic time. *Descriptive Palaeoclimatology* (ed. Nairn) chap. 14.

————, 1962. Darwin and dating the past. *Evolution of Living Organisms* (Melb. Univ. Press) p. 260-268.

GLAESSNER, M. F., 1959. Tertiary stratigraphic correlation in the Indo-Pacific region and Australia. *J. Geol. Soc. India* 1: 53-67.

GRAY, J. E., 1853. A revision of the genera of some of the families of Conchifera or bivalve shells. *Ann. Mag. Nat. Hist.* 2nd ser., 11: 33-44.

IREDALE, T., 1930. More notes on the marine mollusca of New South Wales. *Rec. Austr. Mus.* 17: 401-402.

LAMY, E., 1917. Révision des Mactridae vivants du Muséum d'Histoire Naturelle de Paris. *J. Conchyliol.* 63: 173-275, 291-511.

LUDBROOK, N. H., 1954-1958. The molluscan fauna of the Pliocene strata underlying the Adelaide Plains, Pts 1-5. *Trans. Roy. Soc. S. Austr.* 77: 42-64, 78: 18-87, 79: 1-36, 80: 17-58, 81: 43-111.

————, 1961. Stratigraphy of the Murray Basin in S.A. *Bull. Geol. Surv. S. Austr. 36.*

MARWICK, J., 1931. The Tertiary mollusca of the Gisborne District. *N.Z. Geol. Surv. Pal. Bull.* 13.

————, 1948. Lower Pliocene mollusca from Otahuhu, Auckland. *N.Z. Geol. Surv. Pal. Bull.* 16.

PRITCHARD, G. B., 1896. A revision of the fossil fauna of the Table Cape beds, Tasmania, with descriptions of new species. *Proc. Roy. Soc. Vict.* 8: 74-150.

PRITCHARD, G. B., and GATLIFF, J. H., 1903. On some new species of Victorian molluscs, No. 6. *Proc. Roy. Soc. Vict.* 16: 92-95.

QUOY, J. R. C., and GAIMARD, J. P., 1835. *Voyage de Découvertes de l'Astrolabe*, Zoologie 3. 8vo, Paris and folio atlas.

SINGLETON, F. A., 1941. The Tertiary geology of Australia. *Proc. Roy. Soc. Vict.* 53: 1-125.

SUTER, H., 1913. *Manual of the New Zealand mollusca with an atlas of quarto plates.* Text 8vo 1913, atlas 4to 1915.

TATE, R., 1878. Notes on the correlation of the coral-bearing strata of South Australia with a list of fossil corals occurring in the colony. *Trans. Proc. & Rept. Phil. Soc. Adelaide* for 1877-8, p. 120-123.

————, 1879. On a new genus of fossil Lamellibranchiata. *Trans., Proc. & Rept. Phil. Soc. Adelaide* for 1878-9, p. 129-130.

————, 1885. Notes on the physical and geological features of the basin of the Lower Murray River. *Trans. Roy. Soc. S. Austr.* 7: 24-46.

————, 1887. The lamellibranchs of the Older Tertiary of Australia, Pt. 2. *Trans. Roy. Soc. S. Austr.* 9: 142-200.

WILKINS, R. W. T., 1963. Relationships between the Mitchellian, Cheltenhamian and Kalimnan Stages in the Australian Tertiary. *Proc. Roy. Soc. Vict.* 76: 39-59.

Explanation of Plates

All figures unretouched. All numbers prefixed by 'P' are registered specimens in the palaeontological collection of the National Musum of Victoria.

PLATE XXVIII

Fig. 1—*Zenatiopsis fragilis* Pritchard, P21900, topotype, Fossil Bluff, Wynyard, N. Tasmania, x 2 approx.

Fig. 2—*Z. fragilis* Pritchard, P21902, topotype, same locality as fig. 1, x 2 approx.

Fig. 3—*Z. phorca* sp. nov., P21898, syntype left valve, MacDonald's Bank, Muddy Ck, 4 miles W. of Hamilton, Vict., x 2 approx.

Fig. 4—*Z. phorca* sp. nov., P21922, paratype, same locality as fig. 3, x 1·7 approx.

PLATE XXIX

Fig. 1—*Zenatiopsis angustata* Tate, P22527, topotype, Murray R. cliffs 4 miles S. of Morgan, S.A., x 2 approx.

Fig. 2—*Z. phorca* sp. nov., P22573, a latex cast of P21904, showing dorsal view of articulated teeth plus resilifers, hypotype, Beaumaris, Vict., enlarged.

Fig. 3—*Z. angustata* Tate, P22528, topotype, same locality as fig. 1, x 2 approx.

Fig. 4—*Z. angustata* Tate, internal structures in hinge region of P22528 enlarged.

Fig. 5—*Z. phorca* sp. nov., P21899, syntype right valve from MacDonald's Bank, Muddy Ck, 4 miles W. of Hamilton, Vict., x 2 approx.

Fig. 6—*Z. phorca* sp. nov., P21898, syntype left valve from same locality as fig. 5, x 2·7 approx.

PLATE XXX

Fig. 1—*Zenatia acinaces* (Quoy & Gaimard), enlarged view of structures in hinge region of left valve, New Zealand.

Fig. 2—*Z. acinaces* (Quoy & Gaimard), enlarged view of structures of hinge region of right valve, New Zealand.

Fig. 3—*Zenatina victoriae* (Pritchard & Gatliff), gen. nov. F440, holotype, enlarged view of structures in hinge region of left valve, Port Albert, Vict.

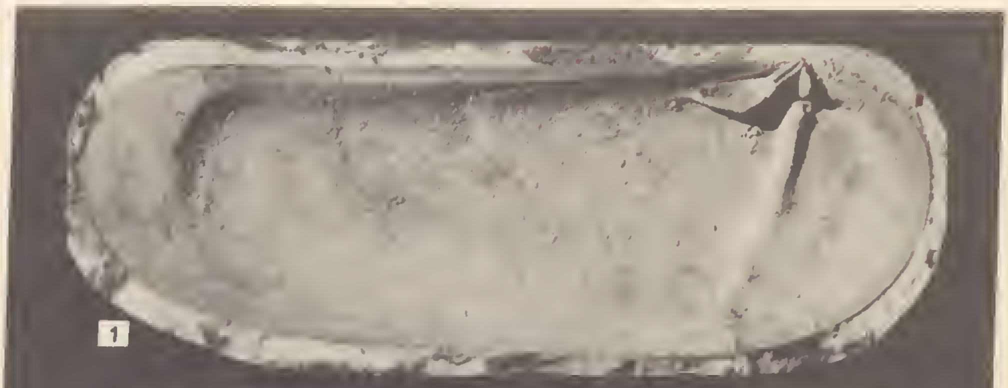
Fig. 4—*Z. victoriae* (Pritchard & Gatliff), gen. nov., ditto, right valve.

Fig. 5—*Z. victoriae* (Pritchard & Gatliff), gen. nov., P21837, hypotype, MacDonald's Bank, Muddy Ck, 4 miles W. of Hamilton, Vict., x 4·5 approx.

PLATE XXXI

Fig. 1—*Zenatiopsis angustata* Tate, lectoholotype, Tate 1879, fig. 6b, Murray R. Cliffs 4 miles S. of Morgan, S.A., x 2 approx.
Fig. 2—Enlargement of hinge region x 4 approx.
Fig. 3—*Zenatiopsis fragilis* Pritchard, P21900, enlargement of hinge region.
Fig. 4—*Z. phorca* sp. nov., P21898, enlargement of hinge region.
Fig. 5—*Zenatina victoriae* (Pritchard & Gatliff), gen. nov., P21839, enlargement of hinge region.
Fig. 6—*Zenatiopsis angustata* Tate, P22527, enlargement of hinge region.
Fig. 7—*Z. phorca* sp. nov., P21899, enlargement of hinge region.
Fig. 8—*Z. phorca* sp. nov., P21922, enlargement of hinge region.
Fig. 9—*Zenatina victoriae* (Pritchard & Gatliff), gen. nov., P21839, hypotype, MacDonald's Bank, Muddy Ck, Vict.
Fig. 10—*Zenatiopsis angustata* Tate, P22527, topotype, Murray R. Cliffs, 4 miles S. of Morgan, S.A.

All illustrations are National Museum of Victoria photographs (by Frank Guy), except Plate XXXI, fig. 1-2 which are Department of Geology, University of Adelaide (photographs by K. J. Pocock).



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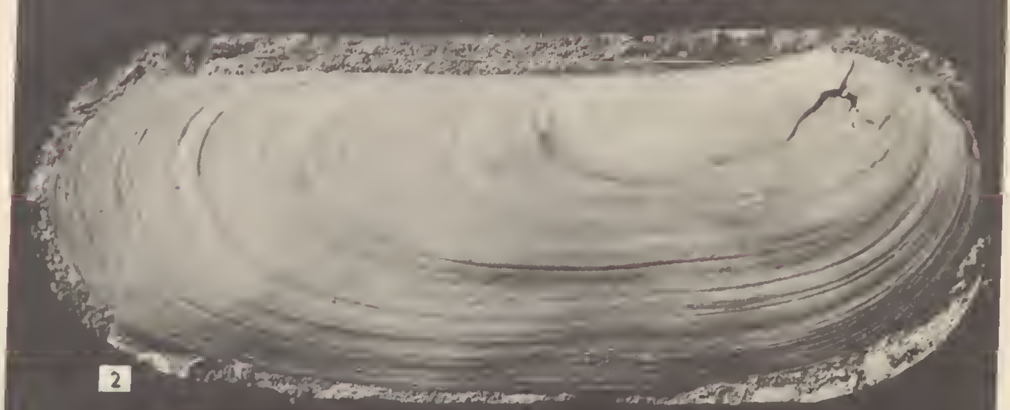

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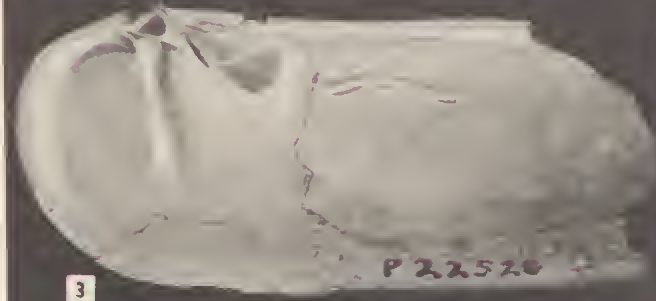

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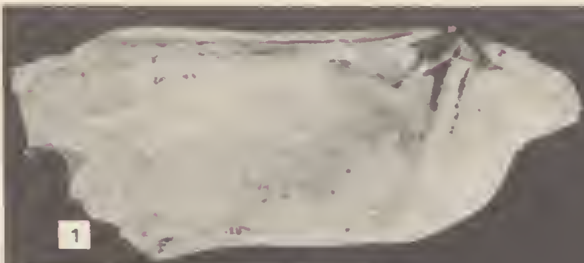
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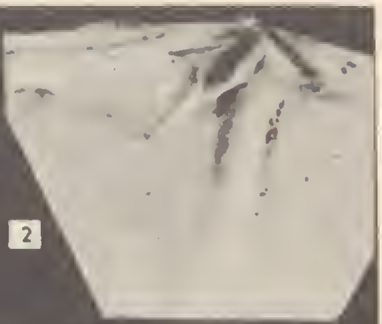
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SURVEY OF CLAY MINERALS IN SOME VICTORIAN SOILS

By G. P. Briner

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While work has been published about the clay mineralogy of soils in other Australian States, the soils of Victoria have not yet been surveyed systematically. Soils have been chosen for the present study so as to include some of the most widely known types, many of which have been examined in the School of Agriculture, University of Melbourne, for their physical or chemical interest. The work has included a detailed study of the range of soils from red to black on the Older Basalt.

Experimental

Preparation of One-Micron Clays

The soil was ground to pass a 1 mm sieve and the organic matter oxidized by an overnight treatment with sodium hypochlorite (12½%) at room temperature (Modification of hypobromite method of Troell (1931)). The sample was centrifuged to remove excess reagent, then shaken and centrifuged first with molar sodium chloride and then with tenth-molar sodium chloride.

The soil was dispersed in water (1500 ml) giving a height of 29 cm in a sedimentation jar. After 3 days the fraction less than one micron was removed by suction, and collected by filtering the suspension on a porous filter candle. The product from the filter candle was dried at 40°C. By this treatment the sample was never heated over 40°C, except for samples submitted to deferration, which were first treated with hypochlorite to remove the organic matter and then with sodium dithionite in a citrate-bicarbonate buffer at 80°C by the method of Jackson (1958). The soil was then washed and dispersed as above.

The resulting clays were ground to pass a 0·2 mm sieve and samples in a standard oblong aluminium carrier were analysed on a Philips X-ray diffractometer, Type PW.1050/PW.1051, using Cu radiations filtered with nickel at the receiving slit. The scatter slit was 1° and the receiving slit 0·1 mm. The power source was adjusted to 800 Watt, i.e. 40 Kv, 20 ma, the goniometer scanning rate was 1° per minute. Routine samples were scanned from 4° 2θ to 65° 2θ. The geiger counter was adjusted to: rate meter 4 or 8, time constant 16 and multiplier 1. For some samples of standard clays the rate meter was made less sensitive. Since clays generally contain much iron, the X-ray patterns are more diffuse with copper than with other sources, but by comparing the traces of samples before and after deferration it was possible to interpret the peaks with some confidence.

Further Treatment of Clays

Additional information was obtained by making use of the following techniques:

1. Heating to 110°C, 550°C and 750°C to decompose minerals selectively.
2. Treatment with glycerol. As a confirmation of montmorillonite and in other doubtful cases, less than 1 micron samples were treated with glycerol overnight and scanned as a paste in the standard carrier.

The identification of the clay minerals from the standard literature was checked with the standard clays supplied by Ward's Natural Science Establishment, Inc. No attempt has been made to particularize the illite beyond its identification by the 10 A and minor peaks and by its non-swelling nature. The disorder of the kaolinite noted in samples 4 and 7 was judged by the gradual slope on the upward peak of the 7 A line.

Discussion

The results of the general survey are given in Table 1.

Soils 1 and 2 represent the best-known agricultural soils of their respective districts. These northern soils, with the drier climates and higher pH, are illitic. The southern soils, with the wetter climate and lower pH, are kaolinitic. These include No. 4 (in the Kooweerup basin), No. 5 (in a basin among Silurian hills), No. 6 (on Silurian mudstone, with some muscovite surviving from the parent rock), No. 7 (on granodiorite; no mica survives into the fine clay), No. 10 (on Pliocene basalt) and No. 12 (on Eocene basalt). The other kaolinitic sample, No. 3 (a sub-soil from the Murray riverine plain), may be a Tertiary deposit and was included because of its extreme sub-plastic properties, which are compatible with a composition of kaolinite and ferric oxide. Non-kaolinitic southern soils comprise the juvenile soil on the Jurassic sandstone of South Gippsland (No. 8), and two soils on Pleistocene basalt from the drier Western District. Turkeith clay (No. 11) is from a gilgai formation a few miles N. of Mt Gellibrand. The other basaltic clay (No. 13) is dealt with at more length below.

A detailed study has also been made of the soils formed on the 'Older' (early Tertiary) basalt of South Gippsland and the E. Central District. While the typical soil in Gippsland is a red-brown clay loam overlying a friable red clay to a depth of several feet (Table 1, No. 12), contrasting soils occur on these older basalts as at Berwick and Phillip Is. The extreme contrast (Table 1, No. 13) is a black friable clay at the surface, with a subsurface clay that swells and cracks with the changing seasons, and passing at the third foot into a gritty clay. This gritty clay contains the primary minerals of the basalt in its sand fraction (plagioclase, augite, olivine weathering to serpentine, as was kindly determined by Dr G. Baker, Mineragraphic Investigations Section, CSIRO). For further study here, additional profiles were sampled at Berwick and at Phillip Is., as well as from the main basalt plateau at Leongatha (Table 2).

The red soils (12, 14, 15, 16) consist of kaolinite and ferric oxide, though the weathering rock from a cutting at Leongatha contains illite as well. The grey and black soils include not only the montmorillonitic member already mentioned (13) but intermediate profiles (17, 18). No. 18 contains kaolinite, but otherwise resembles 13, with its decomposing primary minerals in the third foot. No. 17 has no 2:1 clay in the surface, but contains some in the subsoil. The existence of these intermediate profiles agrees with the description of the basalt soils of Berwick by Holmes et al. (1940), who mapped them either as 'red-brown' (those with bright red colours and friable clays below) or as 'black' (including intermediate colours and properties of clay).

The 'red' and 'black' samples occur close to one another. For example, No. 18 was collected on the same hill as No. 12, both of them near the top of the ridge that runs between Berwick and Beaconsfield.

Similar ranges of soil on basalt have been described and discussed in N. New South Wales by Hallsworth et al. (1952) and in S. Queensland by Teakle (1952) and Ferguson (1954).

TABLE 1

Clay Minerals in the Fraction below One Micron

Soil	District	Depth Inches	Texture or % clay	pH	Clay Minerals (Other Constituents in Parentheses) ‡
1. Tatchera sandy loam	Mallee	18	sandy clay	9·0	Illite (Ca, H)
2. Horsham clay	Wimmera	0-6	clay	7·4	Illite (Q)
3. Katamatite loam	Goulburn Valley	45	63	9·1	Kaolinite
4. Dalmore clay	E. Central	0-6	67	5·1	Metahalloysite, Kaolinite (d)
5. Eumemmering clay	E. Central	0-6	48	5·5	Kaolinite (d) (H, Q)
		33-42	66	6·7	Kaolinite (d) (H, Q)
6. Hallam loam	E. Central	0-8	21	4·7	Muscovite, Kaolinite (Q)
		18-30	73	4·7	Muscovite, Kaolinite
		30-44	55*	4·6	Muscovite, Kaolinite Chlorite
7. Harkaway sand	E. Central	15-20	55	5·2	Kaolinite (d)
		22-30	25*	5·5	Kaolinite (d)
8. Grey Loam† on Jurassic sandstone	S. Gippsland	0-6	loam	5·1	Illite (Q)
		24	—*	5·7	Illite, Kaolinite
Newer Basaltic Soils					
9. Red-brown clay loam	W. Central	12	59	6·2	Illite, Kaolinite (H, Q) Kaolinite (Q)
10. Buckshot Plains	Western	8-12	clay loam	5·6	Kaolinite (H, Q)
		18-40	clay	5·6	Beidellite Illite
11. Turkeith clay	Western	0-7	58	8·1	Kaolinite (tr.)
		54-66	49	8·6	Beidellite Illite Kaolinite (tr.)
Older Basaltic Soils					
12. Red-brown clay loam	E. Central	0-9	36	5·1	Kaolinite (H, Q)
		27-39	79	5·6	Kaolinite (H, Q)
13. Black friable clay	E. Central	6-12	clay	4·9	Montmorillonite, Illite (tr.) (I.O., M)
		24-30	sandy clay*	6·6	Montmorillonite, (P(tr.))

* Decomposing rock.

† According to evidence presented in this number (Dettmann 1963) these sediments are to be assigned to the lower Cretaceous.

‡ Ca = calcite; H = hematite; I.O. = beta FeO.OH; M = magnetite; P = plagioclase; Q = quartz.

References: 1. Taylor & Penman (1930); 2. Skene (1959); 3. Skene & Poutsma (1962); 4. Goudie (1941); 5, 6, 7, 12, 13. Holmes et al. (1940); 9. Werribee State Research Farm; 10. Leeper (1948); 11. Leeper et al. (1936).

Ferguson, working near Toowoomba, finds montmorillonite in black soils and kaolinite in red soils and both together in some intermediates. He accepts the usual sequence in weathering, with montmorillonite being formed first and breaking down finally to kaolinite and ferric oxide. According to him the young montmorillonitic soils can form only when erosion has removed the more weathered material.

Teakle's explanation is similar. He regards the red kaolinitic soil as stable once formed, so that geological erosion would be needed before a black soil could form on that rock. But he also attributes some stability ('pedogenic inertia') to the montmorillonitic clay once it is formed, since it is too impermeable to be leached. The disappearance of the 2:1 clay from the surface of sample 17 (Table 2) does not fit this opinion. The black soils of his study contain free $CaCO_3$, which is absent from the black profiles of Berwick, and detected in small amounts in the subsoil of No. 17.

TABLE 2

Range of Soils on Older Basalt

Clay Number	Location	Depth Inches	Soil Texture	Soil Colour	pH	Clay Minerals (Other Constituents in Parentheses)†
Red and Red-brown Soils						
12a	Berwick	0-9	clay loam	2·5YR 3/2	5·1	Kaolinite (H, Q)
b		27-39	clay	2·5YR 3/6	5·6	Kaolinite (H, Q)
14	Berwick	24	clay	10R 3/4	6·5	Kaolinite (H)
15	Phillip Is. (David Forest)	24	clay	2·5YR 3/4	6·5	Kaolinite (G, H)
16a	Leongatha	18	clay	2·5YR 3/4	6·5	Kaolinite (G, H)
b		60	clay*	2·5YR 3/4	6·4	Metahalloysite, Illite, Kaolinite (tr.)
Grey and Black Soils						
17a	Phillip Is. (Nobbies)	0-6	clay	10YR 3/2	6·7	Metahalloysite (G, H, Q (tr.))
b		18	heavy clay	10YR 3/2	6·9	Metahalloysite, Illite, Kaolinite, Montmorillonite (tr.) (Ca, G, H)
18a	Berwick	6-12	clay	10YR 3/1	5·4	Montmorillonite, Kaolinite (tr.)
b		24-30	clay*	25Y 4/1	6·6	Montmorillonite, Kaolinite (tr.)
13a	Berwick	6-12	clay	10YR 3/1	4·9	Montmorillonite, Illite (tr.)
b		24-30	sandy* clay loam	10YR 3/2	6·6	Montmorillonite (P(tr.))

* Decomposing rock.
† Ca = calcite; G = goethite; H = hematite; P = plagioclase; Q = quartz.
Reference: 12, 13, 14, 18. Holmes et al. (1940).

Hallsworth (1951) also found intermediate types containing illite, as might well be expected. He explains reds and blacks in terms of catenas with red on the upper eluviated slopes, black on the lower illuviated slopes. Such a picture does not apply to Berwick and Phillip Is., where black soils as well as red occur on ridges.

From this work it appears that the constituents of the soils on the older basalt favour the theories of Ferguson that the ultimate products of weathering are kaolinite and ferric oxide and that montmorillonite occurs where the rock has been exposed by erosion.

Acknowledgements

The author would like to thank Professor G. W. Leeper for his advice and help with this project, also Mr G. Mucznik for his ready technical assistance.

References

Dettmann, Mary E., 1963. Upper Mesozoic microfloras from south-eastern Australia. *Proc. Roy. Soc. Vict.* 77 (1).

Ferguson, J. A., 1954. Transformation of clay minerals in black earths and red loams of basaltic origin. *Aust. J. Agric. Res.* 5: 98.

Goudie, A. G., 1941. A survey of soils and land utilization in the Parishes of Kooweerup and Kooweerup East. *Proc. Roy. Soc. Vict.* 54: 93.

Hallsworth, E. G., 1951. An interpretation of the soil formations found on basalt in the Richmond-Tweed Region of New South Wales. *Aust. J. Agric. Res.* 2: 411.

Hallsworth, E. G., Costin, A. B., Gibbons, F. R., and Robertson, Owen K., 1952. Studies in pedogenesis in New South Wales, II. The chocolate soils. *J. Soil. Sci.* 3: 89.

Holmes, L. C., Leeper, G. W., Nicolls, K. D., 1940. Soil and land utilization survey of the country around Berwick. *Proc. Roy. Soc. Vict.* 52: 177.

Jackson, M. L., 1958. *Soil Chemical Analysis.* Constable (London) p. 168.

Leeper, G. W., 1948. *Introduction to Soil Science,* Melbourne University Press.

Leeper, G. W., Nicholls, Ann, and Wadham, S. M., 1936. Soil and pasture studies in the Mount Gellibrand area, Western District of Victoria. *Proc. Roy. Soc. Vict.* 49: 77.

Skene, J. K. M., 1959. Report on soils of the Horsham Soldier Settlement Project. *Soil Survey Report No. 31,* Department of Agriculture, Victoria, Australia.

Skene, J. K. M., and Poutsma, T. S., 1962. Soil and land use in part of the Goulburn Valley, Victoria. *Dept of Agric. Vict. Tech. Bull.* No. 14.

Taylor, J. K., and Penman, F., 1930. Soil survey of Woorinen Settlement, Swan Hill Irrigation District, Victoria. *C.S.I.R. Bulletin* No. 45 (Type 8).

Teakle, L. J. H., 1952. An interpretation of the occurrence of diverse types of soil on basalt in northern New South Wales and Queensland. *Aust. J. Agric. Res.* 3: 391.

Troell, E., 1931. The use of sodium hypobromite for the oxidation of organic matter in the mechanical analysis of soils. *J. Agric. Sci.* 21: 476.

5

NEW BENNETTITALEAN LEAVES FROM THE MESOZOIC OF EASTERN AUSTRALIA

By J. G. Douglas
Geological Survey of Victoria

Abstract

Mesozoic bennettitalean leaves with strongly incurved pinna margins from the Walloon Series, Queensland, are described under the specific name *Otozamites incurvatus* n. sp., and another new form from the Tyers Group, Victoria, is described as *Otozamites boolensis* n. sp. Less well preserved Victorian specimens including *Ptilophyllum cutchense* Morris are also described.

Introduction

A variety of leaf remains from E. Australian Mesozoic sediments have been referred to the Bennettitales after examination of the external form, but anatomical and cuticular studies have been neglected. This is principally due to the fact that most collections consist of weathered outcrop material, but there is ample scope in nearly all Mesozoic areas for selective collections of more finely preserved specimens both from outcrop and mining localities.

Comparison with overseas forms on a morphological basis alone is difficult, and it is to facilitate this, and the correlation and dating of sediments that these Australian forms are described. The best preserved type is from the Walloon Series, Queensland, and the remainder from the Boola Boola Forest area, Victoria. Poorly preserved leaves from this latter area were described by the author (1962) under the names *Otozamites* sp. indet. and *Ptilophyllum*? sp. but the collection of more finely preserved material has allowed some expansion of these determinations.

Description of Types

CYCADOPHYTA

Cycadeoideales

Otozamites incurvatus n. sp.

(Pl. XXXII, fig. 1-6; Pl. XXXIII, fig. 1-5; Pl. XXXVI, fig. 1; Fig. 1-3)

Diagnosis: Pinnate leaf, maximum length preserved 40 mm and width 10-15 mm with pinnae arising from upper surface of rachis at about 45° and set well apart with strongly auriculate base. Pinnae falcate, or falcate-lanceolate, maximum length about 10 mm with lower margin upcurved to meet less strongly upcurved upper margin at an acutely pointed apex. Margins of pinnae strongly incurved, forming flaps directly protecting up to half of the morphological undersurface. Pinnae thick and somewhat coriaceous and attached at the centre of the base, with the upper auricle obscuring most of the rachis.

Venation of about 10 veins radiating from a central basal area and branching to the extremities, and represented on the upper surface by fine grooving.

Specimens Identified: Reg. No. Geological Survey of Victoria (GSV) 58874-58880. Holotype GSV 58878.

LOCALITY: Mine Dump, New Caledonia Coal Mine No. 2, near Rosewood, Queensland.

ROCK TYPE: Fine-grained light grey mudstone containing black carbonaceous plant remains, with interbedded coal bands.

COLLECTOR: Dr J. A. Townrow, Botany Department, University of Tasmania.

DATE: August 1961.

CUTICLE: Rachis—No distinction is evident between upper and lower cuticles. Both consist of rectangular-spindle shaped cells about 50 μ long by 20 μ broad, with strongly thickened longitudinal and transverse walls pitted to give a callus-like sinuous form to otherwise mildly undulating to straight cell walls. Stomata are absent.

Pinna Upper Surface—Cells with extremely heavily thickened and involute walls with lobe thickening reaching almost to the centre of the cell and occupying most of the lumen. Shape basically rectangular much modified by the wall sinuosity, and dimensions vary somewhat according to position on pinnae, but average about 48 μ long and 26 μ broad. Thickness is about 2·5 μ. Stomata and papillae are absent.

Lower Surface—Lower surface of incurved segment—This is similar in thickness to that of the upper surface of the pinnae, but wall sinuosity is less extreme. The folds on the outer pinna margin and the inner edge of the overlapping flap are heavily cutinized.

Upper surface of incurved segment—This consists at the inner edge of involute walled cells with thickening diminishing from that seen on the lower surface, but near the outer extremity changes within 1-2 rows into cells with relatively unthickened walls. Papillae appear in this zone which is generally about one-third of the flap width from the inside margin, and possibly represents the stomata-free marginal zone found in the pinna lower cuticles of other bennettitaleans (cf. *O. boolensis* below). Less than halfway across the flap a fine fold represents the junction of this incurved segment or flap cuticle and that of the protected under-surface of the pinna. Treatment usually causes some contortion in this thin cuticle, but half the flap width appears to be the maximum distance for the position of the transition from flap cuticle to lower surface cuticle. That is, for at least half of its width the flap does not protect cuticular surfaces but provides a thicker lamina.

Lower surface covered by incurved segment and exposed lower surface—The extreme outermost cuticle protected by the flap is thin and tenuous and continues across the unprotected lower surface as vein and intervening cell areas. The former consist of elongated rectangular shaped cells with wall sinuosity less marked than on the upper pinnae surface and bearing short subcircular papillae with outer diameter about 20 μ and inner less than half this figure. The intervening areas also consist of involute walled cells the shape of which are modified by the presence of numerous stomata aligned at right angles to the vein cells. The intervening or stomatal cell areas are generally (depending upon location in respect to major veins, etc.) 3 times as wide as the vein areas which are seldom more than 4 cells wide. Stomata appear to lie in rows within the stomatal areas, the rows being separated by narrow stomatal-free bands of cells which may represent the position of minor veins. There are on average 100 stomata per sq. mm of exposed lower surface cuticle.

Hollow papillae also occur in the intervening areas, where nearly all cells are papillate. Wall thickening is less prominent than on the upper surface except for portions of the specialized cells around the stomatal openings. Stomata are not deeply sunken, and are of typical bennettitalean form with cutinized guard cells (36-48 × 12-16 μ) surrounded by two hemispherical involute walled subsidiary cells (48-67 × 17-22 μ). The guard cells are thickened around the stomatal slit as illustrated in Pl. XXXVI, fig. 1.

REMARKS: The following bennettitaleans from the Walloon Series are recorded by Walkom (1917):

Ptilophyllum (*Williamsonia*) *pecten* (Phillips)
Otozamites queenslandi Walkom
Otozamites obtusus Lindley and Hutton
Otozamites Feistmanteli Zigno
Otozamites cf. *Mandelslohi* Kurr.

Of these *P.* (*Williamsonia*) *pecten*, and *Otozamites feistmanteli* correspond best in pinna size, but reference to Table 1 below, which also includes pertinent overseas forms for comparison, shows no form with the same pinna characteristics as *O. incurvatus*. *Otozamites bechei* types, e.g. *O. linearis* (Halle 1915, from Graham Land), appear to compare best on this form basis.

TABLE 1

Comparison of O. incurvatus *with Queensland and overseas bennettitaleans on the basis of pinna forms*

Species	Pinna characteristics				
	Size	Shape	Arrangement	Xeromorphic modification	Venation
O. incurvatus n. sp.	length up to 10 mm	falcate-falcate lanceolate, base strongly auriculate	well space at about 45° to rachis	incurved margins	about 10 veins at base
P. (Will.) pecten (Phillips) (Queensland specimens)	length 10 mm	long, narrow, very slight auriculation	closely set at wide angle to rachis	—	4 per pinna
P. pecten (Phillips) (Yorkshire specimens)	length less than 10 mm	lanceolate	crowded at wide angle to rachis	lamina thick	—
O. feistmanteli Zigno (Queensland specimens)	length 12 mm	linear, auriculate	overlapping almost at right angles to rachis	—	6-8 at base
O. linearis Halle	length average about 12 mm	lanceolate to oblong falcate	distant, rarely closely set	—	dense. bifurcating

Overseas forms with incurved pinna margins include the bennettitalean, *Pseudocycas roemeri* (Schenk) Holden (Halle 1915), and the unrelated *Cycadopteris anglica*, described by Townrow and Hancock in 1961. Other forms with extremely thick lamina, e.g. *P. pecten*, also show some tendency to incurving of margins.

A type figured by Saporta (1875) as *O. marginatus*, with a purported marginal pinna fold was later classified by Seward (1900) as *O. beani* Lindley and Hutton. Previously (1895) Seward had regarded this somewhat fragmentary specimen as possibly an immature specimen of *O. klipsteinii* Dunker. In any case, *O. marginatus* bears no other resemblance to the Walloon specimens. That the pinna margin of these latter is incurved with an underflap, and not merely swollen and recurved, is readily established by coarse sectioning of the pinna, where two distinct lamina sections may be seen closely appressed, but definitely free, apart from the folded marginal section (see Fig. 3).

Fig. 2 shows the large degree of protection afforded the undersurface of the pinnae by the incurved margin. When it is realized that the incurved portion actually consists of two adjacent surfaces physiologically acting in part at least as lower surfaces, the proportion of leaf surface directly protected by the flap increases a great deal, and averages about 50% over the entire lamina.

This xeromorphic adaption of incurved pinnae margin, not unusual in bennettitaleans of the *Otozamites* and *Ptilophyllum* type (see above), is more spectacularly developed in *O. incurvatus*, and is only one type of drought resistant modification illustrated in other forms by papillae 'mats', thickening of lamina, sunken stomata, etc.

On the basis of cuticular comparison the specimens compare best with *Ptilophllum distanse* Feistmantel and *P. acutifolium* Morris from the Upper Jurassic of India (Jacob and Jacob 1954). The cuticles of both these however, can be readily distinguished from *O. incurvatus* (see Table 2).

TABLE 2

Comparison of O. incurvatus *with overseas forms on the basis of pinna cuticle anatomy*

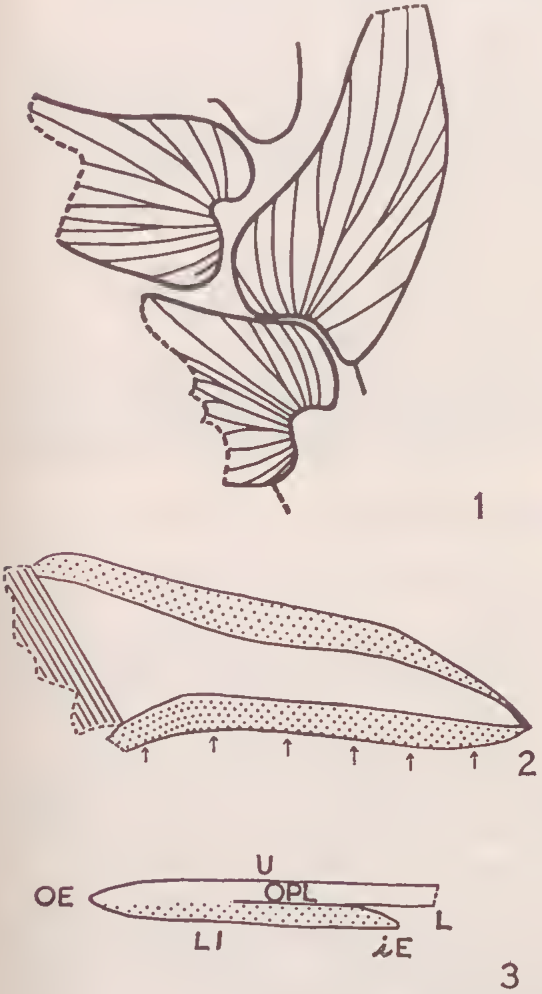
Species	Upper cuticle	Lower cuticle			
		Papillae	Vein areas	Stomata frequency	Subsidiary-cell
O. incurvatus n. sp.	resistant and highly cutinized	circular, prominent	about 4 cells wide	100 per sq. mm	outer walls sinuous
P. acutifolium Morris	extremely delicate	oblong and circular	2-4 cells wide	175-200 per sq. mm	outer walls sinuous
P. distanse Feistmantel	delicate	circular, not prominent	4-5 cells wide	120-125 per sq. mm	outer walls sinuous
P. pecten Phillips	persistent	very prominent, in rows	narrower than *O. incurvatus*	—	outer walls straight

Note: Only the most pertinent and closely comparable species are included for comparison and certain peculiarities, particularly in stomatal construction, of each species are ignored in favour of features in common.

As no previously determined form has the same combination of pinna form and cuticular properties, it is evident that new specific nomenclature is required. The principal problem is whether to include the species under the genus *Otozamites* or *Ptilophyllum*. The former has been chosen on the basis of pinnae form distinctions recapitulated by Harris (1949). Harris here also tentatively postulates a basic cuticular structure which would possibly place the species in *Ptilophyllum*, but until generic classification on anatomical remains is established as a general practice, the more practicable classification on general form will be adhered to.

A new species *Otozamites incurvatus* is thus instituted.

The cuticle of this species is very beautifully preserved, and, apart from the



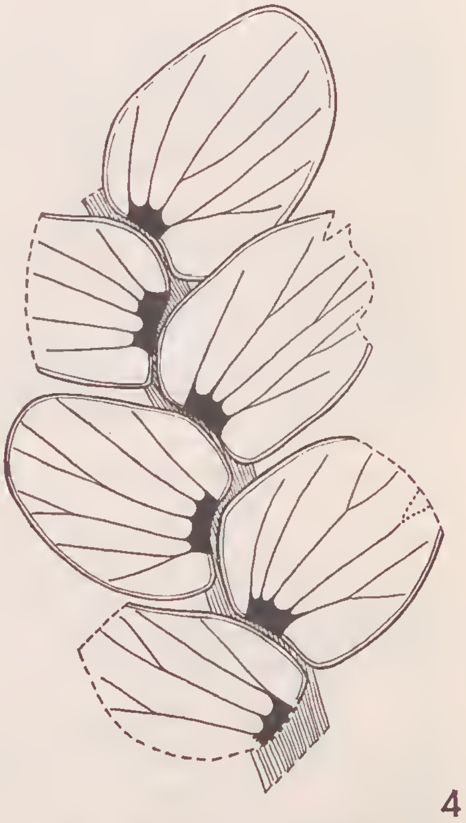


FIG. 1-3—*Otozamites incurvatus* n. sp. Line drawings.

(1) Portion of leaf showing pinna arrangement and venation, upper surface. × *c.* 7.

(2) Pinna, lower surface, with incurved portion dotted. × *c.* 7. Rachis represented by parallel lines. Arrows reading from left (or pinna base) indicate where 36%, 51%, 58%, 55%, 56% and 54% respectively of the pinna lower surface is covered by the incurved segment.

(3) Diagrammatic section through edge of pinnae showing flap-like nature of incurved area. × *c.* 100. For explanation of lettering see 'Explanation of Plates' Pl. XXXII, fig. 4.

FIG. 4—*Otozamites boolensis* n. sp. Line drawing. Portion of leaf showing pinna arrangement and venation, upper surface. × 10.

difficulty of separating adhering layers in the incurved flap region, is readily prepared and mounted using standard oxidation—ammonia techniques.

Otozamites boolensis n. sp.

(Pl. XXXIV, fig. 1-6, 8; Pl. XXXV, fig. 3, 7; Pl. XXXVI, fig. 2, 3; Fig. 4)

DIAGNOSIS: Pinnate leaf, maximum length preserved 55 mm with pinnae arising from upper surface of rachis at an angle generally less than a right angle, and attached at a central basal callosity between two slight auriculations. Pinnae shape oval to oval-falcate also varying according to position on the leaf, the former more characteristic. Lower pinna margin strongly recurved towards the apex, sweeping up to meet a recurving upper margin in a blunt or slightly extended tip. Both margins slightly thickened. Average pinna length 3 mm. Average width at widest section 2 mm.

LOCALITY: Rintoul's Ck, Boola Boola Forest, SE. Victoria. Locality No. 23 Coordinates Misc. Topo. 83 sheet 4, 3011 N, 4473 E. Tyers R., Boola Boola Forest, precise locality unknown (see Reg. No. 1420 below).

SPECIMENS IDENTIFIED: Reg. No. GSV 58781 (holotype), 58780, 58782, 58783, 58784, 58785, 58786, 58789, 59045 (counterpart), 59028, 59029, 59033, 59034, 59035, 59036, 59037, 59038, 59039, 59040, 59041, 59042, 59043, 59045, 59046, 59047. Reg. No. Geology Dept University of Melbourne 1420 '*Thinnfeldia australis* Morris'.

ROCK TYPE: Hard grey-blue mudstone, with black or sepia coloured plant remains.

COLLECTOR: Author (except University specimen).

DATE: November 1958 and August 1962.

CUTICLE: Rachis—Upper and lower cuticles appear to be similar and consist of relatively straight walled rectangular-spindle shaped cells 40-50 μ long and 20 μ broad with walls thickened.

Pinna—Upper Surface—The upper cuticle consists of rectangular-sub-rectangular shaped cells with sinuous walls thickened to a moderate degree at the lobes and saddles. This cuticle appears to be thinner than the lower and usually disintegrates during maceration, but this effect may be due to the absence of any thickening or support in the nature of papillae or hairs. Stomata are also absent.

Lower cuticle—This consists of rows of stomata free, sinuous walled, square-polygonal shaped cells about 10 wide around the pinna margin, with bands of rectangular shaped cells possibly representing vein courses. These cells do not bear papillae or hairs and thickening on the lobes and saddles of the walls is minor.

Stomata are sunken and arranged (Pl. XXXIV, fig. 6) transversely across the long axis of the pinna, apparently haphazardly and closely crowded (averaging 170 per sq. mm) but closer examination shows that distribution reflects vein position and divergence. Size varies from 28-36 × 43-54 μ. The ordinary epidermal cells bear hollow papillae. The stomata are of typical bennettitalean form and have thickened guard cells. The hemispherical subsidiary cells have finely granular non-sinuous outer walls and in some instances bear small flat papillae not evident in either of the two stomata figured (Pl. XXXVI, fig. 2, 3).

REMARKS: The cuticles of this form are not as well preserved as those of *O. incurvatus* described above, but on careful maceration yield cuticles from both pinna surfaces. The sub-ovate pinna shape of *O. boolensis* can be the basis for comparison with some species, e.g. *O. bunburyensis* Zigno (this latter also has strong xeromorphic adaptions with thickened margin and thick hair cover on the pinna lower surface), but the combination of pinna shape and venation characteristics is unique. On morphological grounds the specimen readily falls into the *Otozamites* category. On cuticular details however, the species perhaps has closer affinity to *Ptilophyllum* on the basis suggested by Harris (1949) of papillae on the subsidiary cells overhanging the guard cells. Some of the Indian *Ptilophyllum* species described by Jacob and Jacob (1954) also have somewhat similar cuticles. *P. indicum* Sahni and Sahni seems to perhaps be the closest comparable form, with a similar stomatal density, but the cuticle on the lower surface of the pinna is more strongly defined into stomatal and non-stomatal areas, and pinna form differs.

Otozamites sp. indet.

1962 *Otozamites* sp. indet. Douglas p. 41, Fig. 1; Pl. 7, fig. 1. Specimens identified. Reg. No. GSV 57747, 57748 (counterpart).

REMARKS: The venation characteristics of this specimen (see Douglas 1962, Fig. 1; Pl. 7, fig. 1) are somewhat similar to that of Indian forms of *Ptilophyllum cutchense*, which species is cofossilized at Boola Boola in Loc. 1 (see below). However, leaf size of GSV 57747 is larger than that of *P. cutchense* from this locality and the upper auricle at the pinna base is more persistent and pronounced, hence an *Otozamites* determination is retained.

Ptilophyllum cutchense Morris

(Pl. XXXIV, fig. 7; Pl. XXXV, fig. 1, 2, 4-6; Pl. XXXVI, fig. 4)

1962 *Ptilophyllum*? sp. Douglas p. 43, Pl. 7, fig. 5.
1962 *Otozamites* sp. indet. Douglas p. 41, Pl. 7, fig. 2, 3, 4.

SPECIMENS IDENTIFIED: Reg. No. GSV 53603, 53605 Kadnook (near Coleraine), Western Victoria; 57745, 57746, 57749?, 57750, 57757-1,* 57775, 57776, 57777, 57779, 57780, 57781, 57785, 57786, 57787, 57788, 57790, 57793, 57794, 57796-1-2-3, Boola Boola Forest area (Douglas 1962 Loc. No. 1); 57783,* 57784,* Boola Boola Forest area (Douglas 1962 Loc. No. 27); 59019,* 59020, 59021,* 59022, 59023 (Counterpart) 59024, 59025, 59026, 59027 (Counterpart) Boola Boola Forest area Loc. 28 Coords. Misc. Topo. 83 sheet 5, 3025 N, 4497 E; 59056 Locality unknown (see below).

REMARKS: Pinna shape and angle of insertion on the rachis vary a good deal in these specimens, but the majority of Boola Boola Loc. 1 bennettitalean specimens are now classified in this species. These include Reg. No. 57745 and 57750 formerly (Douglas 1962) called *Otozamites* sp. indet. These are now included in *P. cutchense* because of the lack of prominent auricles on the pinna base, similar pinna and venation form to *P. cutchense*, and in particular the nearby fossilization of similar leaves yielding *P. cutchense* type cuticles. Most of the best preserved cuticle was obtained from Loc. 28 specimens, the stratigraphical position of which in respect to Loc. 1 is not clear, but which appears to be younger. Morphologically however, they are similar. No specimens were found with pinna upper and lower surface cuticles completely preserved.

Some specimens (indicated in list above by asterisk) with pinnae set a little apart, differ from the majority of Indian *P. cutchense* specimens, but examination of cuticles from Boola Loc. 28 specimens of this type show that the structure agrees with the Indian material as far as can be ascertained from the relatively poorly preserved leaves.

Rachis cells are rectangular with thickened and pitted walls. The upper cuticle is thin and tenuous, but fragments were obtained containing square-rectangular cells with sinuous walls thickened on the lobes and saddles.

The lower cuticle bears sinuous walled cells with very wide hollow papillae, a feature characteristic of the Indian form. Stomata are transversely orientated, and in rows, averaging 120 per sq. mm with vein cells indistinguishable. Size is from 15-18 × 22-30 μ. A stomata-free region runs around the margin of the pinna, but narrows near the base. The subsidiary cells have straight outer walls, with a granular texture. The outer walls of the guard cells are also prominent.

The upper surface cuticles of the pinna of both *O. boolensis* and *P. cutchense* are very similar, and difficult to distinguish, and both lower surface cuticles show similarity in differentiation into wide marginal stomata free zones. However, the lower surface cuticles may readily be distinguished by the alignment of *P. cutchense* stomata in more definite rows, the smaller stomatal concentration per unit area in this species, and the absence of small projecting papillae around the stomata. The narrow pinnae of *P. cutchense* are easily distinguished from the ovate pinnae of *O. boolensis* in hand specimen.

P. cutchense is widely dispersed in Victoria, as it has been collected from the far west of the State (Kadnook) and although absent from nearly all horizons perhaps is also present in certain restricted occurrences in the basal part of the sequence in the South Gippsland Strezlecki Group non marine Mesozoic sediments, as the specimen identified from an unknown locality (Reg. No. 59056) was stored in company with fossils from this area. *Ptilophyllum* is not present in the well collected upper part of the sequence in the Strezlecki Group. *O. boolensis* is not found in fossil Loc. 1 in the Boola Boola forest area, but is present at Loc. 23 in this same district. *P. cutchense*, most prolific at Loc. 1, has not been found at Loc. 23. This restriction of both types to different beds appears to be due to peculiarities of deposition rather than appreciable difference in geological age, as the *O. boolensis* locality although stratigraphically lower than any of the Boola Boola *P. cutchense* beds, does not appear to be separated by any radical change in sedimentation.

Although described for convenience under two names, *Otozamites* and *Ptilophyllum* the bennettitalean remains described from Boola Boola however, do fall into a natural group and, I think, probably are derived from one natural genus, the distinction in classification being retained to follow the taxonomic procedure generally followed at present.

AGE OF SEDIMENTS: (i) *O. incurvatus* beds. De Jersey (1960) regards the Walloon Coal Measures in the type area as Lower Jurassic on the basis of comparison with Western Australian microfloras.

(ii) Boola Boola forest Mesozoic beds. The beds in the Boola Boola forest area from which the *O. boolensis* specimens (Loc. 23) are derived are thin persistent laminations of mudstone reaching a maximum thickness locally of 2 ft, but usually of less than 6 in., between massive sandstones resting some 100 ft above very coarse grained basal conglomerates. These mudstones are stratigraphically below the coarse mudstones and fine sandstones containing the *P. cutchense* specimens (Loc. 1, 27 and 28). This basal section of the Victorian non marine Mesozoic called 'Tyers Group' (Philip 1958), is regarded by Dettmann (1963) on microfloral evidence, as Lower Cretaceous in age. This follows similar, but tentative datings in Cookson and Dettmann (1958) and Dettmann (1959).

Although portion of the Indian sequence containing *P. cutchense* appears to be Upper Jurassic in age, Evans (1961) also presents microfloral evidence for a Lower Cretaceous age of much of the Merino Group sediments which have yielded this species at Kadnook.

Certain of the floral elements in other basal beds at Boola Boola stratigraphically between Loc. 1 and 28 (e.g. *Rienitsia*? sp., Douglas 1963) have strong pre-Cretaceous affinities, but the general aspect of the flora is strongly 'Wealden', and in the absence of evidence to the contrary a dating of 'basal Lower Cretaceous' must be assigned to the Boola Boola floras described.

Acknowledgement

I wish to thank Dr J. A. Townrow, Botany Department, University of Tasmania, for supply of the *O. incurvatus* specimens, and for his valuable criticisms of this paper and other studies of Victorian Mesozoic plant remains.

References

Cookson, Isabel C., and Dettmann, Mary E., 1958. Some trilete spores from upper Mesozoic deposits in the eastern Australian region. *Proc. Roy. Soc. Vict.* 70: 95-128.

De Jersey, N. J., 1960. Jurassic spores and pollen grains from the Rosewood coalfield. *Qd Geol. Surv. Pub.* 294.

Dettmann, Mary E., 1959. Upper Mesozoic microfloras in well cores from Woodside and Hedley, Victoria. *Proc. Roy. Soc. Vict.* 71: 99-105.

———, 1963. Upper Mesozoic microfloras from SE. Australia. *Proc. Roy. Soc. Vict.* 77 (1).

Douglas, J. G., 1962. The occurrence of *Otozamites* in south eastern Victoria. *Proc. Roy. Soc. Vict.* 75: 41-43.

———, 1963. Some notes on the Mesozoic flora of Sunnyside Road beach, Mornington Peninsula, Victoria. *Vict. Mines Dept Unpub. Rept* 1963/70.

Evans, P. R., 1961. A palynological examination of samples from the Merino Group, Victoria. *Bur. Min. Resour. Aust. Rec.* 1961/155.

Halle, T. G., 1913. The Mesozoic flora of Graham Land. *Wiss Engeb. Schwed. sudpolar Exped.* 3, 14: 1-123.

———, 1915. Some xerophytic leaf-structures in Mesozoic plants. *Geol. forens. forhandl.* 37, 5: 493-520.

Harris, T. M., 1949. Notes on the Jurassic flora of Yorkshire. *Ann. Mag. Hist.* 12: 275-299.

Jacob, K., and Jacob, Chinna, 1954. Cuticular study of Indian *Ptilophyllum* fronds from Cutch and Jubbulpore. *Pal. Indica* 33: 1-34.

Philip, G. M., 1958. The Jurassic sediments of the Tyers Group, Gippsland, Victoria. *Proc. Roy. Soc. Vict.* 70: 181-199.

Saporta, 1875. Plantes Jurassique 2, 2 Cycadees 168-170.

Seward, A. C., 1895. The Wealden Flora, 2. Gymnospermae.

———, 1900. The Jurassic flora of Yorkshire 1. The Yorkshire Coast.

Townrow, J. A., and Hancock, Josephine, 1961. On *Cycadopteris anglica* Gothan. *Ann. Mag. Nat. Hist.* 13, 3: 297-303.

Walkom, A. B., 1917. The Mesozoic floras of Queensland 1. The flora of the Ipswich and Walloon series. *Qd. Geol. Surv. Pub.* 259.

Explanation of Plates

Plate XXXII

Otozamites incurvatus n. sp.

Fig. 1—Reg. No. 58878 (Holotype) × 3.
Fig. 2—Reg. No. 58878 (Holotype) showing pinna base and traces of venation × *c.* 13.
Fig. 3—Reg. No. 58879 × 3.
Fig. 4—Slide No. 3302 × *c.* 40. Pinna cuticles after treatment, unfolded (except OPL see below), and described as follows: U = Upper surface of pinna; OE = Outside edge of pinna; LI = Lower surface of incurved segment of pinna; iE = Inside edge of incurved segment of pinna; OPL = Adhering cuticles. (a) pinna under-surface covered by flap, (b) upper surface of incurved segment, (c) portion of lower surface of incurved

segment. A diagrammatical section through pinna showing area of derivation of tissues indicated above is shown in Fig. 3.

Fig. 5—Slide No. 3144 × *c.* 520. Rachis cuticle showing thickened and pitted cell walls.

Fig. 6—Slide No. 3146 × *c.* 520. Cuticle from lower surface of incurved segment of pinna, designated LI in fig. 4 above.

PLATE XXXIII

Otozamites incurvatus n. sp.

Fig. 1—Slide No. 3143 × *c.* 520. Cuticle from upper surface of pinna.

Fig. 2—Slide No. 3302 × *c.* 115. Cuticle from relatively unprotected lower surface of pinna (see L fig. 6 above) showing arrangement of stomatal and intervening areas.

Fig. 3—Slide No. 3302 × *c.* 520. Cuticle from relatively unprotected lower surface of pinna showing stomatal area.

Fig. 4—Slide No. 3302 × *c.* 520. Cuticle from relatively unprotected lower surface of pinna (see L fig. 6 above) showing intervening (non-stomatal) area, with rectangular papillated vein cells.

Fig. 5—Lower surface of pinna showing incurved flaps, on either side of partially macerated pinna. × *c.* 25.

PLATE XXXIV

Fig. 1-6, 8—*Otozamites boolensis* n. sp.

Fig. 1—Reg. No. 59036 × 6. Pinna from large leaf with traces of veins remaining.

Fig. 2—Reg. No. 59047 × 3. Atypical leaves. Pinna shape and arrangement vary somewhat from holotype (see fig. 4 below) but venation, size, and associated specimens correspond with holotype.

Fig. 3—Slide No. 3112 × *c.* 25. Pinna after partial maceration.

Fig. 4—Reg. No. 58781 (holotype) × 3.

Fig. 5—Reg. No. 58789 × 3.

Fig. 6—Slide No. 3111 × *c.* 40. Pinna after maceration with upper and lower cuticles adhering, and showing stomatal distribution in lower cuticle.

Fig. 8—Slide No. 3107 × *c.* 520. Rachis cuticle.

Fig. 7—*Ptilophyllum cutchense* Morris. Slide No. 3380 × *c.* 40. Stomata arrangement, lower pinna surface. Pinna oriented with base at top of plate.

PLATE XXXV

Fig. 1—*Ptilophyllum cutchense* Morris Reg. No. 59027. × 3. Selected pinnae outlined for clarity.

Fig. 2— ——— Slide No. 3380. Cuticle from lower surface of pinna showing cells from marginal stomata free zone. × *c.* 520.

Fig. 3—*Otozamites boolensis* n. sp. Slide No. 3470 (from holotype). Cuticle from lower surface of pinna showing stomata, and outer stomata free zone. × *c.* 115.

Fig. 4—*Ptilophyllum cutchense* Morris Slide No. 3325. Rachis cuticle × *c.* 520.

Fig. 5— ——— Slide No. 3325. Cuticle from upper surface of pinna showing thickening on lobes and saddles. × *c.* 520.

Fig. 6— ——— Slide No. 3324. Cuticle from lower surface of pinna showing stomata and associated cells with large hollow papillae. × *c.* 520.

Fig. 7—*Otozamites boolensis* n. sp. Slide No. 3470 (from holotype). Stomata, lower surface of pinna. × *c.* 520.

PLATE XXXVI

Fig. 1—*Otozamites incurvatus* n. sp. Slide No. 3288. Stoma × *c.* 1200, lower surface of pinna. Portion outlined to diagrammatically illustrate papillae (P), outer wall of guard cell (OWG), sinuous outer wall of subsidiary cell (OS), and thickening of guard cell (T).

Fig. 2—*Otozamites boolensis* n. sp. Slide No. 3328. Stoma × *c.* 1200, lower surface of pinna. Portion outlined to diagrammatically illustrate papillae (P), outer wall of guard cell (OWG), possible position of outer wall of subsidiary cell (OS?), and possible position of inner wall of subsidiary cell (IS?).

Fig. 3—*Otozamites boolensis* n. sp. Slide No. 3328. Stoma × *c.* 1200, lower surface of pinna. Portion outlined to diagrammatically illustrate possible papillae (P?), outer wall of guard cell (OWG), outer wall of subsidiary cell (OS), and subsidiary cell (S).

Fig. 4—*Ptilophyllum cutchense* Morris Slide No. 3324. Stoma × *c.* 1200, lower surface of pinna. Portion outlined to diagrammatically illustrate broad papillae (P), obscure outline of epidermal cells (E), guard cell (G), and outer wall of subsidiary cell (OS).

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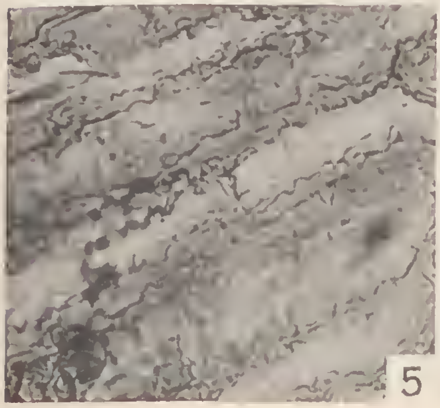

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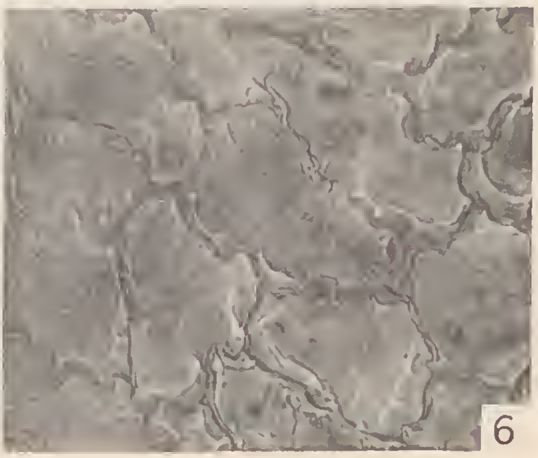

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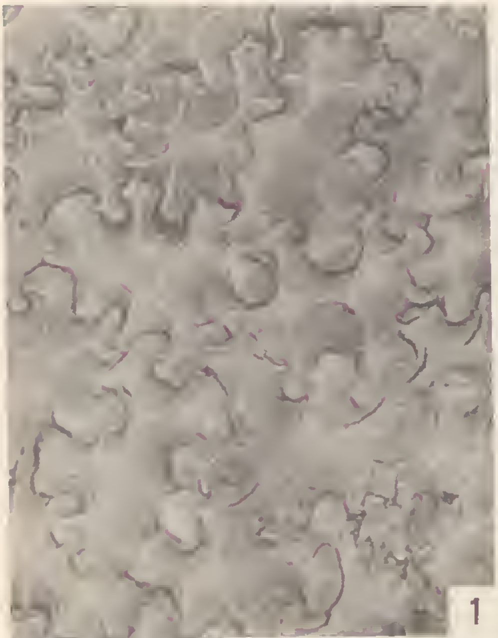
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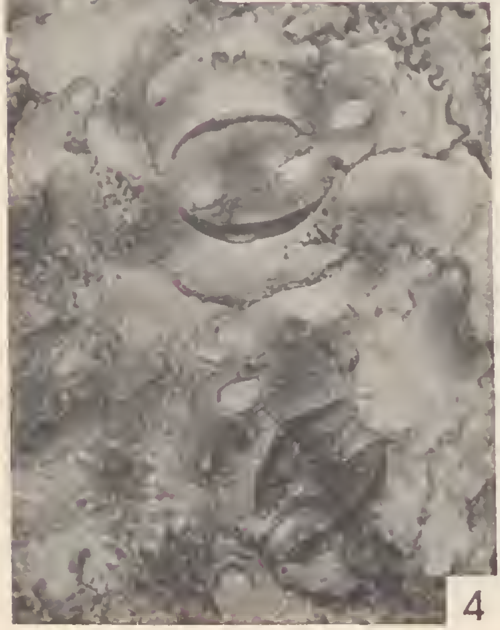
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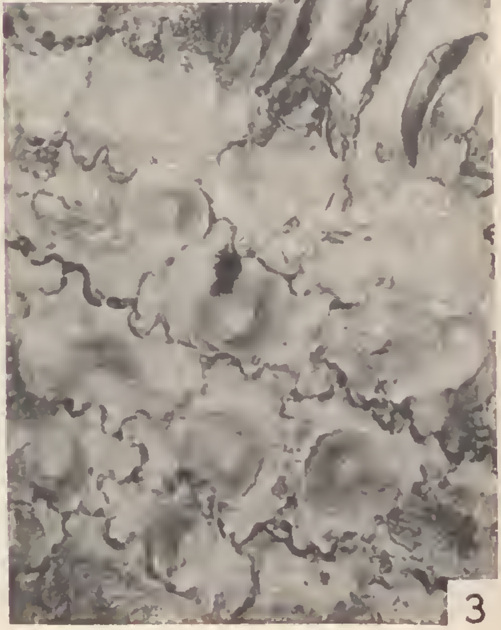
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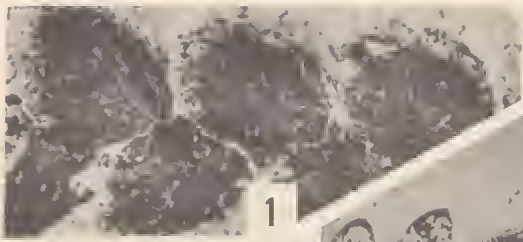

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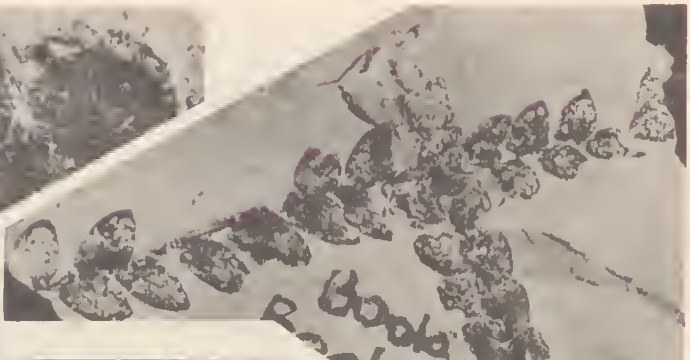

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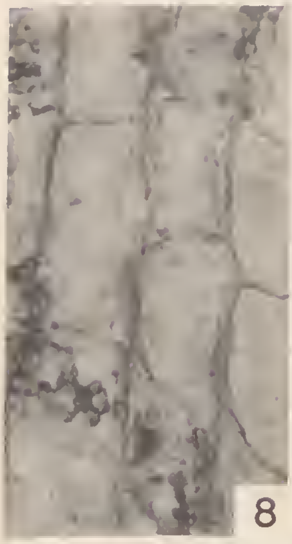

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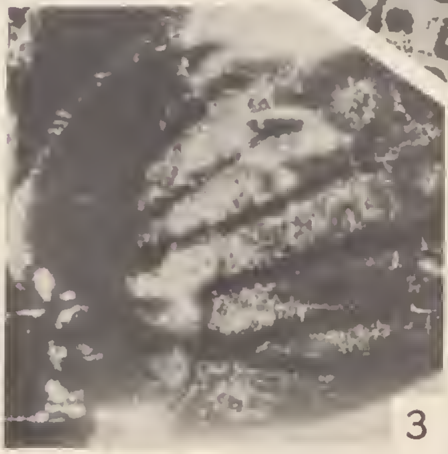

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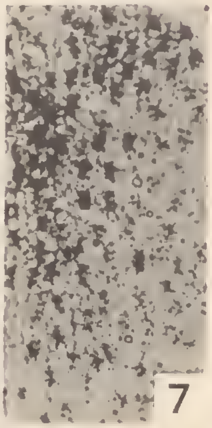

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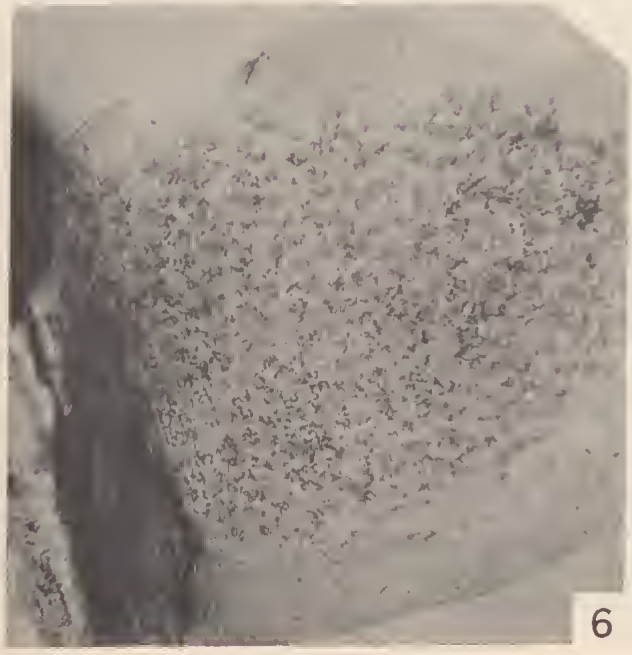

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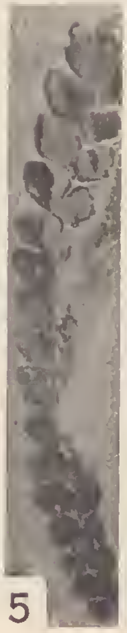

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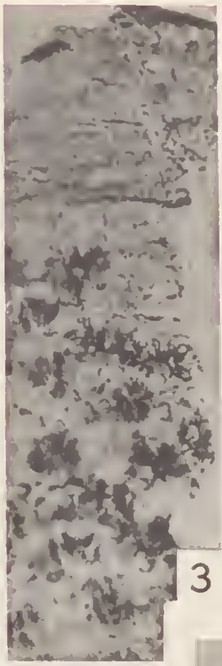
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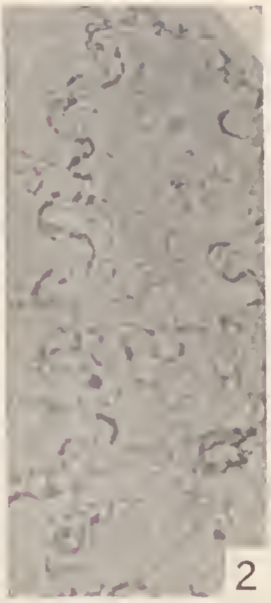
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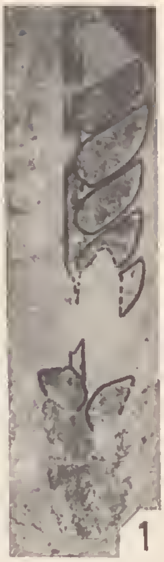
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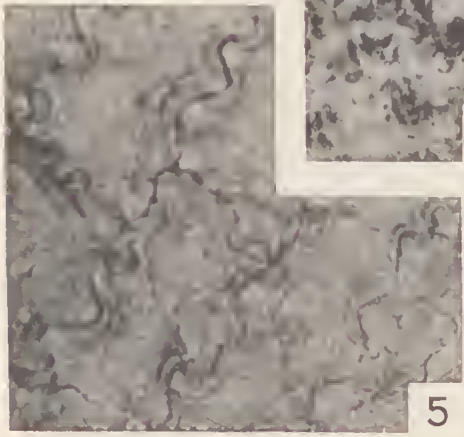
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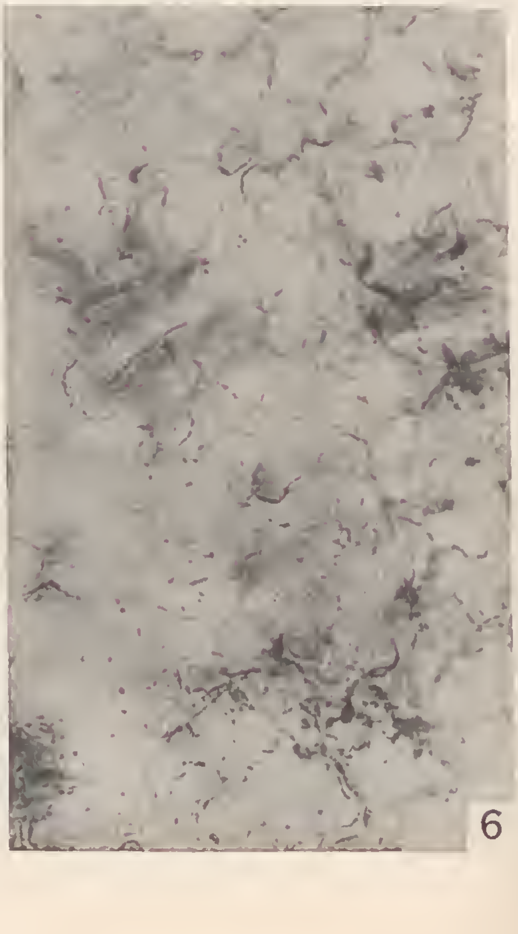
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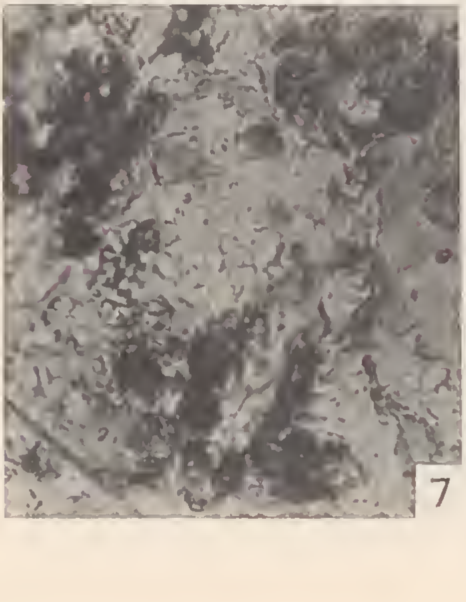
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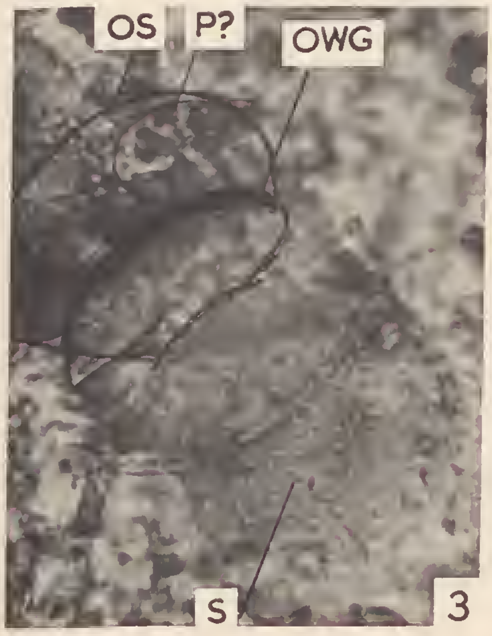

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THE TAXONOMIC POSITION OF CERTAIN EUCALYPTS

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Abstract

The eucalypts are recognized as belonging to two convergent genera: *Eucalyptus* s.s. and *Symphyomyrtus*. The taxonomic position of certain species is clarified. *E. lirata*, *E. microcorys*, *E. guilfoylei*, *E. raveretiana*, *E. brachyandra* and *E. deglupta* are to be included in *Symphyomyrtus*. *E. gamophylla*, *E. cloeziana*, *E. jacksoni*, *E. preissiana*, *E. megacarpa* and *E. mitrata* are to be included in *Eucalyptus* s.s. The information that *E. baileyana*, Series Eudesmieae, has stamens in 4 bundles has been overlooked. A form of *E. similis* (or a closely-related, undescribed species) which has sepals and a lobed staminophore is discussed. It is shown to support the view that the Miniatae are related to the Eudesmieae and to confirm the hypothesis of the petaline origin of the operculum in mono-operculate species. The characters of *E. cloeziana* suggest that it occupies a position intermediate between Eudesmieae and Renantherae. *E. gamophylla* is shown to be closely related to, if not identical with, *E. odontocarpa*.

Introduction

Within the old genus *Eucalyptus* L'Hérit, it is possible to distinguish two convergent genera: *Eucalyptus* s.s. (*Eucalyptus* L'Hérit. emend. D. J. & S. G. M. Carr) and *Symphyomyrtus* Schau. emend. D. J. & S. G. M. Carr (Carr and Carr 1962a). The major characters in which the two genera differ are those of the perianth, the inflorescence, the seed coat and the arrangement of the ovules and ovulodes on the placenta (Carr and Carr 1962b). Previous authors have recognized certain smaller, more or less homogeneous and apparently natural groups of eucalypts which, subject to minor additions and deletions, can be assigned to one or other of the genera. *Eucalyptus* s.s. includes Series Eudesmieae and Miniatae, Sections Renantheroideae, Renantherae, and Renantheroideae Normales. *Symphyomyrtus* takes in Section Macrantherae (with the exclusion of Series Eudesmieae and Miniatae) and Sections Macrantherae Normales, Porantheroideae, Porantheroideae Normales, Terminales, Graciles, Micrantherae and Platyantherae of Blakely (1934, 1955). It is the purpose of this communication to clarify the taxonomic position of certain species which constitute exceptions to the general statement just made, because they were misplaced by Blakely. (As continual reference will be made to Blakely (1934, 1955) and Blake (1953) the dates will not be cited in the text.)

Eucalyptus lirata Maiden

The original material of this species was collected by W. V. Fitzgerald in the Kimberleys (W.A.) in 1905 (Maiden Vol. 5, p. 111; Gardner 1960) and consisted of leaves, fruits and seeds. Maiden described it and remarked that the fruits and seeds were like those of *E. similis* Maiden and that the leaves of both species were like those of *E. eudesmioides* F. Muell. Beyond this he gave no reasons for including *E. lirata* together with *E. similis* and *E. baileyana* in his Series Eudesmieae. Blakely followed the same arrangement. Maiden quoted Fitzgerald's description of the bark: 'rough and greyish, but soft and almost friable, resembling that of some forms of *E. amygdalina* Labill.', but on the next page added that 'Mr Fitzgerald says nothing of the yellowness of the bark in *E. lirata* which is obvious in *E. similis*'. The wishful idea that the bark ought to be yellow like that of *E. similis* was taken up by Blakely in the name 'Yellow Gum' which he coined for the species, although he copied the description of the bark as 'rough and greyish'. The species was not investigated again until 1952 when Gardner collected a specimen near the summit of Mt Felix (Gardner 1960) which is near to the original locality. (We have examined Gardner 11927, 25/5/52, collected on Mt Herbert.) Gardner calls the species 'Yellow Jacket' (one of Maiden's names for *E. similis*) and says 'it has yellow fibrous bark not unlike a paperbark but of a more open texture . . the bark consists of thin, flaky, easily separable layers of delicate texture interspersed with longitudinal fibres'. From this description it would appear to resemble the bark of the Miniatae (described by Blake and by Gardner 1954) more closely than that of any other group. In view of the divergence from Fitzgerald's description it is an extraordinary coincidence that Gardner's account of the colour of the bark should support Maiden's wishful thought, as it appears from closer study that *E. lirata* and *E. similis* are in no way related. The close resemblance of the bark of Gardner's specimens to that of *E. miniata* is also surprising in view of the fact that both species occur together in the same locality (Gardner 1954). Despite the discrepancies in the descriptions of the bark, the identity of Gardner's specimens has been verified by comparison with the holotype, by Mr L. A. S. Johnson of the N.S.W. National Herbarium (information communicated by Mr R. D. Royce, Curator of the State Herbarium of Western Australia).

In *E. lirata* two perianth whorls are developed. The sepals are united to form an operculum which is shed when the buds are half their final size. The scar left by the abscission of the sepaline operculum is therefore prominent prior to anthesis (Pl. XXXVI, fig. 1, 2, 5). The staminophore is annular, i.e. not lobed (Pl. XXXVI, fig. 3). (In a previous paper (Carr and Carr 1962b) the term 'staminophore' was used to mean the flaps of stamen-bearing tissue in certain Eudesmieae. It would be advisable, however, to use the term to mean the stamen-bearing tissue in any eucalypt and to qualify it by such adjectives as 'lobed', 'annular' or 'flanged'.) In addition to the usual terminal gland, the connective of many of the anthers has a small extra gland at its base. This character is, as far as we are aware, not shown by any species of *Eucalytus* s.s., although it is not unusual in *Symphyomyrtus*. The pattern of arrangement of the ovules and ovulodes on the placenta is shown in Pl. XXXIX, fig. 1. The ovules are in 6 longitudinal rows on the broadest part of the placenta; elsewhere they are in 4 rows. The ovulodes are in 4 rows and are restricted to the upper part of the placenta. The ovules are anatropous or almost so. The only species of *Eucalytus* s.s. which shows even a superficial resemblance to *E. lirata* in the combination of this ovule-ovulode pattern with anatropy is *E. curtisii* Blakely and White (Carr and Carr 1962b). In *E. curtisii* the anatropy is maintained in the seed but in *E. lirata* the seeds are of the form described by Gauba and Pryor (1959) as hemitropous (Pl. XXXVII, fig. 4). The inflorescence in *E. lirata* is basitonic. In *Eucalytus* s.s. it is acrotonic or atonic (Carr and Carr 1962a). On these grounds *E. lirata* must be excluded from Series Eudesmieae as well as from *Eucalyptus* s.s. Further investigation will be needed before it can be assigned to a Series in *Symphyomyrtus*.

Eucalyptus baileyana F. Muell.

E. similis Maiden

Maiden (Vol. 5, p. 136-137) included *E. baileyana* in Series Eudesmieae because the stamens are in 4 bundles. Blakely did not incorporate this information in his description of the species and it seems to have escaped the notice of subsequent authors. *E. baileyana* is correctly placed in Series Eudesmieae as it has a single perianth and a lobed staminophore (Pl. XLI, fig. 2). Its inclusion in Eudesmieae is supported by the stellate hairs of the juvenile leaves. *E. similis* is also to be included in *Eucalyptus* s.s. as the perianth is single. Maiden originally associated it with *E. baileyana* on the basis of fruit characters. The chief resemblances are those of the shape of the fruit and the shape, size and insertion of the valves. However, doubts have been raised as to the correctness of its position in the Eudesmieae. Blake suggested that it might well be excluded from the Eudesmieae and placed in Series Miniatae. This suggestion has been supported (Carr and Carr 1962b) on the grounds that (a) *E. similis* has an ovule-ovulode pattern similar to that of the members of the Miniatae, (b) examination of specimens in herbaria had confirmed the general belief that it has neither sepals nor a lobed staminophore, the chief characters of the Eudesmieae. However, it has now become apparent that the range of variation in *E. similis* may not be adequately represented in herbaria. There is a specimen at Kew collected by Mrs M. S. Clemens at Springvale, Queensland (23° 35′ S., 143° 55′ E.), 5/4/46, and labelled '*E. similis*', which has four minute, persistent sepals alternating with the prominent lobes of the staminophore (Pl. XLI, fig. 1). Except for these anomalous features it is acceptable as *E. similis*. It is also from the centre of the restricted area in which *E. similis* is known to occur. Furthermore, the ovule-ovulode pattern is identical with that of *E. similis*. Two possibilities exist: either the material is from an undescribed species or else it is a form of *E. similis* in which the sepals are developed and the stamens are in four bundles. If it is from an undescribed species, it must be one which is very closely related indeed to *E. similis*. In either case, the Clemens specimen supports the hypothesis (Carr and Carr 1959, 1962a) that the single perianth whorl of species such as *E. similis* and, e.g. those in the Renantherae, is petaline in origin. If Blake's suggestion that *E. similis* is allied to the Miniatae is correct, then the Clemens specimen also links the Miniatae with those members of Eudesmieae which have sepals and lobed staminophores. The existence of this specimen therefore lends powerful support to the concept of *Eucalyptus* s.s. put forward in Carr and Carr (1962a).

The range of variation in *E. similis* and *E. baileyana* is clearly not fully understood. If indeed the Clemens specimen is referable to *E. similis*, as seems probable, then it represents a kind of variation in the degree of development of the sepals in a single species which is common to many other species of Eudesmieae. In most collections of *E. baileyana* the orifice of the flower and fruit is undulate and it is not unreasonable to suppose that forms of *E. baileyana* may exist in which the suppression of the sepals is incomplete.

E. gamophylla F. Muell.
E. cloeziana F. Muell.

The only major character the species included in Blakeley's Series Paniculatae (Section Macrantherae Normales) have in common is the compound inflorescence. Blake recognized that this Series is artificial by transferring *E. argillacea* W. V. Fitzg. ex Maiden to Series Buxeales, and suggesting that *E. shirleyi* Maiden is related to *E. pruinosa* Schau. (Series Siderophloiae). The heterogeneity of Series Paniculatae is revealed by the perianth characters of the species included in it. *E. cloeziana* has a single perianth (Pl. XLI, fig. 3, 4) and *E. gamophylla* has free, pesistent sepals (Carr and Carr 1959a) (Pl. XXXVIII, fig. 1, 2). These two species therefore belong in *Eucalyptus* s.s. *E. shirleyi, E. argillacea, E. intertexta* R. T.

Baker, *E. michaeliana* Blakely and *E. howittiana* F. Muell., all have a double perianth, the outer whorl of which is caducous before anthesis (Carr and Carr unpublished data). These species belong in *Symphyomyrtus*.

Because of the structure of its perianth, *E. gamophylla* must be transferred to the Series Eudesmieae. The free, persistent sepals have been neither mentioned nor illustrated by previous authors (Mueller 1878, 1879-1884; Maiden Vol. 4, p. 128; Blakely; Black 1943-1957). Mueller discussed the systematic position of *E. gamophylla* and because he saw certain resemblances between its seeds, and chaff, and those of *E. tetragona* (R. Br.) F. Muell., suggested that possibly the best place for it was with that species. However, on this basis *E. gamophylla* should be placed rather with *E. odontocarpa* F. Muell. as the seeds and chaff of the two are identical in all characters. Although the type specimen of *E. odontocarpa* (Mueller, Sturt's Creek Desert, Feb. 1846) seen at Kew still includes seeds, Mueller did not describe them.

E. gamophylla and *E. odontocarpa* have many characters in common, other than those of the seeds and chaff. The flowers of both have an unlobed (annular)

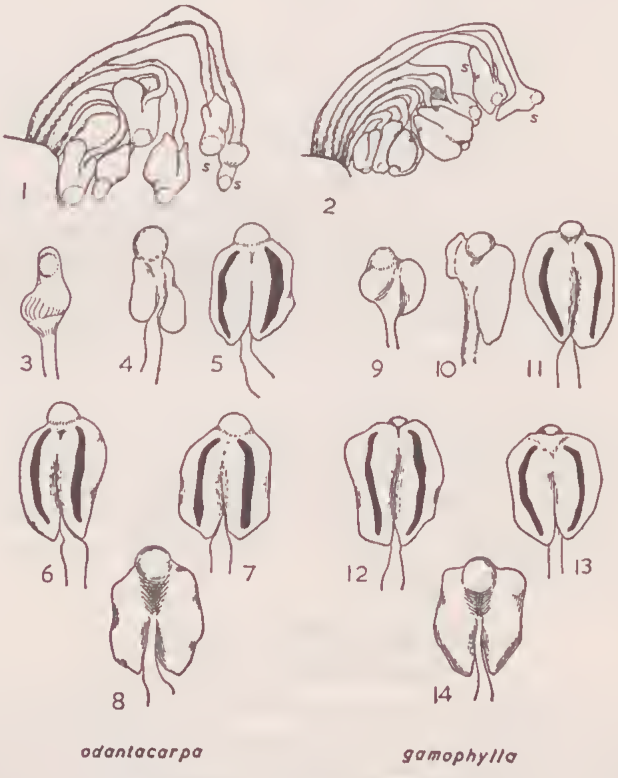

FIG. 1—Drawings 1 and 2 represent the arrangement of staminodia (s) and stamens as seen in a radial section through the staminophore (1) of *E. odontocarpa* (2) of *E. gamophylla*. Drawings 3-7 are of the adaxial surfaces of staminodia (3, 4) and stamens (5-7) of *E. odontocarpa* in the centripetal order in which they are inserted on the staminophore. Drawing 8 is of the abaxial surface of one of the stamens. Drawings 9-13 are of the staminodia (9, 10) and stamens (11-13) of *E. gamophylla* in their centripetal order and 14 shows the abaxial surface of one of the stamens.

staminophore and external staminodes (Fig. 1). In the central flower of each unit inflorescence the ovules are in 2 or 3 rows and the ovulodes in 4 rows (Pl. XXXIX, fig. 2). In the flowers of the second order of branching in the unit inflorescence the ovules are in 2 rows and the ovulodes in 3 rows (Pl. XXXIX, fig. 3, 4). In both species the inflorescence is acrotonic and the annual shoot is commonly terminated by a unit inflorescence. The unit inflorescences are 3-flowered and occur (a) in the axils of leaves or prophylls on, and terminating, short axillary shoots and (b) in the axils of leaves or prophylls on the long annual shoot. The inflorescences are frequently paired in the axils of the long shoot. Both inflorescences of a pair may be simple, as in the type, but in the uppermost axils the more adaxial inflorescence may be compound. The more abaxial inflorescence of a pair is always simple.

In their extreme forms the fruits of *E. gamophylla* and *E. odontocarpa* appear readily distinguishable. The fruits of *E. gamophylla* are 'truncate—or cylindrical-ovate, not angular, the thin edge around the orifice turned slightly inward; valves 3, less frequently 4, very short, inserted not far below the orifice, quite enclosed' (Mueller 1879-1884). To this may be added: the sepals occur as small knobs close to the opercular scar and occupy the high points of the slightly undulate orifice. In *E. odontocarpa* the fruits are of the same order of size as those of *E. gamophylla* and have usually 3 loculi. The valves are similar to those of *E. gamophylla.* Two extreme forms of fruit may be recognized (Pl. XXXVIII, fig. 3, 4, 5). In the first, the sepals are prominent and the orifice is the broadest part of the fruit. In longitudinal section the fruit is campanulate and in cross-section, almost quadrangular. In the second type the sepals are very small and the orifice of the fruit is constricted. In longitudinal section the fruit is truncate-ovate. The cross-section is circular. The two types of fruit are linked by a series of intermediate forms which show variation in the size of the sepals, the constriction of the orifice and the angularity of the fruit. In many of the intermediates the fruit shape is truncate-cylindrical. From the foregoing it will be obvious that the fruits of *E. gamophylla* fall within the range of variation of those of *E. odontocarpa.* Much of the variation in the shape of the fruits of both species appears to depend on the size of the sepals. If the sepals are large and coarse, the orifice is the broadest part of the fruit and the longitudinal ridges below the sepals tend to be prominent and persistent. If, on the other hand, the sepals are small and/or narrow, the orifice of the fruit tends to be constricted and the shape of the fruit to be truncate-ovate. If any longitudinal ridges are then apparent, they are very obscure. The observed variation in the two species is of two kinds, viz. that between collections (different trees or localities) and that between individual flowers of the same unit inflorescence. The pattern of variation within the unit inflorescence is commonly as follows: the median sepals (1) of the central flower are larger than the lateral sepals (2); in the flowers of the second order of branching the lateral sepals (3) are larger than the median sepals (4). The order of sepal size within the unit inflorescence is commonly $(1) \geqslant (3) > (2) \geqslant (4)$. In cases where the sepals are minute, the posterior sepals of the flowers of the second order may be either very obscure or apparently lacking in fruit.

The published descriptions referred to earlier suggest that *E. odontocarpa* and *E. gamophylla* could be distinguished from one another on the basis of the adult foliage. On examination, however, the leaf spectra of the two species show many resemblances. The cotyledons in both are of the type described as reniform and are succeeded by many pairs of leaves which are opposite, sessile and rounded at the base. These in turn are succeeded by leaves which are similar to the earlier ones except that they are perfoliate. In *E. odontocarpa* the juvenile leaves are green when mature (S. T. Blake in litt.). The juvenile leaves of *E. gamophylla* are glaucous in most instances but seedlings with green leaves are known to occur (T. R. N. Lothian in litt.). The leaves of the next stage of growth in both species are glaucous, opposite, broadly-lanceolate and perfoliate. These leaves form the bulk of the 'adult' foliage in *E. gamophylla* and are the 'intermediate' foliage of *E. odontocarpa*. In *E. gamophylla* some of the leaves of the distal portion of the annual shoot may be simply sessile (Mueller 1879-1884) or even shortly-stalked (Black 1943-57; Cameron Herbarium 288/3). Mueller (ibid.) also records that, in some specimens the 'whitish bloom is almost entirely wanting, though neither leaves nor panicles become ever shining'. In *E. odontocarpa* distinct adult foliage succeeds the intermediate leaves. The first adult leaves are opposite, sessile or shortly-stalked, but later leaves are petiolate, linear-lanceolate and shining green when fresh. Towards the distal part of the annual shoot intranodes may develop, resulting in the separation of the members of the leaf pairs (Carr and Carr 1959a).

These comparisons show that the differences between *E. gamophylla* and *E. odontocarpa* are very small or non-existent. Difficulties have been encountered in discriminating between the two in the field. A specimen at Kew (Lazarides 6257) labelled *E. odontocarpa* (identified by N. Forde) is from a plant which, according to the collector's notes has 'connate, mostly glaucous leaves'. The fruits are a perfect match for those of most collections of *E. gamophylla* except that the sepals are unusually long. The leaves are much larger than those of any specimens of *E. gamophylla* which we have seen. The collector's notes also state that *E. gamophylla* occurs in the same area.

A final decision on the relationship between the two species can only be reached after further investigation in the field and from observation of the behaviour of plants in cultivation, but from the evidence of herbarium specimens it is obvious that *E. odontocarpa* and *E. gamophylla* must be very closely related, if not identical. They may be cline forms of a single species, or *E. gamophylla* may be a form of *E. odontocarpa* which flowers precociously or it may be a form of *E. odontocarpa* with persistently juvenile foliage. Such forms are known in other eucalypt species.

In *E. cloeziana* the perianth is single (Pl. XLI, fig. 3, 4) and the seed coat resembles in structure that of members of the Renantherae. The demonstration that the perianth is single depends on the availability of really critical material. Mature buds have only a single perianth whorl and are without an opercular scar, but experience with such species as *E. lehmanni* (Schau.) Benth. (*Symphyomyrtus lehmannii* Schau.) and *E. macrocarpa* Hook. (to be included in *Symphyomyrtus*) has shown that examination of mature flower-buds does not always give reliable evidence. Only by an examination of very young flower buds can one demonstrate conclusively that the perianth is single throughout its development. The whole outer cuticle of somewhat older (but still small) flower-buds of *E. cloeziana* shows a misleading tendency to crack into scurfy fragments which may be mistaken for the remains of an outer perianth whorl.

The seeds have a shape described by Grose and Zimmer (1958) and by Gauba and Pryor (1958) as characteristic of renantherous species (*Eucalyptus* s.s.). The micropyle and hilum are close together on the small basal facet of the seed. In addition, the vascular strands of the raphe are long and much-branched, as described by Gauba and Pryor (loc. cit.) for members of Renantherae. The seed coat is a double structure of which the outer layer is formed by the outer integument. The outermost cell layer is heavily lignified and contains very little tannin. In this feature it resembles *E. acmenioides* Schau, and *E. umbra* ssp. *carnea* (R. T. Baker) L.

Johnson (Johnson 1962), but its seeds are much paler than those of either of those species.

The inflorescence, as in the majority of members of *Eucalyptus* s.s., is acrotonic. The cotyledons are reniform and the primary leaves bear stellate hairs, a character shown by many species of *Eucalyptus* s.s. but by few species of *Symphyomyrtus*. The spectrum of characters of *E. cloeziana* is unusually wide, compared with that of other species of *Eucalyptus* s.s. Some characters are of a kind normally associated with the more advanced members of the genus. For instance, the trees are tall (120-150 ft), the flowers are small and lack sepals, the staminophore is not lobed and the time from initiation of the inflorescence buds to flowering is at least two years (see Carr and Carr 1959a). The ovules are anatropous with a long vascular bundle and resemble those of some members of Section Renantheroideae (Carr and Carr unpublished). In other characters, *E. cloeziana* resembles some members of Series Eudesmieae. The leaves are discolorous and the inflorescences compound. The anther-lobes are parallel, although the dehiscence-slits are convergent at the top (Fig. 2). The ovule-ovulode pattern (Pl. XL, fig. 2) is similar to that of *E. tenuipes* (Maiden and Blakely) Blakely & White (Carr and Carr 1962b). The ovules are confined to the lower part of the placenta and the ovulodes to the upper part. On the broadest part of the placenta the ovules and ovulodes are in 4 or 5 (occasionally 6) longitudinal rows but the ovulodes at the top of the placenta are in two rows.

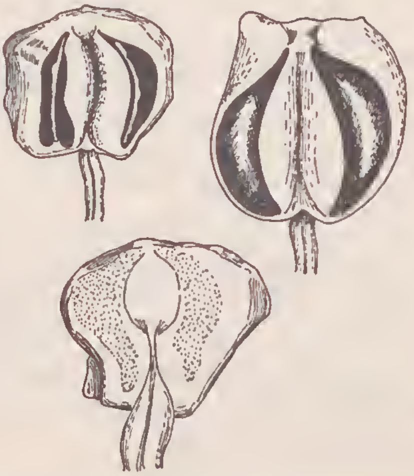

FIG. 2—Stamens of *E. cloeziana*. The upper drawings are of the adaxial surface of representative stamens. The lower drawing shows the abaxial surface of a stamen. The upper left-hand drawing is of an outer stamen, the right-hand one of an inner stamen.

E. cloeziana does not appear to be closely related to any other known species of *Eucalyptus* s.s. In certain characters it is close to Renantherae, in others to the Eudesmieae. The characters of the anthers fall well within the range shown by species of Series Eudesmieae. Although *E. cloeziana* has neither sepals nor a lobed staminophore, neither *E. similis* (as it is described in Blakely and Maiden) nor the members of Series Miniatae have these characters. The strictly anatropous ovules and the ovule-ovulode pattern suggest an affinity with *E. curtisii* Blakely and

White and *E. tenuipes* but in those species the seed characters differ from those of *E. cloeziana*. For the moment, all that can be said is that *E. cloeziana* links the Eudesmieae and the Renantherae. The combination of the characters of these two groups (so widely separated by Maiden and by Blakely) in *E. cloeziana* is important in corroborating the suggestions concerning relationships between species of *Eucalyptus* s.s. put forward in a previous communication (Carr and Carr 1962a).

E. jacksonii Maiden

The transfer of this species from Series Transversae has already been suggested (Carr and Carr 1959a). Its true affinities were recognized by Gardner (1953) who suggested that it should be placed with *E. patens* Benth. and *E. marginata* Sm. Further investigation has shown that this proposal is supported by characters other than those of the perianth. The seed coat is double (Gauba and Pryor 1958) and the ovules and ovulodes are in two longitudinal rows (Carr and Carr 1962b).

E. preissiana Schau.
E. megacarpa F. Muell.
E. mitrata C. A. Gardner

Of these three species which were included by Blakely in the Series Globulares, *E. preissiana* and *E. megacarpa* have already been shown to have a single perianth whorl (Carr and Carr 1959a). Their classification in *Eucalyptus* s.s. is confirmed by seed coat structure (Carr and Carr 1962a) and by the arrangement of the ovules and ovulodes (Carr and Carr 1962b) (Pl. XL, fig. 1). *E. mitrata* is a rare species which is believed to be extinct in its natural habitat (A. J. Gray in litt.) although it is cultivated in western Victoria. Blakely placed it with *E. megacarpa* in a Subseries Glandulares, but Gardner (pers. comm.) suggests that it should be included, together with *E. preissiana* and *E. megacarpa* in a separate Series which he proposes to call 'Megacarpae'. We have recognized its similarities with the other two species but have not been able to satisfy ourselves that the perianth is single throughout its development. The youngest buds available in herbaria have all been found to be cracked at the junction of the hypanthium and operculum. However, the seed coat resembles that of the other two species and the ovules and ovulodes are also arranged in two longitudinal rows (Carr and Carr 1962b). As far as we are aware, this arrangement is exclusive to *Eucalyptus* s.s. The grouping of *E. mitrata* with *E. preissiana* and *E. megacarpa* is therefore justified. For the time being, until the relationships between species within *Eucalyptus* s.s. are fully worked out, it seems best to maintain the group Megacarpae as a unit which might well precede Series Diversiformae in Section Renantheroideae.

E. guilfoylei Maiden (Series Ochroxylon)
E. microcorys F. Muell. (Series Steatoxylon)
E. raveretiana F. Muell. } (Series Myrtiformes)
E. deglupta Blume
E. brachyandra F. Muell.

Series Myrtiformes, as set out by Blakely, includes four species and one variety. We have seen no material of *E. schlechteri* Diels. nor of *E. raveretiana* var. *jerichoensis* Domin. but Blake considers that the former is conspecific with *E. deglupta*. He has shown that *E. raveretiana* var. *jerichoensis* is *E. microtheca* F. Muell. It is convenient to consider the remaining species (*E. deglupta*, *E. ravere-*

tiana and *E. brachyandra*) together with *E. microcorys* and *E. guilfoylei* as they are all obviously wrongly placed by Blakely in his Section Renantherae.

The seeds have been examined by Gauba and Pryor (1958) who found that they differ considerably in form and structure from those of the remainder of the Renantherae. In all five species the seed coat is a single structure, whereas in the rest of the Renantherae the seed coat is a double structure. In all five species the perianth is double and the calyx is caducous. Unopened buds have a prominent scar marking the line of abscission of the calyx. This is shown for *E. raveretiana* in Pl. XXXVII, fig. 6, which also shows the remains of the calyx attached to the tip of the inner operculum. The same feature in *E. guilfoylei* has been illustrated previously (Carr and Carr 1959) and for *E. brachyandra* the illustrations in Maiden (Vol. 3 Pl. 127) and Gardner (1960) may be consulted. As in the other species, the sepaline operculum is abscised very early in the development of the flower bud in *E. microcorys* and *E. deglupta*. It is therefore clear that all five species belong in *Symphyomyrtus*.

Acknowledgements

We wish to thank Mr R. D. Royce, Curator of the State Herbarium of Western Australia, for a gift of material of *E. lirata* and for much useful information; Mr Selwyn Everist, Government Botanist, Brisbane, for information and for material of *E. cloeziana*; Sir George Taylor, Director, Royal Botanic Gardens, Kew, for allowing us access to the collections there and for permission to publish fig. 1 and 2 of Pl. XLI.

The work was supported by a grant-in-aid to S.G.M.C. by the Royal Society; Mrs Carr is also the holder of a Leverhulme Research Fellowship.

References

BLACK, J. M., 1943-1957. *Flora of South Australia*. Government Printer, Adelaide.

BLAKE, S. T., 1953. Studies on Northern Australian species of *Eucalyptus*. *Aust. J. Bot.* 1: 185-352.

BLAKELEY, W. F., 1934. *A Key to the Eucalypts*. Workers' Press, Sydney.

————, 1955. *A Key to the Eucalypts*. 2nd Edition, Canberra.

CARR, D. J., and CARR, S. G. M., 1959a. Developmental morphology of the floral organs of *Eucalyptus*. I. The inflorescence. *Aust. J. Bot.* 7: 109-141.

————, ————, 1959b. Floral morphology and the taxonomy of *Eucalyptus*. *Nature, London*. 184: 1549-1552.

————, ————, 1962a. Natural groups within the genus *Eucalyptus* in *The Evolution of Living Organisms*, Ed. Leeper, p. 426-425. Melbourne.

CARR, S. G. M., and CARR, D. J., 1962b. Convergence and progression in *Eucalyptus* and *Symphyomyrtus*. *Nature, London*. 196: 969-972.

GARDNER, C. A., 1953. *Trees of Western Australia*. Leaflet 2064. Dept of Agric. Western Australia.

————, 1954. *Trees of Western Australia*. Bulletin 2195. Dept of Agric. Western Australia.

————, 1960. *Trees of Western Australia*. Bulletin 2724. Dept of Agric. Western Australia.

GAUBA, E., and PRYOR, L. D., 1958. Seed coat anatomy and taxonomy in *Eucalyptus*. 1. *Proc. Linn. Soc. N.S.W.* 83: 20-31.

————, ————, 1959. Seed coat anatomy and taxonomy in *Eucalyptus*. 2. *Proc. Linn. Soc. N.S.W.* 84: 278-291.

————, ————, 1961. Seed coat anatomy and taxonomy in *Eucalyptus*. 3. *Proc. Linn. Soc. N.S.W.* 86: 96-111.

GROSE, R. J., and ZIMMER, W. J., 1958. A description of the seeds of 70 Victorian eucalypts. *For. Comm. Vic. Bull.* 8.

JOHNSON, L. A. S., 1962. Studies in the Taxonomy of *Eucalyptus*. *Contributions N.S.W. Nat. Herb.* 3: 103-126.

MAIDEN, J. H., 1909-1928. *A Critical Revision of the Genus* Eucalyptus. Government Printer, Sydney.

Mueller, F., 1878. *Fragmenta phytographiae Australieae*. XI: 40.
————, 1879-1884. *Eucalyptographia*. A descriptive atlas of the eucalypts of Australia and the adjoining islands. Government Printer, Melbourne.

Explanation of Plates

Plate XXXVII

Fig. 1-5—*E. lirata*. (1) young flower bud with outer operculum still present and covering the bud. (2) young flower bud which has just lost the outer operculum (both x 10). (3) Fruit (x 10) to show the unlobed staminophore. (4) Seed (slightly immature); M, micropyle; H, hilum (with the chalaza to the right) (x 25). (5) Mature flower bud, showing the prominent opercular scar (x 9).

Fig. 6—*E. raveretiana*, showing the prominent opercular scar and a fragment of the outer operculum (O) at the tip of the inner one (x 25).

Plate XXXVIII

Fig. 1—*E. gamophylla*. Young unit inflorescence showing the prominent sepals and the abscission scars of the two bracts (x 15).

Fig. 2—Fruit of *E. gamophylla* to show the persistence of the sepals (arrow) and the undulate orifice (x 12·5).

Fig. 3, 4 and 5—Fruits of *E. odontocarpa*, showing extremes of fruit shape. 3, 4, fruits with large sepals; 5, fruits with small sepals (x 4).

Plate XXXIX

Dissections showing the ovules and ovulodes *in situ* on the placenta of (1) *E. lirata* (x 34), (2) *E. gamophylla* (x 45), (3) *E. odontocarpa* (x 39), and (4) *E. gamophylla* (x 38). (2) is from the central flower of a unit inflorescence. (3) and (4) are from lateral flowers of unit inflorescences, and illustrate the close similarity of ovule-ovulode arrangement in the two species. The ovules are shaded in the explanatory outlines on the interleaf.

Plate XL

Fig. 1—Dissection of *E. megacarpa*, showing the ovules and ovulodes *in situ* on the placenta. The ovulodes (the smaller dark structures at the top) and ovules are in two longitudinal rows (x 35).

Fig. 2—Dissection of *E. cloeziana*. Ovules in 6 longitudinal rows and 3-4 transverse rows. The only ovulodes shown are the two structures at the top of the placenta. Another transverse row of 2 ovulodes is hidden by the curve of the placenta (x 48).

Plate XLI

Fig. 1—Immature fruit of '*E. similis*' (collected at Springvale by Mrs Clemens—see text), showing persistent sepals (arrows) and lobed staminophore (x 8) (Kew negative 5584).

Fig. 2—Fruit of *E. baileyana* from Mueller's type material at Kew, showing lobed staminophore (arrows) and absence of sepals (x 8) (Kew negative 5585).

Fig. 3—*E. cloeziana*. Longitudinal section of very young flower bud to show the single operculum (x 40).

Fig. 4—An enlargement of the same, showing that the cuticle is continuous over the junction between the operculum and the hypanthium (x 85).


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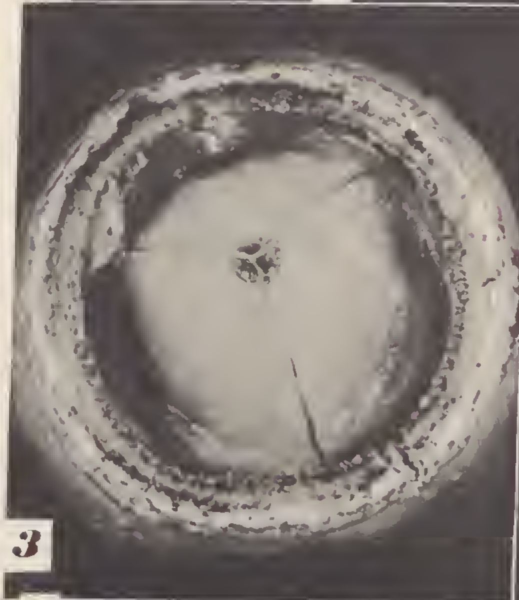
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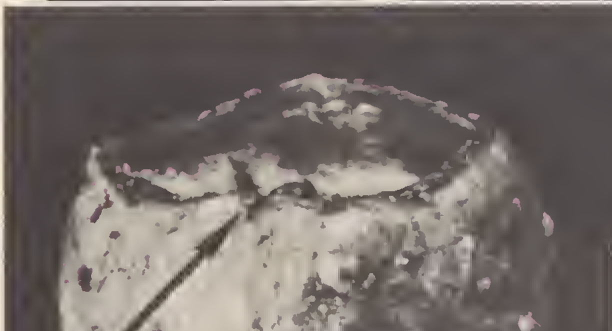

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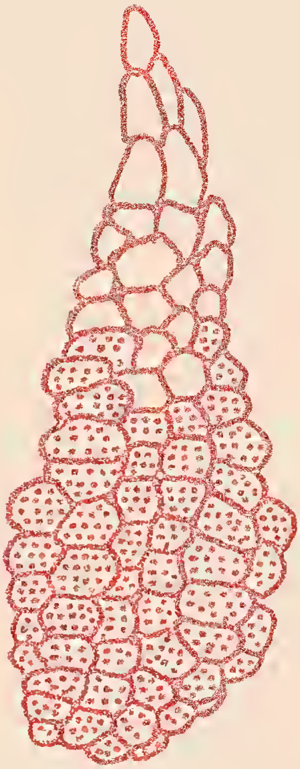

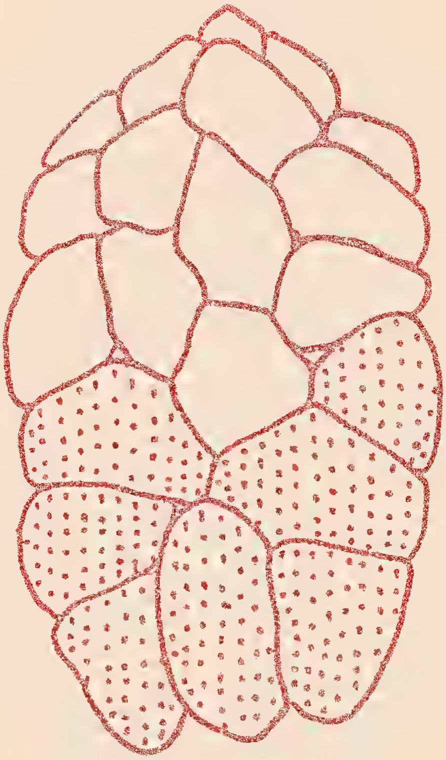

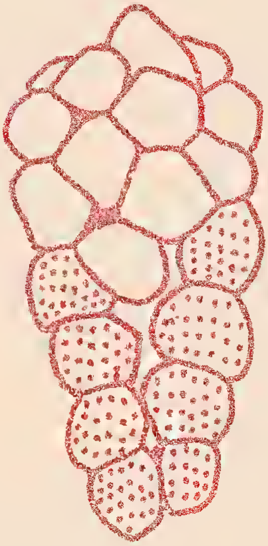

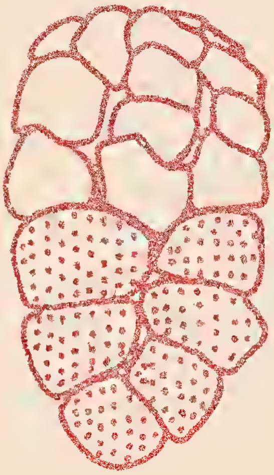

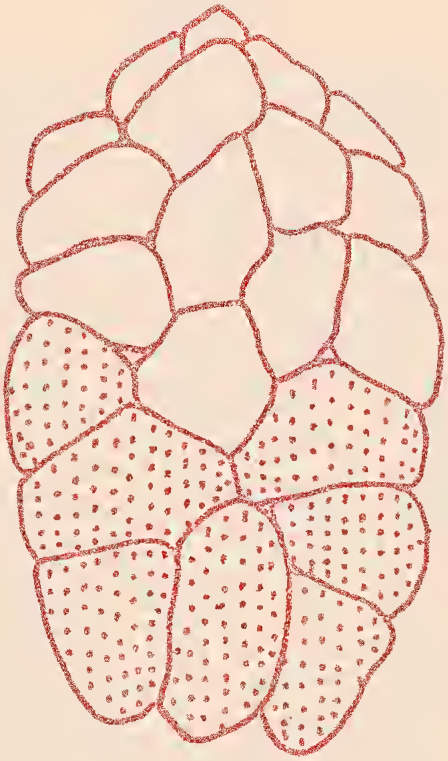

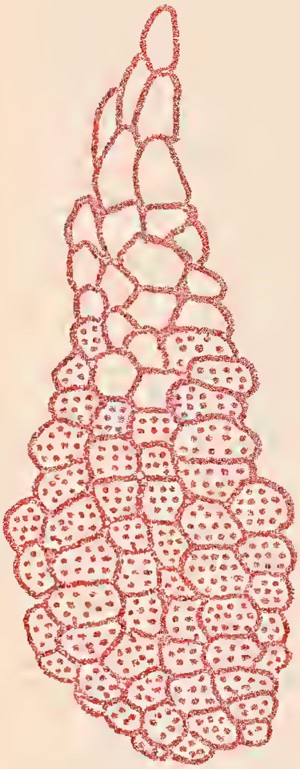

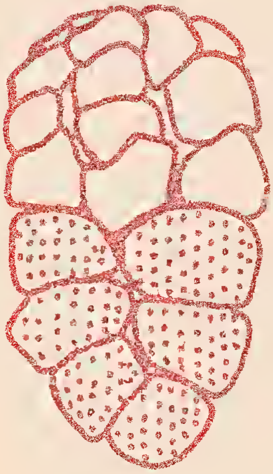

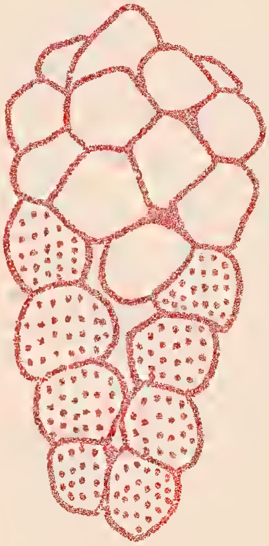

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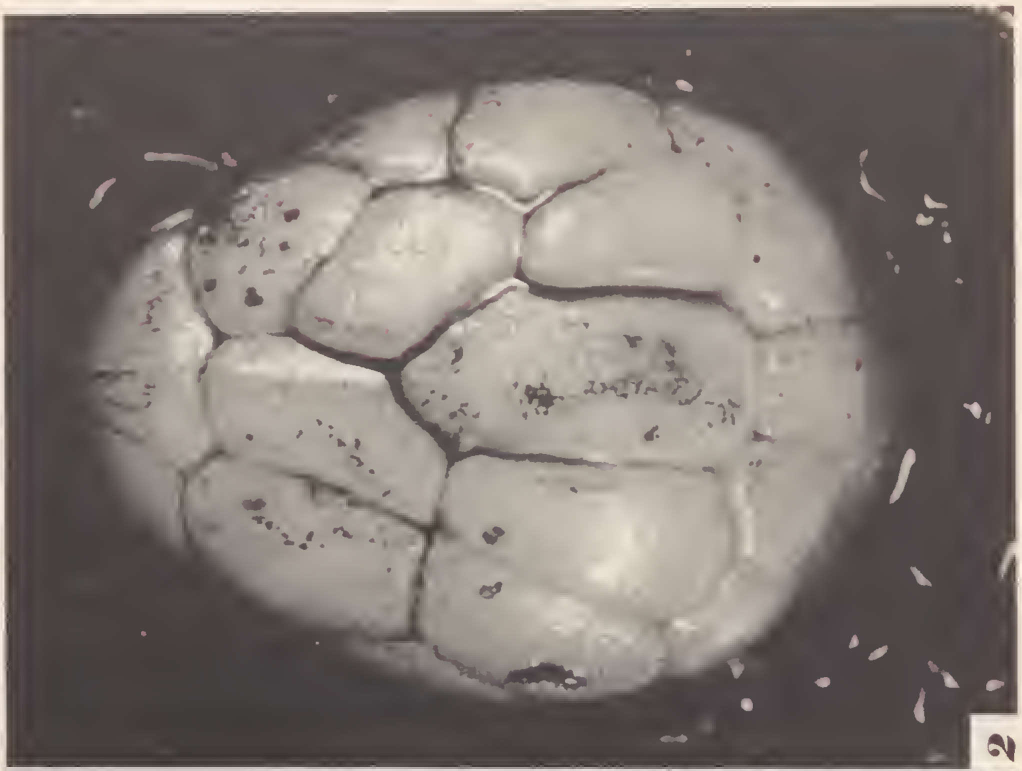

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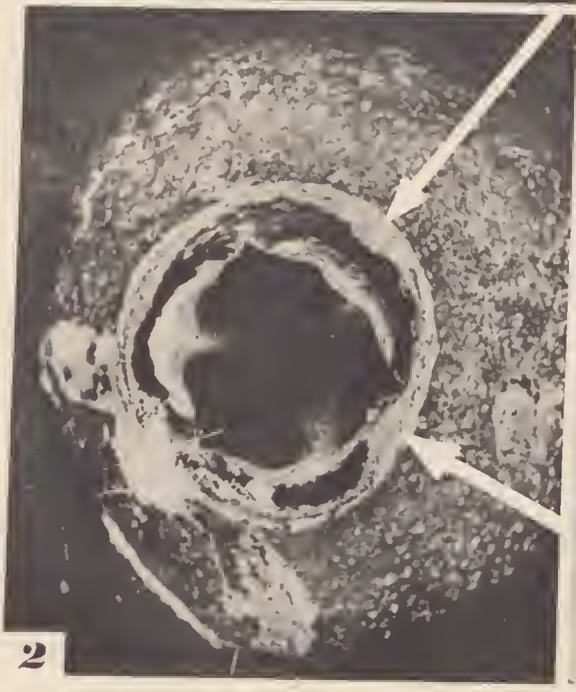

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A PRELIMINARY ACCOUNT OF THE HERPETOLOGY OF THE GREAT SANDY DESERT OF CENTRAL WESTERN AUSTRALIA

Reptiles and Amphibians of the Bindibu Expedition

By Donald F. Thomson and William Hosmer
Department of Anthropology, University of Melbourne

Although central Australia, formerly the Northern Territory of South Australia, has received the attention of numerous scientific expeditions, both zoological and anthropological, most of this work has been carried out in the country northward from Oodnadatta to the region of Alice Springs, and particularly in the MacDonnell Ra. The MacDonnell Ra., renowned in scientific literature as the home of the Arunta tribe, extend for more than 350 miles in an E.-W. direction and form an elevated 'island' some 3,000 ft above the surrounding desert, and rise to 5,000 ft above sea level. This is predominantly a broken and rugged terrain, outcropping with rocks and boulders, but has an abundant water supply in soaks and deep rockholes and formerly supported a rich fauna, including many interesting mammals and reptiles and a relatively dense population of aborigines.

The first and most notable scientific investigation of this country was carried out by the Horn Expedition in 1894. This expedition, staffed by a group of carefully chosen workers, included Professor (later Sir) Baldwin Spencer as zoologist, and Dr E. C. Stirling, a physiologist of Adelaide University as anthropologist, and in the course of a few months of concentrated work, achieved remarkable results.

The discoveries of the Horn Expedition, both zoological and anthropological, focussed scientific interest on C. Australia, but this was centered largely on the country around Alice Springs and the territory that Finlayson, who collected mammals extensively there, knew so well and described graphically as the 'Luritja' country—a collective name loosely used for the virile tribes of the Musgrave and Petermann Ra.

But meanwhile, the vast expanse of spinifex and sand hills that stretches N. and W. of L. Mackay on the Northern Territory/Western Australian border was neglected by scientific workers. This desert and semi-desert country, extending westward for upwards of 700 or 800 miles to the Oakover R. on the NW. coast of Western Australia, was first crossed by Col. Warburton in 1872-3 and named by him the Great Sandy Desert.

Giles made several journeys into this area in the period 1872-76, and 20 years later, in 1896-7 David Carnegie, an Englishman engaged in prospecting on the Western Australian goldfields, made an extraordinary journey with camels and horses. Carnegie's journey was an epic of courage and endurance, for his party traversed both the Gibson and Great Sandy Deserts, travelling northwards across the sandhills which run E. and W. in long parallel lines for hundreds of miles. He reached Hall's Ck in the Kimberleys and returned S. on a course parallel to his route on the northward journey, in the following year. But, apart from journeys of these explorers and brief visits from one or two venturesome prospectors who travelled with camels, the area remained largely unknown and unexplored. Most recent of these visitors was Michael Terry in 1933.

On account of the low annual rainfall and lack of any surface water to sustain grass other than the rank, fibrous and indigestible *Triodia*, it is unfit for cattle. This country has never been stocked, and so it remains today in a virgin state. Except for a few rockholes there is almost no accessible permanent water in hundreds of square miles. Even camels cannot subsist in this territory unless watered at native wells, as shown by the journals of Warburton, Carnegie and Giles. The dependence of these explorers on the aborigines led to serious interference with, and cruelty to, the natives and by depleting their meagre water supply, antagonized them. It is not possible to maintain a string of camels in this desert, apart from the Canning Stock Route, now abandoned, where wells and bores were established.

In recent years, the W. end of this great no-man's land, distinguished as the Canning Basin, has been thoroughly mapped by the Bureau of Mineral Resources, staffed chiefly by geologists. But up to 1957 no account of the fauna or flora of the sand dune country of the Great Sandy Desert had been published and no systematic study of the ecology of the virgin desert country had been made.

In 1957, following reports of nomadic aborigines still living in the arid regions N. of L. Mackay, a party was organized, consisting at the outset of three men—Dr Donald F. Thomson, organizer and leader; William Hosmer, technical assistant and wireless operator; and W. McColl, driver and general assistant—sponsored by the Royal Geographical Society and the University of Melbourne, and backed by Australian Consolidated Press. The narrative of this expedition, on which we penetrated to a distance of 600 miles W. of Alice Springs, is told in *The Geographical Journal.*

Although specimens were collected whenever possible throughout the expedition, the principal collecting camps were: the neighbourhood of Mt Doreen and Mt Singleton (some 220-230 miles NW. of Alice Springs); Kimai Well; Waimbirr'ngi Bluff; Labbi Labbi Rockhole; and Wirrarigulong. The route finally adopted as the

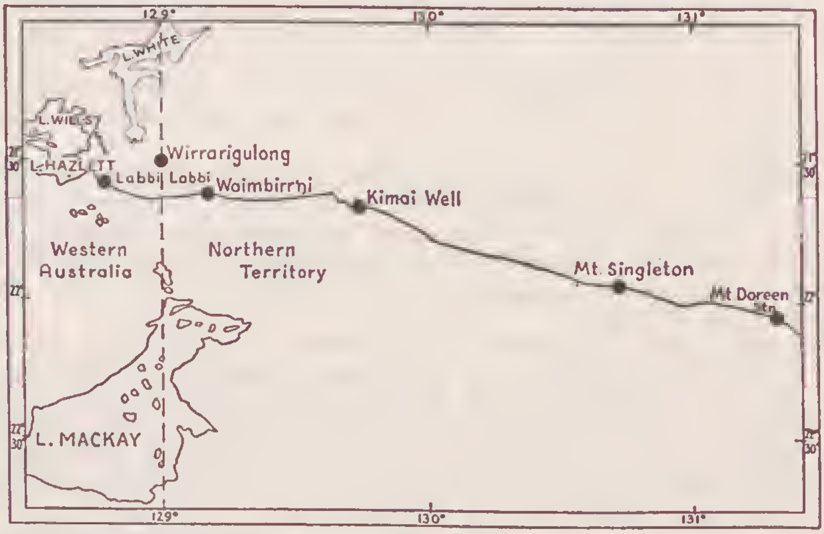

FIG. 1—Route of western reconnaissance from Mt Doreen Station (225 miles NE. of Alice Springs) to establish a depot. Labbi Labbi Rockhole, 5 miles SE. of L. Hazlett, was discovered; it provided permanent water and was selected as the site for an air drop by the R.A.A.F. Chief collecting stations are also shown on this map.

best approach to Labbi Labbi, where the forward base was established, is shown on the map (Fig. 1). A brief account of the terrain and of the associated flora in each of these areas is set out below.

The neighbourhood of Mt Doreen and the territory westward to Mt Singleton, a distance of about 60 miles, is well watered with an average annual rainfall of 10·66 inches. The country is undulating, often outcropping with rocks and boulders, and comprises savannah woodland with small patches of mulga (*Acacia aneura*). In normal seasons it is well grassed, with comparatively little spinifex (*Triodia* spp.) and is considered good cattle country. The vegetation of this area, as might be expected, is much less strongly xerophilous than in the desert farther west. Trees of this area are Eucalyptus—chiefly bloodwoods, including *E. dichromophloia* and *E. papuana*, the latter well known in C. Australia as the Ghost Gum—with numerous acacias, Grevillea and Hakea, which become dominant further W.

A short distance W. of Mt Singleton, the country becomes broken, with rock outcropping, and beyond this is a belt of dense, low, quite old mulga, after which the country changes abruptly to semi-desert with sandy plains covered with dense spinifex in place of edible grasses, which acts as an effective sand binder and restricts wind erosion. This semi-desert area showed unmistakable signs of a long drought. The spinifex was bleached a pale yellow, almost white, from long exposure to the pitiless sun and had become brittle. Isolated beefwood (Grevillea) low and gnarled, and desert oaks (*Casuarina decaisneana*) solitary or in small clumps, were noted and provided relief from the bare sand. A change was noticed at once in the character of the fauna. For several days almost no sign of life was marked—no kangaroos, wallabies or emus, nor the howl of a dingo at night. Birds were rarely heard but a few, chiefly small honeyeaters, were seen in spinifex or low undergrowth. These birds with their brushed tongues are able, no doubt, to adapt themselves to long drought and the arid conditions of desert terrain.

As Kimai Well, about 80 miles W. of Mt Singleton, was approached, bloodwoods—more dwarf and of less luxuriant habit than in the vicinity of Mt Doreen—became more frequent, singly or in small clumps on low ground below the dunes or on rocky outcrops. Desert oaks were also seen, sometimes in stands of an acre or more in extent. These trees, with their thick rough back, are extremely sensitive to fire and when the dry spinifex, impregnated with resin, burns, the she-oaks die for they do not regenerate like most of the typical trees and shrubs of the desert, most of which are of dwarf habit and have the capacity, after a spinifex fire, to send up shoots from a thick fleshy rootstock, situated often several feet below the surface. When the desert oak dies the thick, cork-like bark shrinks away from the cambium and hangs loosely, providing refuge for lizards, notably certain species of gecko and the small and attractive Lace Lizard or 'goanna' (*Varanus gilleni*) which we found in numbers in this region, always under the loose bark of dead Casuarina trees.

Two species of tea-trees, *Melaleuca lasiandra* and *M. glomerata*, were noted in the desert, sometimes growing separately, sometimes in association. These two shrubs, low, stunted, of strongly xerophilous character, were often intermingled with dwarf-growing Mallee eucalypts, especially *E. pachyphylla*, as well as with many species of Grevillea, Hakea and many acacias (Pl. XLIII, fig. 1). Mulga is often regarded as characteristic of the arid interior. It was plentiful in isolated patches in semi-desert, but rarely seen in the true desert except for small clumps which were noticed occasionally above rocky outcrops—which, after rain, dammed seepage water and left soaks—and sometimes in low troughs or depressions where rain water concentrates and the sand is intermingled with silt.

Close to Kimai the long drought broke, and a deluge of rain fell, and continued for two or three days. The effect of this rain on animals, especially lizards and small rodents, was immediately noticeable, and the vegetation also responded unbelievably.

Kimai is in the territory of the Walberi tribe—members of which are now gathered into Yuendemu and other Government Stations—but is today a hunting ground of the desert Bindibu. There is a permanent well at Kimai, 7 or 8 ft deep in sandstone rocks laid down in horizontal strata, from the seams of which water from springs seeps to maintain the level in the well. This well lies in a shallow basin or trough, roughly circular in outline and 200-300 ft across, the perimeter a sandy ridge or outcrops of limestone rock. Inside this basin are dense clumps of tea-tree, chiefly *M. glomerata*. This shrub with its 'bottle-brush' flowers attracts many insects, which no doubt provide food for the lizards that find refuge in its shade.

From Kimai Well to Waimbirr'ngi Bluff, about 45 miles W. and close to the Western Australian border, the terrain becomes more arid and gives way to true desert of red sand covered with spinifex. At Waimbirr'ngi a great outcrop of rock with large boulders rises on a bluff from which we named the camp (Pl. XLII, fig. 2). A well, fed by seepage from springs among the rocks, lies at the foot of the rocky headland, still in the territory of the Walberi tribe, and a favourite camping place of the nomadic Bindibu. Very primitive camps, noted under low shrubs close to the well showed signs of recent occupation and proved that nomadic aborigines still hunted far out in the desert. It was the detailed examination of the bones at these camp fires that gave an idea of the animal food on which these people were depending. The surrounding area was typical sandy desert terrain, rough and hummocky, covered with dense clumps of spinifex. Westward, tiers of low red sand hills in parallel lines extend like the prongs of a giant fork.

About 30 miles W. of Waimbirr'ngi, across the Western Australian border, lies the high escarpment above Red Cliff Pound, outcropping with bare, deep red rocks. From the top of these cliffs we looked across the Pound and the sunken valley beyond, encircled by low hills, to L. Hazlett, Wills and White—a bleak pale blue, or dazzling white with salt—lying 5 or 6 miles away. Above the Pound we found the fine deep rockhole, called Labbi Labbi by the natives, which was to form our base camp and most important collecting site (Pl. XLIII, fig. 2). Labbi Labbi consisted of a large rockhole in a creek bed on the fringe of the escarpment, below which were a series of smaller pools. The escarpment was rough and broken, and the outer slopes were sparsely clothed with gnarled, stunted shrubs, chiefly Grevillea. Conspicuous among these were *G. agrifolia* with its coral-red flowers, and numerous dwarf acacias, especially *Acacia monticola*, the reddish-brown bark hanging in tassel-like strips, its foliage a delicate fresh green despite its barren habitat on the rock face. Among the rocks were several species of *Solanum* with mauve or purple flowers and a number of Cassias, including *C. pruinosa* and *C. desolata*. Close to the dry water courses that wound through Hidden Valley, were found such forms as *C. notabilis* and *C. venusta*, with yellow flowers standing out against the red laterite rocks. The pound or amphitheatre was a haven, sheltered from the bitter winds of the desert, and here some interesting reptiles were collected.

Wirrarrigulong, a great shallow clay pan covering 10-15 acres in low-lying land between sand dunes about 20 miles NE. of Labbi Labbi, was discovered on a hunting expedition with the desert Bindibu, and formed one of the most interesting collecting camps in the desert. This low basin between the dunes was impregnated by a deep deposit of fine red clay. After a fall of 2 to 3 inches of rain, followed by an even heavier downpour about four weeks later, it filled with water. This clay pan, one of the most spectacular but least reliable sources of water in the desert, carried water a foot or two in depth, coloured red from the fine particles of colloidal clay in suspension. After a short time, exposed to the intense heat of the sun, the clay pan began to dry up rapidly and within the space of a few days, in which collecting was carried out, it became undrinkable on account of the concentration of clay in suspension.

But for a few weeks Wirrarigulong was transformed and animals that we had not seen in hundreds of miles of travel in the desert suddenly appeared—emus (*Dromaius novae-hollandiae*), Red Kangaroo (*Megaleia rufa*) and even wild duck —and the vegetation in the area was almost luxuriant compared with the surrounding desert.

At each of these watering places the Bindibu who accompanied us hunted relentlessly, so that in competition with the people, who were our chief concern, we were handicapped since the natives of the desert consider almost all lizards as game, including the small and rough-skinned agamids which in less arid areas are not considered as food by the aborigines.

A total of 169 reptiles and amphibians were secured; of this number only 5 were snakes. A list of species collected on this expedition, with brief descriptions and notes, is set out below.

LACERTILIA

Family GEKKONIDAE

Genus **Nephrurus**

Nephrurus wheeleri Loveridge 1932

Proc. New England Zool. Club 13: 31 (type locality Yandil near Wiluna, W.A.).

MATERIAL EXAMINED: Labbi Labbi (SE. of L. Hazlett) W.A., 1, DFT No. 1275.

DESCRIPTION: The single specimen collected does not differ significantly from the description of the type. The only additions are in measurements. Head width 22·8 mm, head length 25·99 mm giving a width to length ratio of 0·88. Distance eye to naris 7·3 mm, internarial width 5·2 mm, ratio eye-naris to internarial width 1·40. Total length 109 mm. Length, snout to vent only, 92 mm (tail regenerated and truncated in this specimen). Colour after preservation, pale brown above with transverse dark brown bands of which the two across the nape are broadest and most distinct. Ventral surface white.

HABITAT: This bizarre-looking gecko was found under dense spinifex.

DISTRIBUTION: The species was first recorded in Wiluna on the Canning Stock Route in C. Western Australia. It appears, therefore, to be a desert-haunting species.

Genus **Heteronota**

Heteronota binoei Gray 1845

Cat. Liz. Brit. Mus. 174 (type locality Houtman's Abrolhos, W.A.).

MATERIAL EXAMINED: Mt Doreen Station, N.T., 19, DFT No. 1317-1335.

DESCRIPTION: The dorsal tubercles are arranged in 13 or 14 longitudinal rows, except in one individual (DFT No. 1335) on which they are irregularly disposed in 18 rows. This latter example agrees well with the description of *Heteronota derbiana*

(Gray), whereas the series having 13 to 14 rows of tubercles fit the description of *H. binoei* given by Boulenger (1885, p. 74). Lucas & Frost (1896, p. 120) have advanced reasons for regarding *H. derbiana* as synonymous with *H. binoei*, but after examination of this series, we are inclined to question this. Colour after preservation of the typical *H. binoei* is brown above, with distinct broad yellow crossbands, of which there are 5 on the body and 8 on the tail. *H. derbiana* form is brown above with small irregular dark brown and pale brown mottling.

HABITAT: The banded series were all taken under loose stones on a rocky hillside, but the unbanded example (DFT No. 1335) was collected under a fallen tree in open sandy country.

DISTRIBUTION: The species is widely distributed and occurs in all mainland states, but is apparently absent from the colder parts of N.S.W. and Victoria.

Genus **Peropus**

Peropus variegatus (Dumeril & Bibron)

Hemidactylus variegatus Dumeril & Bibron 1836, *Erpet. Gen.* 3: 353 (type locality Tasmania and Bay of the Chiens Marins, W.A.).

MATERIAL EXAMINED: Mt Doreen Station, N.T. 18, DFT No. 1350-1367; Labbi Labbi, W.A., 14, DFT No. 1368-1381.

DESCRIPTION: The head is longer than broad, measurements of heads of 6 adult specimens show a mean length to breadth ratio of 1·2. On account of variability of these measurements the following note is added: Measurements of head length are taken from anterior margin of ear to tip of snout; breadth at widest part of head; snout from anterior margin of eye to tip of snout. Male specimens possess from 8 to 13 preanal pores; these are absent in females. The lamellae are completely divided, inner digits are clawless. The largest specimen (DFT No. 1354)—total length 101 mm, tail 53 mm, ratio tail length to total length 0·53.

HABITAT: This species inhabits rocky terrain and all specimens taken by the expedition were found under slabs of rock.

DISTRIBUTION: The species ranges across the continent S. of a line connecting Geraldton, W.A., Alice Springs, N.T., and Mackay, Q'ld (Loveridge 1934).

Family AGAMIDAE

Genus **Amphibolurus**

Amphibolurus maculatus gularis Sternfeld 1925

Abh. Senckenb. Naturf. Gesell 38: 231 (type locality Hermannsburg, N.T.).

MATERIAL EXAMINED: Labbi Labbi, W.A., 6, DFT No. 1288-1293.

DESCRIPTION: This race is said to differ from the typical form by the possession of a larger tympanum, being nearly as large as the eye, and its distinctive colouration. Present examples agree in detail with the above description. Mean tympanum to eye ratio for the 6 specimens is 0·90. The male (DFT No. 1288) is characterized by intense black colouration of the under surfaces of tibia and tarsus, and more prominent dorsal pattern than in the females. The male possesses 54 femoral and preanal pores, in a continuous series; these are absent in the females. Loveridge (1934, p. 318) noted a female, gravid, with a tendency towards secondary sexual colouring of males. This is true of 3 of the 5 females in which ventral areas are dusky in precisely the same areas that are black in the male.

HABITAT: This dragon appears to be the most common of the agamids occurring W. of Mt Singleton in the Great Sandy Desert, where it lives under roots of spinifex, burrowing in the sand to a depth of about a foot.

DISTRIBUTION: The centre of distribution appears to be the MacDonnell Ra. region of C. Australia, and the race is widespread in the arid interior.

Amphibolurus caudicinctus (Gunther)

Grammatophora caudicincta Gunther 1844, *Zool. Erebus & Terror. Rept.* 19 (type locality Nickol Bay, W.A.).

MATERIAL EXAMINED: Mt Doreen Station, N.T., 4, DFT No. 1251-1254.

DESCRIPTION: No attempt has been made here to untangle the complex involving the present species and two related forms, *A. imbricatus* Peters and *A. rufescens* Stirling and Zietz. Loveridge (1934, p. 319) indicates the possibility of the two latter species being races of *caudicinctus*. The 4 specimens each possess 22-24 femoral and preanal pores; the ventral scales are smooth, very faintly keeled in one specimen (DFT No. 1254). The tibia length to snout-vent length ratio ranges from 0·30 to 0·32. The dorsal colour after preservation is reddish-brown. The pattern consists of 5 or 6 narrow white cross-bands, between which are 4 round black spots, arranged transversely. The inner 2, placed one each side of the vertebral column, are most conspicuous; the outer spots, situated dorso-laterally, are less distinct. The tail is cross-barred with about 22 narrow white stripes.

HABITAT: This species occurs only in rocky terrain where it hides under slabs of rock. They are difficult to capture alive during the day when they are active, but can be secured easily at night when they are asleep beneath rocks.

DISTRIBUTION: W. and C. Australia.

Amphibolurus reticulatus inermis (De Vis)

Grammatophora inermis De Vis 1888 (1887), *Proc. Linn. Soc. N.S.W.* (2) 2: 812 (type locality central Q'ld.).

MATERIAL EXAMINED: Mt Doreen Station, N.T., 17, DFT No. 1382-1398; Kimai, N.T., 14, DFT No. 1399-1412; Labbi Labbi, W.A., 17, DFT No. 1413-1429.

DESCRIPTION: There does not appear to be any variation in the number of pores possessed by the sexes in these specimens, the males possessing a mean number of 23 femoral and preanal pores (range from 18-27) and females a mean of 22 (range from 15-25) but the pores of the females are less distinct. Largest specimen (DFT No. 1394) total length 247 mm, tail 140 mm, ratio tail length to total length 0·57. Colouring is variable, but usually consists of a network of pale yellowish-brown spots on the dorsal surface of the body, with a narrow mid-dorsal stripe of yellow or pale brown. The tail is usually uniformly brown, but indistinct pale blotches may be present; throat mottled with brown, becoming more intense and distinctly reddish in breeding males.

HABITAT: This desert race is numerous and widespread in the arid sandy regions. It burrows in the sand, often under spinifex, and in this high temperature is extremely agile. The burrow is from 2-3 ft deep. The Bindibu name for this dragon, which forms an important part of their food supply is 'linga'.

DISTRIBUTION: Sandy interior only of S.A., W.A., N.T. and Q'ld.

Amphibolurus barbatus minor Sternfeld 1919

Mitt. Senckenb. Naturf. Gesell 1: 78 (type locality Hermannsburg, MacDonnell Ranges, N.T.).

MATERIAL EXAMINED: Labbi Labbi, W.A., 2, DFT No. 1270 and 1271.

DESCRIPTION: These 2 specimens are a male and female, both sexually mature. The male (DFT No. 1270) possesses 16 femoral and preanal pores; the female has 13 pores. Total length, both specimens, 321 mm but in the male the tail is considerably longer than in the female, ratio tail to total length being 0·71 in the male, 0·65 in the female.

HABITAT: Both lizards were brought into camp by aborigines but no aboriginal name could be given and no information as to circumstances of capture. Note: This is one of the two species of *Amphibolurus* that were collected in the desert which had retained an arboreal habit in spite of the intense heat and arid conditions. It has been regarded by Sternfeld as a small race of *A. barbatus barbatus*, but is now being re-examined.

DISTRIBUTION: C. Australia.

Genus **Tympanocryptis**

Tympanocryptis cephalus Gunther 1867

Ann. Mag. Nat. Hist. (3) 20: 52 (type locality Nickol Bay, W.A.).

MATERIAL EXAMINED: Labbi Labbi, W.A., 6, DFT No. 1299-1304.

DESCRIPTION: Nostril closer to eye than to tip of snout; dorsal scales slightly keeled, those of the occipital region larger and without keels; ventrals smooth, except for scales bordering lower jaw, which are obtusely keeled. Males possess 2 preanal pores, no femoral pores; pores absent in females. Ratio tail to body length in 2 male specimens (DFT No. 1299 and 1300) 1·30 and 1·33; ratio in 3 females varies from 1·01 to 1·22. Ratio, tibial length to body length ranges from 0·19 to 0·22 (mean, 0·204). Largest specimen (male DFT No. 1300) measures 122·7 mm. Colour after preservation pale orange-brown above with 5 broad but indistinct cross-bands, with 12 dark bands separated by almost white interspaces on the tail, throat dark brown in males.

HABITAT: These lizards were found in sandy areas under spinifex.

DISTRIBUTION: Range extends from N. W.A. across N.T. to Q'ld, extending S. in the N.T. to the C. parts of S.A.

Genus **Physignathus**

Physignathus longirostris (Boulenger)

Lophognathus longirostris Boulenger 1883, *Ann. Mag. Nat. Hist.* (5) 12: 225 (type locality Champion Bay and Nickol Bay, W.A.).

MATERIAL EXAMINED: Labbi Labbi, W.A., 2, DFT No. 1272 and 1273.

DESCRIPTION: Nostril nearer to eye than to tip of snout; ratio eye-naris to internarial distance, 0·67 in the male (DFT No. 1272), 0·70 in the female (DFT No. 1273). Scales of the dorsal surface are keeled. A well-defined nuchal crest is present followed by a faint vertebral crest, becoming obscure toward base of tail. Scales of the throat appear smooth, but under a lens prove to be obtusely keeled. Scales of the belly and lower surfaces of tail strongly keeled. There are 79 rows of scales around the centre of the body in both specimens. The female is the larger of the two specimens—total length 393 mm, tail 301 mm, ratio tail to total length 0·77, ratio tibial length to distance of snout to vent is 0·25 in both sexes. Male—total length 260 mm, tail 195 mm, ratio tail to total length 0·75. Colour after preservation is greyish-brown with a white border along the lower jaw, broadening toward the tympanum. A broad stripe of white extends from the neck to the insertion of the hind limbs. Ventral colour in male, pure white; that of the female mottled profusely with brown. The male possesses 17 femoral and 4 preanal pores, the preanal pores in two pairs separated by 8 scales; female without pores.

HABITAT: Both specimens were collected on a sand hill, where they sought refuge in dead hollow limbs of trees.

This species was nowhere numerous, and was very agile and difficult to capture.

DISTRIBUTION: Range extends from N. W.A. through the N.T. and inland S.A. to the drier parts of Q'ld. Distribution appears to be restricted to arid and semi-arid areas especially mulga country.

Genus **Moloch**

Moloch horridus Gray 1841

Grey's Journ. Exped. W. Australia 2: 441 (type locality W.A.).

MATERIAL EXAMINED: Kimai, N.T., 12, DFT No. 1233-1244.

DESCRIPTION: The series is typical of this species. The largest individual, a female (DFT No. 1237) measures 184 mm, tail length 78 mm, ratio tail length to total length 0·42. This remarkable agamid has been well described by Waite (1929).

HABITAT: Specimens were collected by natives in semi-desert country in open spinifex and mulga scrub.

DISTRIBUTION: Arid interior of C. Australia, most of W.A., S.A. and N.T. as far N. as Elliott, and possibly the drier parts of W. Q'ld.

Family VARANIDAE

Genus **Varanus**

Varanus gouldi flavirufus Mertens

(Pl. XLV, fig. 3)

Varanus (Varanus) gouldii flavirufus Mertens 1958, *Senck. Biol.* 39: 250 (type locality Alice Springs, N.T.).

MATERIAL EXAMINED: 4 specimens: Mt Singleton, W.A., 1, DFT No. 1260; Kimai, N.T., 1, DFT No. 1261; Labbi Labbi, W.A., 2, DFT No. 1262 and 1263.

DESCRIPTION: This race differs from the typical form in colour which is predominantly yellow or reddish, the 4 specimens studied agreeing with the type description. The largest is a female (DFT No. 1263) total length 764 mm. The 3 females of the series collected have tail to total length ratio ranging from 0·59 to 0·63, and eye-naris to internarial width ratio from 1·18 to 1·43. The only male (DFT No. 1260) has tail to total length ratio 0·59, eye-naris to internarial width ratio 1·39.

HABITAT: These monitors were captured in semi-arid country, sparsely covered with spinifex and stunted trees. This species is not arboreal and when hunted seeks refuge in burrows in the sand.

Distribution: This lizard inhabits the semi-arid and desert regions of the N.T. and the interior of W.A.

Varanus gilleni Lucas & Frost 1895

(Pl. XLII, fig. 1)

Proc. Roy. Soc. Vict. 7: 266 (type locality between Glen Edith and Deering Ck, also Charlotte Waters, N.T.).

Material Examined: Near Kimai Well, N.T., 3, DFT No. 1255-1257.

Description: A single male (adult—DFT No. 1255) and 2 females (juvenile) were collected. Claws strongly recurved, the fourth finger slightly longer than the third. Ratio, eye-naris to internarial distance in the male is 0·80, in the 2 juveniles 0·81 and 0·86. Total length of male 315 mm, tail length 174 mm, ratio tail to total length 0·55. Tails of the 2 juveniles were incomplete and measurements are not recorded.

Habitat: This pygmy monitor inhabits the semi-desert regions where it is strictly arboreal, living under the loose bark of desert oaks (*C. decaisneana*). The species is docile and inoffensive.

Distribution: Desert and semi-desert of S.A. through C. Australia as far N. as Newcastle Waters, N.T.

Varanus eremius Lucas & Frost 1895

(Pl. XLV, fig. 1)

Proc. Roy. Soc. Vict. 7: 267 (type locality Indracowra, N.T.).

Material Examined: Labbi Labbi, W.A., 1, DFT No. 1258.

Description: The specimen collected, a male, agrees with the description by Lucas & Frost (1895). Claws are slightly recurved, the third and fourth fingers equal in length. Total length 460 mm, tail length 295 mm, ratio tail to total length 0·64. Colour after preservation is orange-brown above with dark brown spots irregularly disposed over head, body and limbs. The tail has longitudinal lines, a median yellow bordered by a brown line on each side. Another dark brown line appears on each side, edged below with yellow. The throat is marbled with grey, the remainder of the undersurface cream.

Habitat: This monitor was found in a burrow on top of a sand dune, to which it was tracked by footprints and marks of keeled tail.

Distribution: The species ranges over the desert and semi-desert of the N.T. and W.A.

Varanus acanthurus brachyurus Sternfeld 1919

(Pl. XLV, fig. 2)

Mitt. Senckenb. Naturf. Gesell 1: 78 (type locality Hermannsburg, N.T.).

Material Examined: Mt Doreen Station, N.T., 5, DFT No. 1246-1250; Labbi Labbi, W.A., 1, DFT No. 1259.

Description: The sample consists of one male (DFT No. 1259) and 5 females, of which 4 are juvenile. The male is the largest specimen—length 505 mm, tail length 295 mm, ratio tail to total length 0·58, tail to body length 1·40, eye-naris to internarial width 1·21. The adult female (DFT No. 1246) shows ratio of tail to total length 0·51, tail to body length 1·47, eye-naris to internarial width 1·29.

Habitat: This species and its various geographical races appear to be restricted to rocky outcrops and ranges in the interior. All the monitors from Mt Doreen district were found under slabs of loose rock, and the specimen from Labbi Labbi was found basking on a rock ledge. The species is not as agile as most of the other Australian monitors, and little difficulty was experienced in securing the specimens.

DISTRIBUTION: Throughout the N. parts of Australia, except the NW. where the type form is found, and in N. Q'ld where a distinct race, *V. acanthurus primordius* has been described. The population on Groote Eylandt is regarded by Mertens (1958) as racially distinct on the basis of colour pattern, and has been named *V. acanthurus insulanicus*. *V. acanthurus brachyurus* is readily distinguished by the serrated nature of the scales at the base of the tail.

Family SCINCIDAE

Genus **Tiliqua**

Tiliqua occipitalis multifasciata Sternfeld 1919

(Pl. XLIV, fig. 2)

Mitt. Senckenb. Naturf. Gesell 1: 79 (type locality Hermannsburg, N.T.).

Two specimens of this subspecies were taken at Labbi Labbi, W.A., by Bindibu natives, but they were eaten by the aborigines and no specimen was collected.

DESCRIPTION: This race is distinguished from the typical form by the more numerous bands across the body, numbering from 12 to 15, and from 10 to 12 on the tail.

DISTRIBUTION: Loveridge (1934) records examples from Broome, W.A., Birchip Downs, Mt Peake, Anningie, Teatree Well, and Hermannsburg, N.T.

Genus **Egernia**

Egernia inornata Rosen 1905

Ann. & Mag. Nat. Hist. (7) xvi: 139 (type locality W.A.).

MATERIAL EXAMINED: Waimbirr'ngi, N.T., 1, DFT No. 1264.

DESCRIPTION: This specimen has 38 rows of scales around the centre of the body; prefrontals in contact medially; 5 auricular lobules; 7 supralabials, the fifth and sixth below the eye. There are 23 lamellae beneath the fourth toe. Length 211 mm, tail length 106 mm, ratio tail to total length 0·50, ratio eye-naris to internarial width 1·27.

HABITAT: This skink was dug from a deep burrow under a clump of spinifex.

DISTRIBUTION: Mitchell (1950, p. 284) records examples from the S. part of N.T., the N. part of S.A. and the Frazer Ra. district of W.A.

Egernia kintorei Stirling & Zietz 1893

(Pl. XLIV, fig. 1)

Trans. Roy. Soc. Sth Australia xvi: 171 (type locality Northern Victoria Desert, W.A. 'lectotype').

MATERIAL EXAMINED: Labbi Labbi, W.A., 1, DFT No. 1265; Kimai, N.T., 1, DFT No. 1266; Waimbirr'ngi, N.T., 2, DFT No. 1267 and 1268.

DESCRIPTION: This species has recently been described from a lectotype in the South Australian Museum by Mitchell (1950, p. 284). The present series possess 47 to 49 rows of scales around the centre of the body. There are 8 supralabials, the sixth and seventh below the eye, but separated from the orbital periphery by a complete series of infraoculars. Lamellae beneath the fourth toe vary from 19 to 21. The largest specimen, a male (DFT No. 1265)—total length 379 mm, tail length 189 mm, ratio tail to total length 0·50.

HABITAT: These skinks were found in burrows under clumps of spinifex, and have the same habitat as the closely related *E. inornata* Rosen. *E. kintorei* is a larger species and differs also in having a yellow ventral surface, which is white in *E. inornata*.

DISTRIBUTION: Recorded from C. and NW. Australia, probably also occurring in W. N.S.W. and Q'ld.

Genus **Sphenomorphus**

Sphenomorphus australis (Gray)

Tiliqua australis Gray 1839 *Ann. Nat. Hist.* 2: 291 (type locality Australia).

MATERIAL EXAMINED: Labbi Labbi, W.A., 5, DFT No. 1294-1298.

DESCRIPTION: One specimen (DFT No. 1294) has 30, the remaining 4 each have 28 rows of scales around the centre of the body, prefrontals in medial contact, nasals in contact in 3 specimens (DFT No. 1296-1298) and separated in two. Ear opening vertical with 3 anterior lobules. One specimen (DFT No. 1296) has 2 pairs of nuchals, the remaining 4 each have 3 pairs. There are 8 supralabials, the sixth below the eye. The lamellae beneath the fourth toe vary from 21 to 24. The largest specimen, a female (DFT No. 1295)—length 249 mm, tail length 170 mm, ratio tail to total length 0·68. After preservation the colouration was variable, ranging from a uniform brown to a striped or variegated pattern.

HABITAT: These lizards were collected in open sandy areas among clumps of spinifex close to rocky outcrops. In the hot conditions of the desert they moved with great rapidity.

DISTRIBUTION: From NW. W.A. through N.T. to Q'ld and S. to N.S.W.

Sphenomorphus ocellatus (Boulenger)

Lygosma ocellatum Boulenger 1896 *Ann. Mag. Nat. Hist.* (6) 18: 233 (type locality Roebuck Bay, Broome, W.A.).

MATERIAL EXAMINED: Labbi Labbi, W.A., 2, DFT No. 1286 and 1287.

DESCRIPTION: DFT No. 1286 is an adult with 36 rows of scales around the centre of the body, these scales decreasing in size on the lateral line and towards the ventral surface. Prefrontals are in broad contact and equal in size to the frontonasal. There are 5 supralabials anterior to the subocular, 4 anterior ear lobules. There are 26 keeled lamellae beneath the fourth toe. Tail incomplete, length snout to vent 84·0 mm, tibial length 11·2 mm, ratio tibial length to snout-vent length 0·13, ratio eye-naris to internarial distance 1·80. Colour after preservation brown above with white spots arranged longitudinally, edged above and below with black; sixth and seventh supralabials white anteriorly, black posteriorly. DFT No. 1287 is a juvenile and differs from the adult in the following respect: scale rows around midbody 34; lamellae beneath fourth toe 23, ratio eye-naris to internarial distance 2·10, tibial length to snout-vent length 0·12; tail complete; total length 115·0 mm, ratio tail length to total length 0·62. Chin shields are edged with black and 3 dark longitudinal lines appear on belly from throat to vent.

HABITAT: Captured in open sandy desert among spinifex.

DISTRIBUTION: The species has been taken in W.A. from the Canning Stock Route, the NW. and as far S. as Quairading and Beverley.

Genus **Ablepharus**

Ablepharus greyi (Gray)

Menetia greyii Gray 1844 *Zool. Erebus & Terror Rept.* Pl. v, fig. 4 (type locality W.A.).

MATERIAL EXAMINED: Mt Doreen Station, N.T., 1, DFT No. 1281.

DESCRIPTION: This skink differs from Boulenger's description (1887, p. 349) in having 20 instead of 22 rows of scales around the centre of the body, and the frontal shield separated from the frontonasal by a broad contact of the prefrontals, instead of in contact with the frontonasal. Total length 66 mm, tail length 39 mm, ratio tail to total length 0·59, eye-naris to internarial distance 1·27. Dorsal colour after preservation, light brown with white stripe extending from the fourth supralabial, through the small ear opening, above the insertion of the forelimb to the groin, this white stripe being edged with a broad dark brown stripe above and a narrow dark brown stripe and 2 indistinct stripes below. Ventral surfaces are white.

HABITAT: This specimen was found under a small rock at the base of a rocky hill.

DISTRIBUTION: The species seems to be restricted to the dry regions of W.A., N.T., N.S.W. and Q'ld.

Genus **Cryptoblepharus**

Cryptoblepharus taeniopleurus (Peters)

Ablepharus (Morethia) taeniopleurus Peters 1874 *Monatsb. Akad. Wiss. Berlin* 375 (type locality Bowen, Q'ld).

MATERIAL EXAMINED: Labbi Labbi, W.A., 3, DFT No. 1283-1285.

DESCRIPTION: The name *Cryptoblepharus* of Wiegmann (1834) is used instead of *Ablepharus* Fitzinger (1823) on the authority of Mittleman (1953). The specimens under examination agree with the description of the type specimen. The largest of the specimens (DFT No. 1299)—length 68 mm, length of tail 33 mm, ratio tail to total length 0·49, eye-naris to internarial distance 1·50. In life, tails were red and in colouration agreed with the lizard described by Lucas & Frost (1896) as *Ablepharus lineoocellatus* var. *ruficaudus* (Pl. X, fig. 3). This lizard is considered as synonymous with *A. taeniopleurus* by Loveridge (1934, p. 378).

HABITAT: All 3 specimens were found in rocky terrain under small slabs of rock.

DISTRIBUTION: W.A., N.T., Q'ld and S.A.

Genus **Rhodona**

Rhodona bipes Fischer 1882

Arch. fur Naturg. 48: 292, Pl. xvi, fig. 10-15 (type locality Nickol Bay, W.A.).

MATERIAL EXAMINED: Labbi Labbi, W.A., 1, DFT No. 1278.

DESCRIPTION: The single specimen collected agrees with the type description; there are no forelimbs but hind limbs are present, each with 2 digits. Limb length amounts to 9·4 mm, the outer digit measures 3·1 mm, the inner 1·2 mm. Ratio eye-naris to internarial width 1·4, length snout to vent 51 mm. The tail in this specimen is regenerated. Colour after preservation pale yellowish-brown with two series of dark brown spots down the mid dorsal line of body and tail, and a brown lateral stripe commencing at the nostril, continuing through the eye and temporal region, broadening and extending along body and tail.

HABITAT: This specimen was found under a rock at the base of a tree.

DISTRIBUTION: The species has been reported from W.A., central area of N.T., and S.A.

OPHIDIA

Family TYPHLOPIDAE

Genus **Typhlops**

Typhlops diversus Waite 1894

Proc. Linn. Soc. N.S.W. (2) 9: 10 (type locality Australia).

MATERIAL EXAMINED: Labbi Labbi, W.A., 2, DFT No. 1305 and 1306.

DESCRIPTION: These 2 blind snakes fit Waite's (1894) description exactly. There are 20 rows of scales around the centre of the body, the nasal cleft contacts the preocular; diameter of body is included 64-66 times in total length. Total length—larger specimen (DFT No. 1305) 364 mm, smaller specimen 192 mm.

HABITAT: These blind snakes were secured in loose sand when the surface was disturbed soon after rain.

DISTRIBUTION: This species inhabits the arid regions of C. Australia, including parts of W.A. and S.A.

Family BOIDAE

Genus **Aspidites**

Aspidites ramsayi (Macleay)

(Pl. XLIV, fig. 3)

Aspidiotes ramsayi Macleay 1882 *Proc. Linn. Soc. N.S.W.* 6; 813 (type locality Bourke, N.S.W.).

MATERIAL EXAMINED: Kimai, N.T., 1, DFT No. 1269.

DESCRIPTION: This specimen is a female having 52 rows of scales around the centre of the body; 285 ventral scales and 52 subcaudals; the anal scale is entire. There are 11 or 12 supralabials, the sixth entering the orbital periphery. There are 2 preoculars on the left side and 3 on the right, with 3 postoculars on the left side and 4 on the right; there are 2 loreals. Total length 1562 mm, tail length 120 mm, ratio tail to total length 0·076.

HABITAT: This python ranges throughout the sandy regions of C. Australia where it lives in burrows. An excellent account of this snake is given by Waite (1929, p. 203). The Bindibu who brought in this specimen called it 'kuka', i.e. the generic name for all game or animal food.

DISTRIBUTION: This species occurs throughout the dry interior and extends into all States except Victoria. Its range extends northward as far as a line from lower Kimberley in W.A. through Newcastle Waters in the N.T. to the Dawson Valley in Q'ld.

Family ELAPIDAE

Genus **Acanthophis**

Acanthophis pyrrhus Boulenger 1898

Ann. Mag. Nat. Hist. (7) 2: 75 (type locality Station Point, N.T.).

MATERIAL EXAMINED: Mt Dorcen Station, N.T., 1, DFT No. 1245.

DESCRIPTION: This specimen, a male, possesses 21 scale rows around centre of body, 145 ventrals, a single anal scale and 40 entire caudals. The characteristic compressed and strongly imbricate terminal caudal appendage is missing. On the head are 4 prefrontal shields (the median pair considerably larger than the outer); nasal scale entire and in contact with the single preocular; 2 postoculars and 2 suboculars; 6 supralabials, the third and fourth touching the orbital region. The temporal formula is 1 + 3, and the lower posterior temporal is deeply wedged between the fifth and sixth supralabials. Measurements—body length 367 mm, tail (incomplete) 65 mm, head width 14·1 mm, head length 22·7 mm, ratio head width to head length 0·62; eye to naris 3·3 mm, internarial distance 5·1 mm, ratio eye-naris to internarial distance 0·65; horizontal diameter of eye 2·8 mm.

The hemipenis has been examined (*in situ*) and found to extend to the fourteenth pair of caudals, the sulcus spermaticus bifurcated at the tenth pair of caudals. Base of the organ is smooth, becoming spiney at about the middle and continuing to the tip, the spines being arranged in 14 diagonal rows. The maxilla carries paired fangs, followed after a long diastema by 2 small teeth.

HABITAT: This snake was found under a stone at the base of a rocky hill. The region is dry, semi-desert country supporting only sparse vegetation.

DISTRIBUTION: This desert form of the Death Adder ranges over a wide area of C. Australia. It has been collected in W.A., S.A., N.T., and in far W. Q'ld. This specimen was a typical desert form, highly coloured in contrast with the sombre colour, predominantly grey, of the typical species, *A. antarcticus*, of the higher rainfall areas.

AMPHIBIA

Family LEPTODACTYLIDAE

Genus **Notaden**

Notaden nichollsi Parker 1940

Novit. Zool. 42 (1): 63 (type locality Roebuck Bay, Broome, W.A.).

MATERIAL EXAMINED: Labbi Labbi, W.A., 6, DFT No. 1311-1316.

DESCRIPTION: These specimens agree well with the type description, except that one of our specimens has the naris slightly closer to the eye than to tip of the snout. Ratio eye-naris to internarial distance averages 0·97, range for the 6 specimens being 0·94 to 0·99. The largest specimen, a female (DFT No. 1316) measures from snout to vent 61·0 mm, and the 4 males range from 52·0 mm to 60·0 mm. Colour after preservation is greyish-brown, with a few scattered black spots on the dorsal area; flanks are peppered with small white spots, as are the upper surfaces of the limbs and the cloacal region. The throat in the male specimens is dark brown.

HABITAT: Following a deluge of rain, traces of a white mucilaginous secretion were noted on the crest of a dune and the surface was disturbed around raised mounds marking points of entry into the sand. On digging to a depth of about 4 ft, at which depth the sand was moist and cool, these frogs were found. The name applied to this frog by the Bindibu is 'dirri'.

Distribution: This species ranges from N. W.A. to the C. region of N.T.

Notes

Gekkonidae were not only restricted in the number of species collected, despite special attention to this group, but also in the actual numbers that were secured. The distribution of lizards of this family was influenced to a greater extent by the heat and the arid conditions, and more obviously, than that of any other group.

Except in the case of *Nephrurus wheeleri*, of which a single specimen was collected at Labbi Labbi under a dense clump of spinifex, the geckos taken at Mt Doreen and at Labbi Labbi were found only under large rocks, or on rocky outcrops where they were well protected from excessive dehydration by the sun, and where they could forage at night, since all these species are nocturnal in habit. None was discovered under bark, a habitat normally favoured by these lizards, since bark or wood exposed to the sun must inevitably become excessively hot in this arid terrain, where trees are small and often widely dispersed, resulting in maximum exposure.

The known distribution of *N. wheeleri* indicates that this species is largely desert-dwelling, or belongs at least to an arid habitat. As has been indicated, the specimen collected was found under heavy spinifex, which would protect it from exposure to sun heat or the dehydrating effect of hot air, and humidity would be maintained by evaporation from the ground and by transpiration. Arthur Loveridge of the Museum of Comparative Zoology, Harvard, Cambridge, Massachusetts (1934), recorded having collected 5 specimens of this lizard at Yandil, near Wiluna in C. Western Australia. Specimens attributed to this species were collected by the Horn Expedition and were determined by Lucas & Frost (1896) as *N. laevis*, which was considered synonymous with *N. platyurus*. Subsequently, however, these specimens were referred by Loveridge to *N. wheeleri*.

As has been pointed out, climatic conditions are much less severe in the vicinity of Mt Doreen, and there is a seasonal growth cycle which is predictable and is reflected in the fauna. In the rocky outcrops of this area, generally under stones, a number of geckos were collected, referable to two species of separate genera—*Heteronota binoei*, of which 19 specimens were obtained, and *Peropus variegatus*, 18 of which were secured near Mt Doreen. A further 14 specimens of *P. variegatus* were collected in rocky outcrops at Labbi Labbi, in desert terrain.

In the dragons, 7 genera occurred in the actual desert, each represented by a single species, and most of these were sufficiently numerous to provide a major reserve of food for the nomadic desert people. It is of interest to record the fact that the Bindibu are the only people known to one of the authors (D. F. Thomson) in many years of experience among tribal aborigines, who regularly exploited the agamids, with the exception of *Chlamydosaurus kingii* and *Amphibolurus barbatus*—as food. Among the Bindibu, the only lizard of the agamid group that enjoyed immunity was *Moloch horridus*, popularly, though anomalously, known as the 'Mountain Devil'.

The foregoing preliminary notes on the Agamidae collected on this expedition show that two of these lizards, members of different genera, *Amphibolurus barbatus minor* and *Physignathus longirostris*, contrived to maintain the arboreal habit characteristic of many of the dragon lizards, and unlike the species which occurred in the open sands, they had not adopted a burrowing habit.

Physignathus longirostris, an arboreal lizard with an extremely long tail, is remarkable for the extraordinary rapidity of its movements. A number of specimens were seen and two collected. These lizards were found in dead hollow limbs of dwarf Mallee Eucalypt trees where they were protected from the direct heat of the sun. These hollow spouts were often cracked and fissured and so were well aerated, enabling the lizards to survive as they could not have done on the surface of the sand. The retention of this and certain allied species in the genus *Physignathus*, members of which are typically aquatic in habit, is open to question, and will be re-assessed by the authors at a later date.

The second of the desert agamids to retain the arboreal habit characteristic of the genus was *A. barbatus minor*, of which a number were taken by the Bindibu and two (No. DFT 1270 and 1271) were collected. These lizards occurred generally in the low-lying area below the cliffs that border Red Cliff Pound, near Labbi Labbi rockhole. They occurred also in clumps of fairly dense mulga that grew in a silt deposit left by drainage waters in a basin to the E. of Labbi Labbi. It was noted that all specimens examined showed consistently the small size and the characteristics that appear to justify the term 'minor' for this rather distinctive geographical race, which may lead to its separation as a distinct species.

Moloch horridus occurred among spinifex, under which it sheltered, but in spite of its apparently heavy protective armour, it was never seen on the exposed sand of the open desert.

Two species of the agamid lizards, *A. caudicinctus* and *Tympanocryptis cephalus*, were rock-haunting forms, living close to the boulder zone of rocky hills and escarpments and sheltering under stones. Neither species had adopted a colonial habit.

The two remaining agamids, the desert form of *Amphibolurus maculatus gularis*, which is regarded as a distinct race by Sternfeld on specimens collected at Hermannsburg in the MacDonnell Ra., and *Amphibolurus reticulatus inermis*, have both adopted a sand burrowing habit upon which their survival in the desert depends. While the spinifex cover remained, these burrows were relatively shallow, but after the spinifex had dried out and been swept by fire, laying bare the sand, these tunnels were often very deep. Both species are strongly colonial.

After a long drought, lizards of these two species were collected in very large numbers by the Bindibu outside Labbi Labbi from 'reservoirs' deep in the sand. An aborigine was seen to halt suddenly on an expanse of bare sand, cast around for a few seconds, and having detected signs which he knew from long experience to be significant, dig straight down with his hands, at the same time using his wide concave spear-thrower as a scoop. In this way he uncovered a colony of 12-15 of these *A. reticulatus inermis*, tapped their heads on his spear-thrower as he extracted them, and gathered them into a bunch by gripping them around the necks. They were carried back to camp and cooked lightly in the embers of a fire, each lizard being picked up half-cooked, the abdominal cavity torn open, and the mesenteric fat, the liver and heart picked out and eaten. Each lizard in turn was treated in this way and then replaced in the embers, when the ashes were raked over and they were cooked again for a few minutes. The rough file-like skin was thus removed, and practically the whole of the little reptile, including most of the bones, was eaten.

There is no doubt that the sand burrowing and the gregarious habit have enabled these lizards to withstand the intense heat and arid conditions in the sandy desert, and that the ability of the aborigines to find these colonies and to utilize every part of these apparently insignificant lizards has been a factor in the survival of the Bindibu in parts of the desert where the white man, strange to this environment, sees no game and can find nothing that appears to be edible.

The agamid lizards that have been discussed are not the only animal food, but they are a safe reserve in times of real adversity. These reptiles appear to feed at night or early in the morning, so that the hunter must find the tell-tale tracks on the sand before the dew dries away in the sun, and the wind obscures them.

As the above list shows, 4 species of *Varanus* were collected, all of which were keenly relished by the Bindibu. The habit of *V. gilleni* of seeking shelter under the thick bark of the desert oak (Pl. XLII, fig. 1) has been described. *Varanus acanthurus brachyurus* is a rock-haunting species that occurred at Red Cliff Pound and in the rocky outcrop at Waimbirr'ngi. *V. eremius* and *V. gouldi flavirufus* were found in the spinifex that fringed the dunes and these reptiles sought refuge underground in burrows in the sand. In an environment as harsh as the Great Sandy Desert, where the tracks of even small reptiles can be picked up unerringly by the aborigines when the spinifex covering has been denuded, lizards, especially large forms like *Varanus* are nowhere numerous, except where a heavy spinifex cover has remained long unburned, giving them sanctuary to breed.

Of the skink lizards obtained on this expedition, all but one species were collected between Kimai and Labbi Labbi. The exception was a single specimen of *Ablepharus greyi*, a small active lizard which was found under a slab of stone at Mt Doreen.

Of the larger species, which play an important part in Bindibu economy, *Tiliqua occipitalis multifasciata*, the western or desert form of the familiar Blue-tongued Lizard of coastal Australia, was seen at Labbi Labbi and at Kimai, where a number of specimens were secured by the Bindibu nomads when we first met them in camp near the well. These lizards, with their fleshy bodies and thick tails, were savoured by the Bindibu, whose food gathering routine we could not risk upsetting on our first contact. These people had camped near the well for some days during which we were on a reconnaissance over the Western Australian border, and when we returned to Kimai the game, including larger edible lizards, had been depleted so that the area was no longer a promising collecting ground.

On the first reconnaissance, William Hosmer remained at Waimbirr'ngi with a young Bindibu man. In the sandy terrain close to the bluff he secured specimens of 2 fine *Egernia* which the native dug from burrows 3′ 6″ to 4′ deep in the sand. Both lizards are a fresh salmon pink on the dorsal surface, sometimes with a coppery tinge, body scales on each smooth and with a metallic sheen. Subsequently these lizards were identified as distinct species, *E. kintorei*, of which 3 specimens were collected, and a single specimen of *E. inornata*. The former species is larger and has a pale yellow ventral surface in contrast with the white undersurface of *E. inornata*. Other distinctive characters are apparent in the description.

We soon learned that both these lizards were valued highly by the Bindibu as 'kuka', the generic term applied to all game and to all animal food, and that both were known to the people by the name 'war'na'. In the months that we spent with the Bindibu we came to understand the importance of these skink lizards which, with certain agamids, had adopted a sand-burrowing habit for survival, and provide a reserve of animal food that, in a less harsh and arid environment, would not be available in such concentration, or so readily accessible.

Of the 5 snakes collected on this expedition, 2 were of the family *Typhlopidae*, the status of which await final determination.

The single specimen of *Acanthophis pyrrhus* collected was found under a rock at the base of a hill in semi-desert terrain near Mt Doreen. This Death Adder had scales of a bright coppery-red colour, and bore serrations in ridges like a file.

Two specimens of one of the python group, *Aspidites ramsayi*, were obtained, one at Kimai well, the other, a smaller specimen, conspicuously marked on the dorsal surface by the transverse brownish bands characteristic of this snake, was dug out of a hole in a sand dune near Wirrarigulong.

The genus *Liasis* was represented by a single specimen, *Liasis childreni*, of which a skull only was found among the boulders of Waimbirr'ngi Bluff.

As might be expected under desert conditions and at the end of a long drought, amphibians were conspicuous by their absence in most parts of the Great Sandy Desert. Frogs were never seen in any of the wells or rockholes and no frog spawn was noted, even following the torrential rains that fell in June 1957, nor were any frogs seen in the open, as often occurs in other arid areas after very heavy rain, in spite of the fact that some hundreds of miles of desert were traversed. The fact that many of the permanent waters or morasses, such as L. Mackay and L. Hazlett, Wills and White, have a heavy concentration of salt may contribute to the almost complete absence of frogs in this desert. Frogs are extremely intolerant to brackish water, particularly on account of the respiratory function of the epidermis. The only drinking water of the desert Bindibu occurred in wells, rockholes, and claypans, none of which would provide sufficient pure, i.e. mineral free, permanent water, nor a sufficiently low temperature, with the probable exception of Labbi Labbi.

The deluge of rain, amounting to several inches, in June 1957, fell suddenly while we were in Red Cliff Pound. For the first and only time when we were in the desert, Labbi Labbi overflowed and poured like a waterfall into Red Cliff Pound. The creek beds in Hidden Valley, emptying into L. Hazlett, became raging torrents, and the country was impassable for several days. When we could get our vehicles out, we camped under a sand dune about 3 miles E. of Labbi Labbi. The night was clear and cold, with the heaviest dew we had ever experienced. Early the following morning we found that the sand on the crest of the dune had been disturbed and showed tracks that were new to us. There were traces of a milky mucilaginous secretion, and slightly raised ridges at the point where the tracks stopped. The Bindibu guide to whom we showed the tracks evidently recognized them and began to dig into the sand to a depth of about 4 ft, where we found 6 adult specimens of *Notaden nichollsi*, to which the Bindibu gave the name 'dirri'. No trace of a burrow was seen, so that in digging into the sand, the frogs had closed the tunnel behind them, thus reducing circulation of air and doubtless also the loss of water by evaporation, by the amphibians deep in the moist sand. The frogs appeared to be in good condition and showed no sign of dehydration. It seemed reasonable to assume that they had emerged from their deep burrow during the previous night after heavy rain had fallen, and that they were fully hydrated and capable of enduring a further long term in the arid conditions.

The fact that no less than 6 adult specimens were discovered on this occasion in one place suggests that this frog is not uncommon, which is also supported by the fact that it was obviously well known to the Bindibu natives, but it has adopted a specialized habitat and habits to survive. A review of known facts on water metabolism of vertebrate animals in desert conditions, including reptiles and amphibians, has been presented by Robert Chew (1961).

In view of the apparently sporadic and unpredictable nature of the rainfall in this area, and the absence of any water storage on the surface sand, the breeding habits of this frog may be worth study.

Again, it was noted that the sand on the crest of these dunes was looser and coarser in texture than on the sides of the sandhills, and although it was more exposed to the heat of the sun and to the bitter winds that often blow, we confirmed an early observation that the flora on the crests was often less stunted and less strongly xerophilous than of the sides. At a depth of 4 ft, we found the sand was moist and cool.

During the entire period of more than 5 months in the desert, the 6 specimens of *N. nichollsi* referred to above were the only frogs seen and collected. However, a thin, high-pitched, rather musical call which was unmistakably that of a small frog, was often heard after nightfall, particularly after the rain, in the low-lying country away from salt marshes or other areas where the sand might be impregnated with salt, calcium salts, lime or other chemicals. Repeated attempts to secure specimens of this presumed frog that was heard, the call of which was reproduced on tapes, proved fruitless.

There is no doubt that the feral cat which, with the European fox, has penetrated to the remotest part of the desert, has taken a heavy toll of the desert fauna, including those of the rocky outcrops and boulder zones. Because the feral cat is relished by the Bindibu and hunted by these people in the open, where it is an easy prey, its only refuge is among big outcrops of rocks where it can breed. But it must inevitably have depleted the small game of these boulder zones, as well as of the terrain in the immediate vicinity. Doubtless, in this way the cat has had a disturbing and disruptive influence on the distribution of reptiles and mammals, especially in the Great Sandy Desert, and to a slightly lesser extent, of birds, that is difficult to assess today.

Acknowledgements

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References

Boulenger, G. A., 1885-1887. *Cat. Liz. Brit. Mus.* London, vol. 1-3.

Carnegie, D. W., 1898. *Spinifex and Sand.* C. Arthur Pearson Ltd, London.

Chew, R. M., 1961. Water metabolism of desert-inhabiting vertebrates. *Biol. Rev. Camb. Phil. Soc.* 36 (1): 1-31.

Chrapliwy, P., Smith, H. M., and Grant, C., 1961. *Herpetologica* 17: 5-12.

Finlayson, H., 1935. *The Red Centre.* Angus & Robertson, Sydney.

Giles, E., 1875-6. *E. Giles's exploration 1875-6.* South Australian Parliamentary Paper No. 18.

Gray, J. E., 1845. *Cat. Liz. Brit. Mus.* London, p. i-xxviii and 1-289.

Kinghorn, J. R., 1926. A brief review of the family Pygopodidae. *Rec. Aust. Mus.*, vol. 15, p. 40-64.

Loveridge, A., 1933. New agamid lizards of the genera *Amphibolurus* and *Physignathus* from Australia. *Proc. New England Zool. Club,* 13: 69-72.

————, 1934. Australian reptiles in the Museum of Comparative Zoology, Cambridge, Massachusetts. *Bull. Mus. Comp. Zool. Harvard* 77 (6): 243-383.

Lucas, A. H. S., and Frost, C., 1896. On the reptiles of the Horn Expedition. *Horn Sci. Exped. to Central Australia* 2: 112-151. Melville, Mullen & Slade, Melbourne.

Mertens, R., 1958. *Zool. Anz.* Leipzig 159 (1-2): 18.

Mitchell, F. J., 1948. A revision of the lacertilian genus *Tympanocryptis. Rec. Sth. Austr. Mus.* 9: 57-86.


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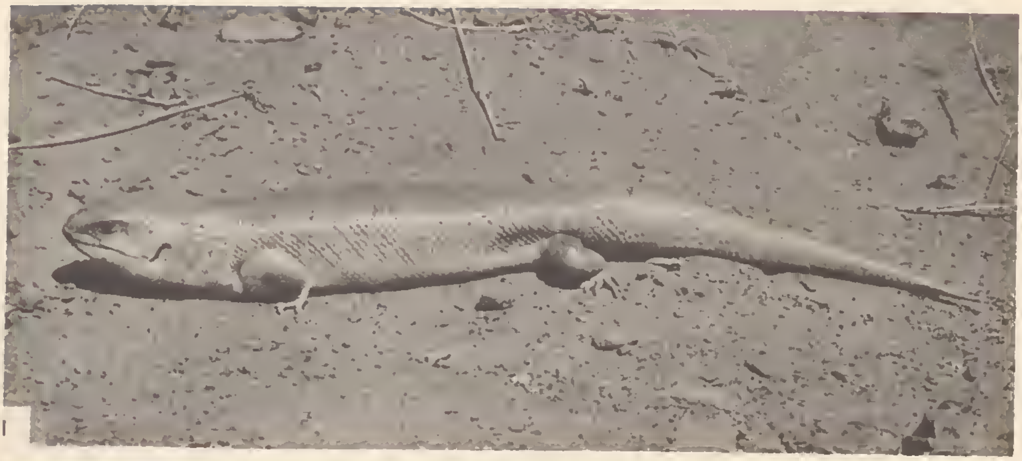

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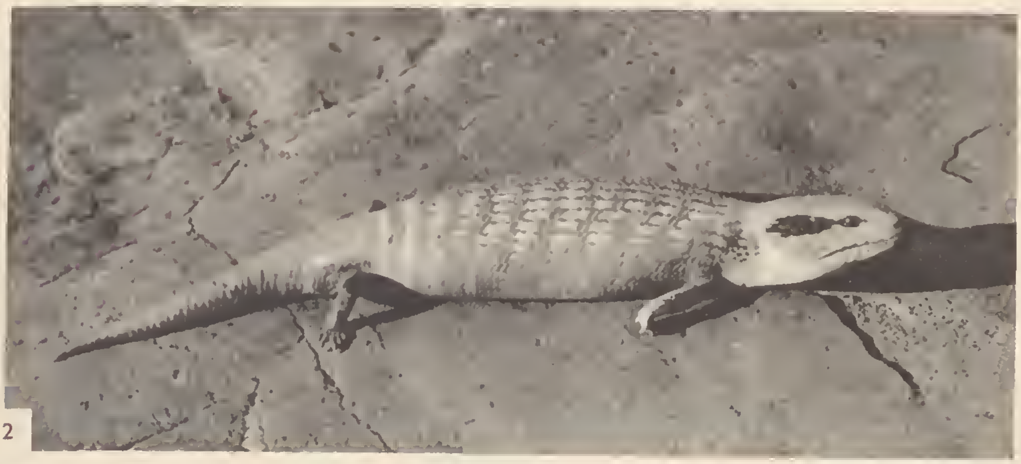

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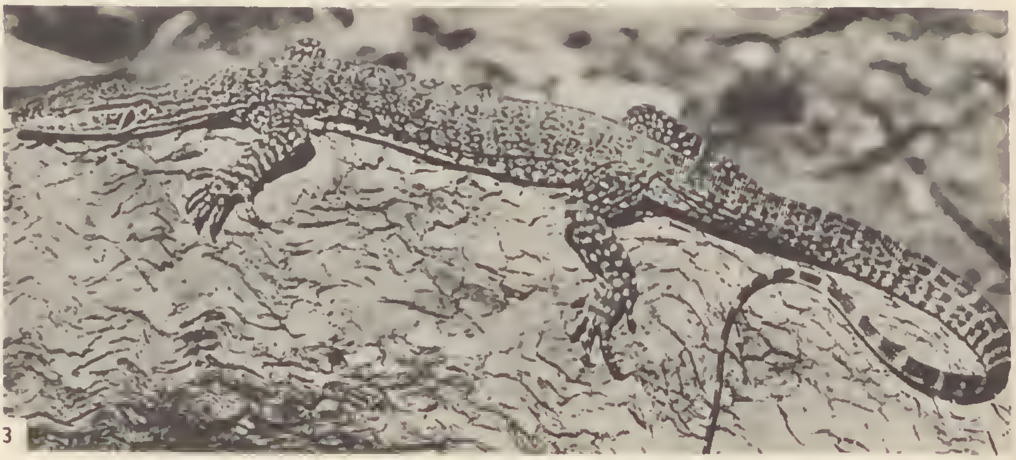
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———, 1950. The scincid genera *Egernia* and *Tiliqua* (*Lacertilia*). *Rec. Sth. Austr. Mus.* 9: 275-308.

MITTLEMAN, M. B., 1953. A generic synopsis of the lizards of the subfamily Lygosominae. *Smithsonian Misc. Collections* 117 (17): 1-35.

TERRY, M., 1934. Explorations near the border of Western Australia. *Geogr. Journ.* 84: 498-510.

———, 1957. The Canning Basin of Western Australia. *Geogr. Journ.* 123: 157-163.

THOMSON, D. F., 1962. The Bindibu Expedition. *Geogr. Journ.* 128 (1-3): 1-278.

WAITE, E. R., 1929. *The Reptiles and Amphibians of South Australia.* Government Printer, Adelaide, Flora and Fauna series, p. 5-270.

WARBURTON, P. E., 1875. *Journey across the western interior of Australia.* Sampson Low, Marston, Low, & Searle, London.

Explanation of Plates

PLATE XLII

Fig. 1—Desert oak, killed by fire, showing heavy rough bark that in dead trees provides shelter for *Varanus gilleni* Lucas & Frost.

Fig. 2—The rugged jutting headland of Waimbirr'ngi Bluff which overlooks the desert N. of L. Mackay and E. of the N.T./W.A. border. A well or soak filled by seepage from fissures in the rocks furnished water for parties of desert nomads who made frequent visits on their hunting expeditions.

PLATE XLIII

Fig. 1—Desert terrain, showing the sand denuded of its cover of spinifex. In the centre of the photograph are dwarf shrubs, chiefly Mallee eucalypts and *Acacia* spp. which develop rosettes of green leaves from the fleshy rootstock deep underground.

Fig. 2—A Bindibu boy shows his 'catch' to William Hosmer at Labbi Labbi. In his right hand are two specimens of *Varanus acanthurus brachyurus* Sternfeld. Hosmer examines a specimen of Ramsay's Python, *Aspidites ramsayi* (Macleay).

PLATE XLIV

Fig. 1—One of the large, fleshy-tailed skink lizards, *Egernia kintorei* Stirling & Zietz, which are called 'war'na' by the desert Bindibu who dig these reptiles out of burrows deep in the sand.

Fig. 2—*Tiliqua occipitalis multifasciata* Sternfeld, a highly coloured desert form of the Western Blue-tongue lizard. This specimen was collected at Kimai Well but was later eaten by the aborigines.

Fig. 3—One of the 3-4 snakes that were collected in hundreds of miles of travel in the Great Sandy Desert. A young specimen of Ramsay's Python, *Aspidites ramsayi* (Macleay), showing the strongly developed transverse bands of the juvenile form.

PLATE XLV

Fig. 1—*Varanus eremius* Lucas & Frost, a desert species showing the effect of long drought in its loose flaccid skin. Like all these reptiles it is hunted incessantly by the Bindibu.

Fig. 2—*Varanus acanthurus brachyurus* Sternfeld, a species that inhabits rocky outcrops like those at Mt Doreen Station, Waimbirr'ngi Bluff and Labbi Labbi.

Fig. 3—*Varanus gouldi flavirufus* Mertens, a terrestrial sand-burrowing race not uncommon in the Great Sandy Desert where it is hunted by the aborigines.

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8

LAND USE IN THE SILVAN-MONBULK REGION, DANDENONG RANGE, VICTORIA

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Abstract

Employing two different classifications, the land use has been mapped for an area of about 30 square miles focused about Silvan and Monbulk. Explanations have been offered for certain correlations between factors of the environment and patterns of land use. Problems of the area have been analysed from data collected from interviews with landholders.

Introduction

This paper deals with the land use, in 1962, of an complex area on the E. flanks of the Dandenong Ra.

The area surveyed, the Silvan-Monbulk region, is an arbitrarily defined area of approximately 30 square miles. It is bounded on the N. by the Warburton railway line from Mt Evelyn to Wandin North, and thence by the Warburton main road to the Woori Yallock Ck. This creek forms the E. boundary. The S. limits approximate the line of the Kallista-Emerald road. The W. boundary is the Olinda Ck from Mt Evelyn to the Silvan Reservoir, the reservoir, Chalet Rd and a line S. from the Olinda-Monbulk-Mernda Rd to The Patch (Fig. 1). These W. limits approximate the Evelyn Fault and Monbulk Monocline (Edwards 1956).

No previous land use surveys have been made of this area. Because of the limited size but complexity of the area, and the need to map and correlate as many factors of the physical and cultural environment as possible, two different land use surveys were carried out—a unit-area survey and a sectional survey. In the former, by the use of a fractional code, major land use, farming economy, weed cover, weed type, and state of maintenance of farm buildings were recorded in the numerator while slope, drainage, cultivation practices, and degree and type of soil erosion were recorded in the denominator. In the sectional survey, a detailed breakdown of varieties of land use was mapped. (Copies of maps and land use classifications are filed in the Department of Geography, University of Melbourne.)

The field work was carried out in May and June 1962 by 3rd-year students of the Melbourne University Geography Department under the direction of the senior author. Direct field-by-field mapping of land use was recorded on base maps at a scale of 1 in. to 10 ch. of the Dandenong Ra. Area, Sheets 4-6, 10-12, 16-17, 22 and 23. Vertical air photographs, flown in 1961 and enlarged to 1 in. to 10 ch., also were used, boundaries being corrected where necessary and brought up to date. In non-urban areas a census of farms was attempted to collect data about history, farm management, crops, yields, costs, and problems. In some areas, absenteeism and pressure of time resulted in more restricted sampling. In such cases, as broad and characteristic a sample as possible was then selected. Interviews were conducted on about 75% of the 400 odd rural holdings visited; another 5% was excluded due to the owner or occupier being unable or unwilling to co-operate, frequently because of language difficulties, or to the farmer being absent at off-the-farm work.

In urban areas, a census was taken of commercial and servicing enterprises and restricted interviews, a 5% sample, were conducted with urban residential landowners.

Geology and Surface Relief

The area is essentially a low-lying erosional basin, although portions of the higher N. and E. flanks of the Dandenong Ra. have been included near Monbulk; it forms the W. third of the larger Woori Yallock Basin (Gregory 1912, Easton 1908, Edwards 1940), and is well protected from the W. and S. by the 1,400-2,000 ft high Dandenong Ra. Approximately two-thirds of the area is characterized by a series of narrow, undulating, basalt ridges, ranging in altitude from 600-900 ft, separated by wider valleys that are some 200 ft lower. This basalt area is found in a broad triangle with its base from N. of Silvan to Monbulk and its apex near Seville (Easton 1908). Flanking areas developed on the easily eroded Silurian sedimentary rocks to the N. and E. are lower (300-600 ft) and more undulating with wider valleys and rounded ridges. Steep slopes and altitudes from 800-1,100 ft occur on the S. margins at The Patch where resistant Devonian Middle Dacites occur (Edwards 1956). Maximum altitudes from 1,000-1,500 ft and steep slopes are found to the W. of Monbulk on Upper Dacite rocks (Edwards 1956) (Fig. 1).

The main streams flow northwards. Both the Olinda and Woori Yallock Ck originated respectively as a W. and an E. lateral stream to the Tertiary Older Basalt flow that infilled the valleys across the Basin floor during the Oligocene (Edwards 1940). The present landforms are the result of this inversion of relief with basalt residuals remaining as cappings on the ridges between the valleys. Both the Warburton road and railway from Mt Evelyn make use of a lower area, cut in the Palaeozoic sedimentaries, thus avoiding the generally concordant basalt-capped areas to the N. and S.

Vegetation

Dry sclerophyll forest dominated by several different species of *Eucalyptus* formerly covered most of the area. *Eucalyptus obliqua-E. radiata* association is found on the well-structured, deep, red loams derived from basalt. Trees are dense and tall (over 70 ft) with a three-tiered understorey up to 10-12 ft high. A lower, more open *E. radiata-E. elaeophora* association occurs on the podzols formed on the Silurian sedimentary rocks. Harsh, sclerophyllous shrubs form a dense, 4-6 ft-high understorey. *E. ovata* is found on ill drained, poorly aerated soils, where rainfall is less than 40 in. such as along the Woori Yallock Ck. *E. goniocalyx* is found in a few sheltered valleys on krasnozem soils, notably along Sassafras Ck where *E. regnans* also occurs on deep alluvial soils where rainfall is in excess of 50 in.

Forested areas, largely secondary in nature, serve an important function to agriculture as windbreaks, by reducing runoff, and by slowing down exploitation.

Climate

The humid, mesothermal (Cfb) climate of the Silvan-Monbulk region, though essentially similar to Melbourne's climate (Gentilli 1948, Leeper 1955), has differences due to altitude and local relief. There is an increase in rainfall and a corresponding decrease in temperature with altitude (Table 1). Average annual temperature at Silvan (850 ft) is 4-5°F cooler than at Melbourne (114 ft), while Sassafras (1,400 ft), outside the area to the W., is approximately 10°F cooler. Mean annual precipitation at Sassafras is double that of Melbourne, falling on only one-third

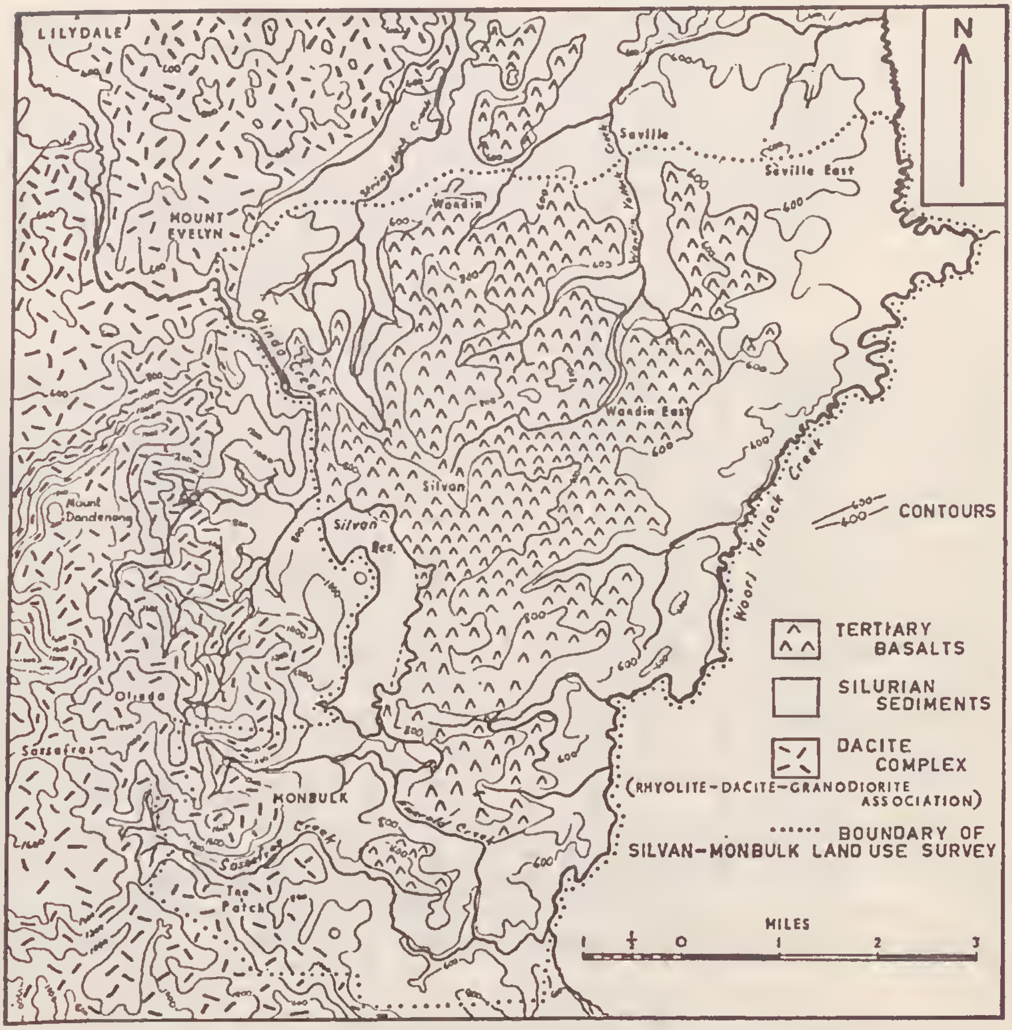

FIG. 1—Geological and locational map of the Silvan-Monbulk Region and adjacent areas.

more rain days. This closely parallels conditions observed in the Mt Lofty Ra. of South Australia (Trumble 1939, Cochrane 1963).

Mean annual precipitation is 40-42 in. increasing to 50 in. in the higher SW. area. Frequent mists and cloud-drip considerably enhance effective precipitation on the higher slopes to the W. and S. of Monbulk. Because of low average monthly rainfall from December to March, combined with high summer temperatures, and a high rate of evaporation, irrigation of summer crops is often necessary for optimum yields on the free draining, basaltic soils. Except for these three summer months, however, the Transeau Ratio (P/E) does not fall below 0·33 throughout the year (Clifford 1953, Leeper 1955). One localized modification of the hot, dry summer occurs in the immediate vicinity of the Silvan Reservoir where slightly cooler, moister

TABLE 1

Comparative Climatological Data

Station	Data	J	F	M	A	M	J	J	A	S	O	N	D	Year
Silvan	Rainfall (pts), 48-yr mean	248	263	290	403	408	470	417	408	397	474	342	323	4390
	No. of rain days, 5-yr mean	8	11	13	14	19	16	24	19	19	18	16	14	191
Stations near area: Sassafras	Rainfall (pts), 36-yr mean	315	316	385	464	464	525	468	450	444	524	413	378	5146
Scoresby (8 miles W.)	Rainfall (pts), 13-yr mean	157	268	204	318	419	274	328	321	406	442	410	298	3845
	Mean temperature, °F, 8-yr mean to 1955	66·4	65·4	63·0	57·2	52·1	48·2	47·7	49·5	52·8	55·9	58·3	62·9	56·6
	Mean total sunshine hrs	269	196	209	135	103	75	100	126	152	181	188	271	2005
Station beyond area: Melbourne (20 miles W.)	Rainfall (pts), 50-yr mean	187	207	216	217	214	207	198	196	233	269	245	238	2627
	Rain days	8	8	10	13	15	15	16	17	15	15	13	11	156
	Mean temperature °F, 30-yr mean	67·3	68·3	65·1	59·3	54·5	50·3	49·4	51·2	54·7	58·3	61·5	65·3	58·8

conditions have favoured the development of tulip growing, notably the harvesting of bulbs during January to March.

Detailed climatic figures for temperature and any figures for humidity, sunshine hours, and frost incidence are not available for the region, but figures intermediate between those of Melbourne and Sassafras can be assumed. Ground frosts occur frequently between February and October, particularly in small cleared areas and where air drainage occurs. Snowfalls have been recorded infrequently from May-October, chiefly to the W. of the area in the high portions of the Dandenong Ra. (Commonwealth Bureau Meteorology 1958).

Brief History of Settlement

From the early 1850's timber splitters entered surrounding forested areas to supply the needs of railways, piers and bridges. In 1867 the 'Dandenong and Woori Yallock State Forest' was set aside as a reserve. The Parish of Monbulk was opened for selection in 1893, and potatoes, market garden produce, and raspberries were quickly established on small cleared portions of the 10-acre selections. Daniel Camm established a jam factory at Monbulk in 1909, the Monbulk Co-operative Fruitgrowers' Association pre-dating it by 12 years. Subdivision quickened after the First World War, and to an even greater extent after 1945. Where urban use has replaced agricultural land use this does not necessarily indicate an unsuitable climate or soil, but simply the fact that the land has become too valuable to be farmed; it became more profitable to sell it unimproved, particularly as the demand for building blocks increased with the 'urban sprawl' eastwards from the metropolis. The building of 'hills' homes for business men and retired folk has been particularly popular in an arc of high land from Monbulk to The Patch (Fig. 7). The decentralization of light industry to the Dandenongs area in the last 10 years has played an important part, and the recent electrification of the railway as far as Belgrave (1962) has encouraged commuting.

In spite of this, the natural advantages of the area are such that specialized enterprises such as berry fruit growing will remain and expand providing production can be intensified and returns increased (Avent 1954-60).

The Town Planning Board's Interim Development Order of 1959 has 'frozen' subdivision in, e.g. The Patch, awaiting detailed studies and land use zoning (Coulson 1959).

Farm Size and Tenure

The acreage of individual holdings varies considerably; while property sites in the urban centres, Monbulk, Mt Evelyn, The Patch, Seville, Wandin, and Seville East are by their very nature small, the farms range from a fraction of an acre to over 300 acres, and in at least one case to 500 acres. There is, however, no significant overall parallel between farm size and geographic location. Diversification of production, and an increased percentage of farm area given over to grazing typify the larger properties. Conversely, the smaller the property, the more intensive the enterprise, and generally speaking, the greater is the extent of well-structured red loams capable of sustained cultivation for vegetables and berries (Pl. XLVI). For this reason a farm with sheep and cattle grazing, grain crops, orchards, and berries, totalling 120 acres, is found only 200 yards away from a 4-acre holding devoted solely to vegetables.

The area as a whole produces 97% of the total Victorian berry fruit output, and the mean property size of 356 growers, with more than half an acre under berries, is 29·1 acres (Bureau Agricultural Economics 1962).

The 10-acre selections made available by subdivision around 1900 account in part for the smallness of many present holdings. Subsequent engrossment, necessary for economic farming, has been more than balanced around developing service centres by more recent fragmentation and urban subdivision.

Although a few smaller properties are rented, tenure is largely freehold, and

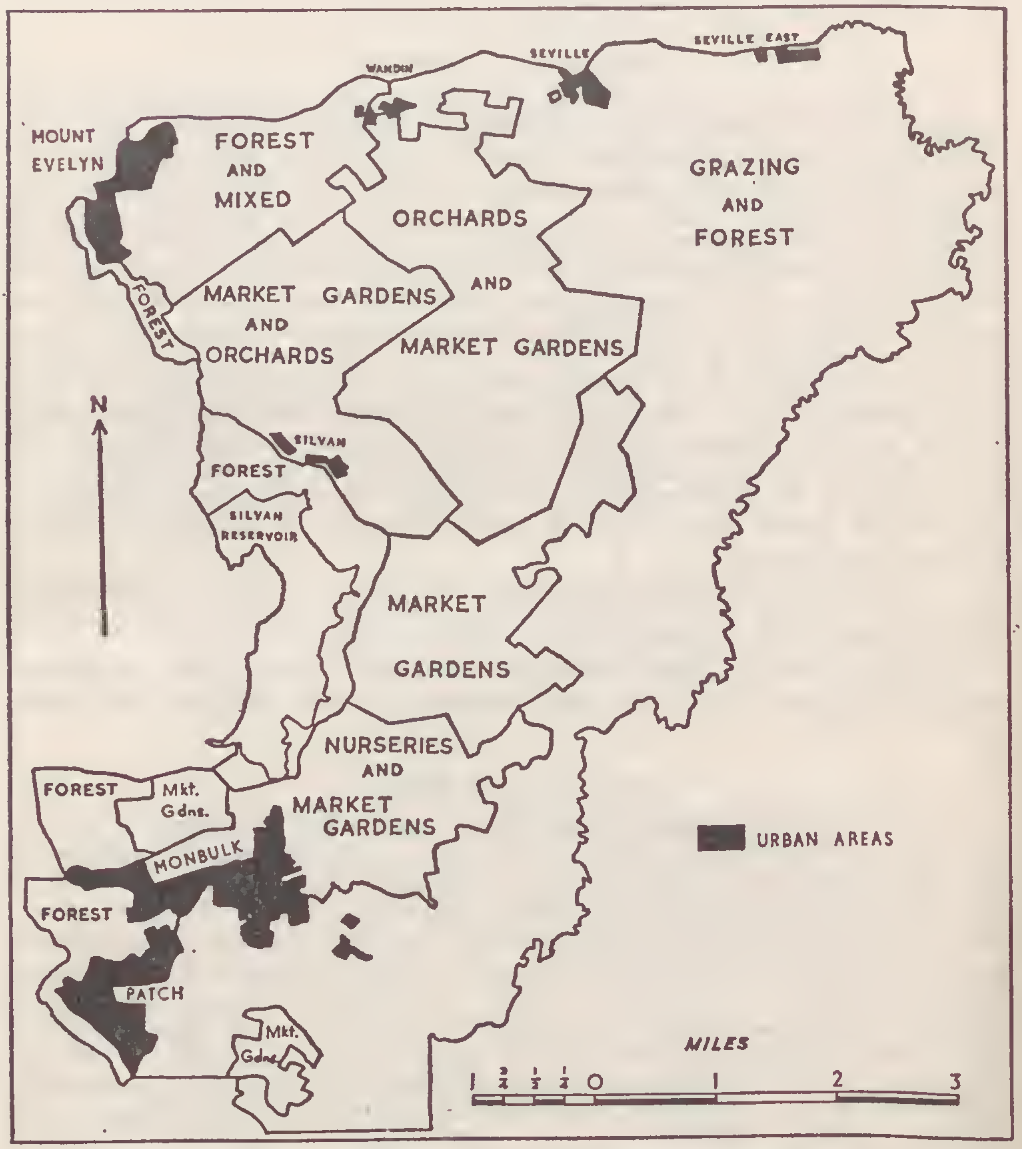

FIG. 2—Predominant land use areas of the Silvan-Monbulk Region, June 1962.

occupancy ranges from the time of the original sub-division 70-80 years ago, to a matter of 2-3 years or less where small, uneconomic market gardens have changed hands several times in the last 10 years. The inexperience and lack of working capital of some settlers has been an important stimulus to this recent turnover. Some small market gardens are rented, and others are worked by absentee 'weekend farmers'.

Nature and Intensity of Land Utilization

The Silvan-Monbulk region exhibits a great range in degree of exploitation, from virgin sclerophyll forest, through newly and partially cleared areas, through rough, and improved grazing, and orchards, to intensive berry fruit growing and market gardening (Fig. 2, Pl. XLVI). Though not strictly definable in terms of soil type, the gradation in rural land use falls into three major categories: (1) Vegetables, berries, bulbs and small stone fruit orchards on deep red loam soils of the basaltic tongue through the centre of the region, from Wandin and Silvan to Monbulk (Fig. 5, 6, 8) and to a lesser extent on the krasnozems to the W. and S. of Monbulk where root vegetables (Fig. 7) and ornamental nurseries are found (Fig. 5). Some large stone fruit orchards are also found on prosperous, long-established holdings between Silvan and Wandin East (Fig. 6). (2) Scrub and grazing interspersed with pome fruit orchards and vines predominate on the grey podzols of the lower areas between 300-700 ft elevation, near Seville in the N. and flanking the Woori Yallock Ck in the E. (Fig. 4). (3) Partly cleared and forest areas, grazing, large orchards (often not fully mature) and a greater percentage of mixed farming occur in areas flanking or astride both the red loams and the grey podzols (Fig. 5, 8). There is a broad correlation between geology, soil type, farm enterprise, and property size (Cf. Fig. 1-8).

The differentiation between various types of farm enterprise is most marked in the case of market gardening. Most market gardeners, and a smaller percentage of berry fruit growers, depend solely on this one form of land use for income (Summerhayes 1958). This is closely related to the need for intensive application of capital and labour. On the other hand, fewer properties are given over solely to orchards. Even though orchards may provide the major income, there is a tendency for a diversity of production covering grazing, poultry, pigs, and berries; such diversification allows a more economic spread of labour and of machinery. It also caters for different soil capabilities and relief—particularly aspect (Fig. 1, 5, 8), and, while labour and capital inputs vary, there is some measure of insurance against the failure of any one income source. On the other hand, the area exhibits examples in which each of the above is the sole enterprise on certain farms (Pl. XLVI). This monoculture is successful on some properties, though with orchards there is usually a variety of trees if not in enterprise, and if berries alone are grown, an alternative income source must normally be found for the winter months, such as outside work in factories or as hired labour on larger properties (Avent 1954-60, Summerhayes 1958).

Within the Silvan-Monbulk region, as for Evelyn County as a whole (Comm. Bur. Cen. Stats Vict. 1962, Bur. Ag. Econ. 1962) apples, cherries, non-canning pears, lemons and limes, non-canning peaches, and plums, in order, were found to be the principal orchard fruit. Strawberries and raspberries predominate in berry production. Strawberry crops are the most important source of income within the area. Loganberries, youngberries, boysenberries, lawsonberries, and gooseberries are also grown. Plant nurseries (Fig. 2, 5) produce tulips, hyacinths, daffodils, gladioli, Canadian pines for the Christmas-tree market, and large numbers of fruit trees for orchardists and Melbourne home gardeners. Potatoes are by far the most important vegetable in both acreage and production, though there is a multitude of others, such as carrots, peas, beans, tomatoes, celery, cauliflower, Brussels sprouts, broccoli, sweet corn, and chilis or capsicums. In terms of livestock there are ten times more sheep and fat lambs than cattle or pigs slaughtered for human consumption; there are more dairy than beef cattle or pigs. Four times as much land is under pasture as under crop in the Evelyn County; the ratio is less than 2:1 in the Silvan-Monbulk region. Oats is the principal cereal for grazing and hay.

While the large-scale maps (Fig. 3-8) should be studied for details of land use in June 1962, the broad pattern is shown in Table 2.

TABLE 2

The Varied Pattern of Land Use

(Based on 5 sample areas of 500 acres each)

Relative position in survey area	Areal % given to—							
	Forest/ scrub/ recently cleared	Grazing	Berry fruit crops from vines/ canes	Bulbs	Market garden	Orchards	Urban	Other
NW. (nr Evelyn)	42	11	2	–	–	6	–	39
NE. (nr Seville)	7	80	–	–	2	8	1	2
E. Central (Wandin East)	16	18	–	–	33	22	–	11
W. Central (nr Silvan Res.)	32	1	4	3	5	11	–	44
SW. (nr Monbulk)	30	6	3	3	7	2	21	28

Within the limitations of any generalized presentation of land use, Table 2 indicates at least a minimal geographic differentiation: grazing is more important in the N. and the E. (Fig. 4); berry fruit crops from vines, and bulbs are important in the moister W. centre and S. (Fig. 5, 6); orchards are comparatively evenly distributed N. to S., though more important in the centre (Fig. 6, 8), and less important off the loams to the S. near Monbulk (Fig. 7); and market gardens are common on the E. and S. within the 'basalt triangle' (Fig. 5, 6). The area off the basalt, in the NW. near Mt Evelyn, is largely forested and is characterized by very mixed land use (Fig. 8); it is an economically marginal area containing numerous, small, sub-economic, part-time farm units. It must also be borne in mind that areal dominance does not necessarily mean economic nor even productive dominance, in fact the reverse may often be true, and bulb growing near Silvan would be a case in point.

Country of Origin, Length of Occupance, Farm Type

Data were collected on the country of origin (nationality) of the occupiers of 211 properties, approximately half of those in the area surveyed. Table 3 compares country of origin with type of soil worked. While this appears to have some significance, the parallel must not be developed too far. Because of the random

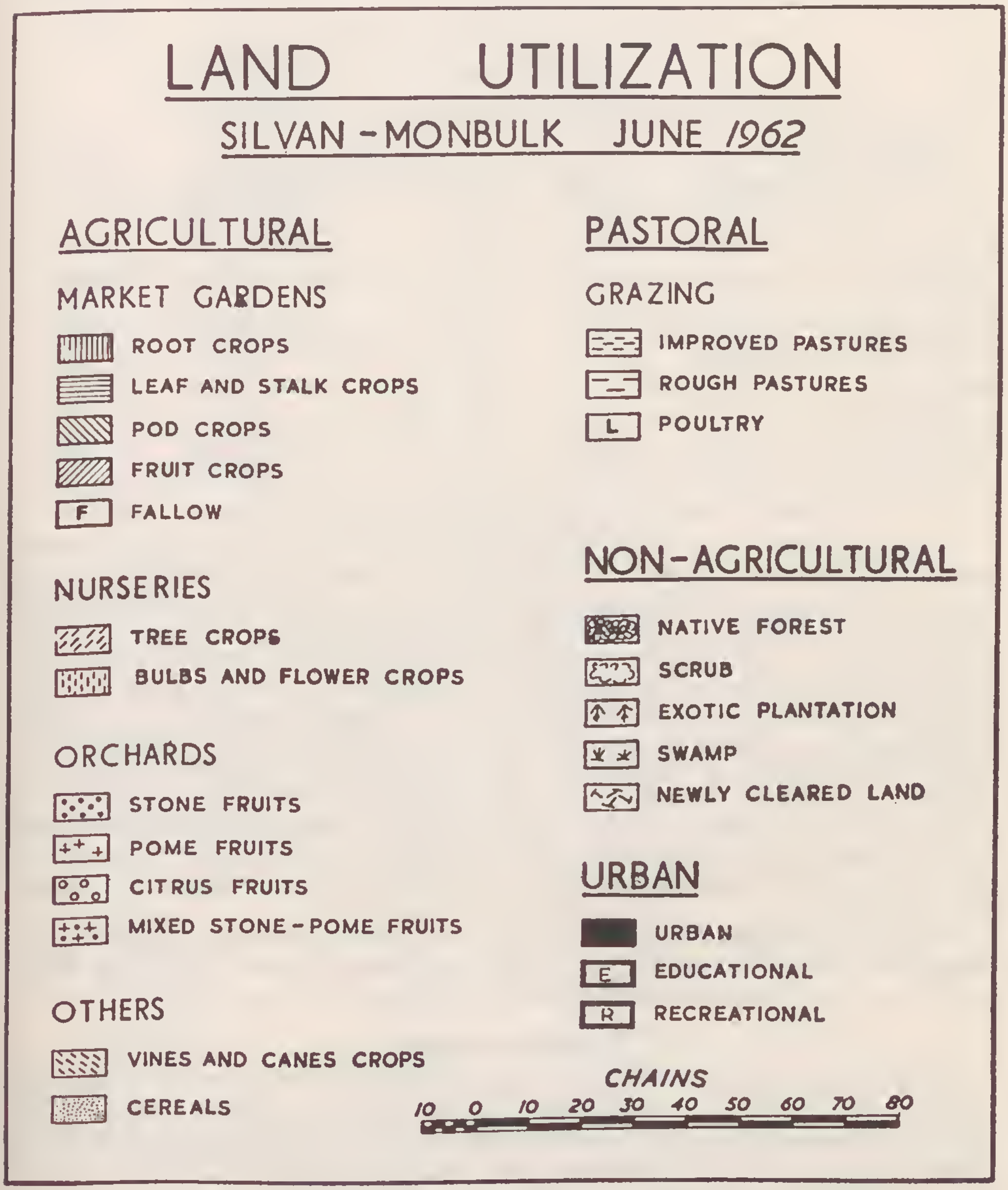

FIG. 3—Key for detailed land utilization maps shown in Fig. 4-8.

sampling involved, no final conclusions can be drawn, but it seems clear that Australians and Italians predominate, the former being more numerous in every case except on the poorer, solely podzols holdings. Prior occupancy would account for this in most instances. The parallel, already mentioned, between nature of farm enterprise and soil type, should be borne in mind.

Table 3

Country of Origin: Farm Soil Type

(211 Properties)

Farm soil type	% of total by country of origin of occupier				Total %
	Australia	Italy	Holland	Other European Countries	
Basaltic red loam	15·4	12·0	—	0·9	28·3
Podzols	0·5	2·8	0·5	0·5	4·3
Basalt/podzol transition	24·6	17·5	6·6	9·5	58·2
Krasnozem (The Patch)	24·6	17·5	6·6	9·5	58·2
Total %	47·6	32·3	9·0	10·9	99·8

The Australians, even if not descendants of the original settlers, have usually been on the land for a considerable time. In most cases other national groups are more recent arrivals, particularly during the last 10 years. While Australians practise all types of farming, the Italians are almost solely market gardeners (hence their importance on the red loam areas) and family labour, usually unpaid, is a feature. A number of the Italians have no previous farming experience, and no scientific horticultural knowledge, so off-the-farm work is essential to augment farm income; the Monbulk jam factory is one common avenue. Soil exploitation and decline in fertility are the frequent consequence, yet, as with other nationalities, individuals more adaptable and willing to learn and experiment are reasonably successful.

The Dutch are mainly involved in the nursery business, especially tulips and bulb growing, and, because of the moister conditions required, they are found in the vicinity of the Silvan dam (Fig. 5, 6), and on the deep dacite krasnozems around The Patch (Fig. 7).

The other European migrant farmers, such as Poles, Greeks, Yugoslavs, and Hungarians, seem on the whole to be more experienced and to be making better adjustments to Victorian conditions than the Italians.

Costs and Rewards

Although this report is not concerned to give a detailed analysis of the farming economy, data collected make it possible to tabulate costs, returns, and yields that may be taken as typical (if not precisely average) of the area in question; these are presented as general costs (Table 4), and a more detailed breakdown of certain aspects of production (Table 6).

Table 4

General Costs

		Unit	Cost or payment	Comments
1 Trees, Plants, Bulbs, etc.	Strawberry runners	1000	£12/10/-	Ag. Dept (Toolangi)
	" "	"	£7/10/-	Growers' Assocn concession
	Cherry trees	100	£17/10/-	3/6 ea.
	Apples trees	"	"	"
	Peach trees	"	"	"
	Citrus trees	"	£90	18/- ea.
	Bulbs	acre	£2,000	Approx. 100,000/acre (Hyacinths, Tulips*)
2 Labour	Strawberry picking	lb	8d	A good day 100 lb (£3/15/-)
	Orchard work	hour	7/6 to 8/6	Seasonal labour
	Cherry picking	case	12/- to 14/-	Seasonal labour
	Nursery labour	week	£20	Unskilled
3 Transport	Berries to market	15%	3/6 per £1	Transport commission
Contract Rates, etc.	Ploughing	day	£30	Tractor and plough
	Dam construction	day	£80	Bulldozer
	Clearing	acre	£80-100	Bulldozer
	Channel water	1000 gals	2/-	
4 Land	Near Monbulk	acre	£600	Approx. only, depends on position, condition, etc.
	Near Silvan	acre	£300-£350	

* Tulips, formerly imported from Holland, are now prohibited in large numbers by quarantine regulations.

Table 5

Fertilizers: A Sample Survey

Crop	Fertilizer	Amount per acre (usually spring topdressed)	Cost/ton
Youngberries	B & B[1]	15 cwt	£20–24
"	2·2·1 c.m.[2]	18 cwt	£24 11 0
Loganberries	5·2·1 c.m.	7 cwt	£20 7 0
Gooseberries	B & B Potash	10 cwt 3 cwt	
Berry fruits	5·1·1 c.m.	7 cwt[3]	£18 15 0
Carrots	5·2·1 c.m.	10–12 cwt [4]	£20 7 0
Potatoes	"	15 cwt	
Tomatoes	"	5 cwt	
Beans	"	2–5 cwt	
Broccoli, sprouts	2·2·1 c.m.	8–20 cwt	£24 11 0
Pasture	2·2·1 c.m.	Autumn 3–5 cwt	£24 11 0
Orchards	2·2·1 c.m. 1·1·1 c.m.	4–5 lb 6 cwt	£25 5 0
Cherries	2·2·1 c.m.	10 cwt	£24 11 0
Citrus	2·2·1 c.m.	5–8 cwt	£24 11 0

[1] Blood and bone; [2] Complete manure; [3] Recommendation by Ag. Dept; [4] 10 cwt/acre is Ag. Dept recommendation.

Table 4 is by no means exhaustive but the wide scope of the report, together with the restricted time in the field, made it impracticable to seek more detailed data. In particular, there was no attempt at property or plant and machinery valuation, nor at an economic analysis of the relative importance of paid and unpaid labour. Some of these aspects are discussed in Bur. Ag. Econ. (1962). On the other hand, overall labour costs are not great when it is realized that there is very little permanent hired labour, even less casual labour. Picking labour does constitute a considerable expense during the particular harvest season, and in some cases reaches a third of total production costs. Fertilizer costs are next in importance, providing at least a tenth of total costs for more intensive types of farming (market gardens and berry growing), less for orchards, and at a minimum for pastures.

Table 5 indicates that, in a number of cases, fertilizer applications are heavier than those normally suggested by the Victorian Department of Agriculture extension officers. This is warranted in a few examples of unusually serious soil depletion, but very often the amounts now used are arbitrary or approximate; some farmers, principally new Australians, have no contact with departmental officers, and use inadequate amounts of fertilizer, while in other instances the one formula has been applied for a number of years despite changing soil needs, such as increasing potassium deficiency. As far as actual costs are concerned, the price per ton is fairly stable and uniform; prices are reduced 26/- per ton if the buyers' bags are used, or by 34/- per ton if delivered in bulk. A number of farmers indicated that they did not know that advice was available from agricultural department officers on such matters.

TABLE 6

Production Costs: Silvan Area

Yield per acre	Beans 100 bags*	 200 bags	Carrots 500 cases*	Strawberries 1 ton	 4 tons
Plants/seed	£3	£3	£5	£13	£13
Fertilizer	12	12	12–16	12	12
Labour	30	35	15	100	110
Picking	50	100	125	75	300
Marketing	19	37	60	42	168
Depreciation	10	10	—	10	10
Interest on capital	20	20	—	20	20
Rates	2	2	—	2	2
Insurance	3	3	—	3	3
Sundries	10	10	10	62	113
Total cost	£159	£232	£230	£339	£751
Cost per unit	£1/11/10	£1/3/8	9/3	£339	£187/15/-

* Bag = 1 bushel; case 1⅓ bushels.

A large number of vegetable and berry growers rely on agents for transport and marketing; others, notably the farmers with very large properties, generally provide their own transport. Approximately half the orchardists and three-quarters of the market gardeners sell market produce through agents on a 15% commission. Of the three market channels, roadside, local factory, and Melbourne, only the latter is catered for by agents at the uniform rate. Most high-grade produce is marketed

TABLE 7

Average Profits on Carrots: Silvan Area

Market price/case	Production cost/acre	Market price (500 cases)	Profit
8/–	£200	£200	£ –
16/–	230	400	170
£1	245	500	255
£2	320	1,000	680
£3	395	1,500	1,105

at Melbourne with second quality fruit going to local processors, the ratio between the two depending on Melbourne prices. The Victorian State Government and the Melbourne City Council enforce marketing regulations at the Victoria Market. Growers' organizations do not exercise supervision over producers and agents.

Table 7 gives details of financial returns over the last 2-3 seasons for carrots (de Vaus 1962). Although this table indicates the possibility of profits of up to £1,000/acre, the market price in early 1963 was only of the order of 16/-, and during the 1961-62 season frequently fell below 10/-. A similar comment would apply to many of the returns listed in Table 8.

Yields

It is relevant at this stage, while discussing economic rewards, to tabulate typical yields produced over the last 2-3 seasons for the more common crops in this area.

The range in yields cited is primarily an indication of year-to-year fluctuation. Nevertheless, such factors as better management, or more suitable soils, may mean

TABLE 8

Returns: Wandin-Monbulk

Crop	Unit	Grower's return	Comment
Tomatoes	bushel	8/–	
Carrots	case (1⅓ bush.)	10/– to 50/–	
Beans	bushel	45/–	£105/ton
Peas	bushel	30/–	(48 lb bags)
Potatoes	3-bushel	40/–	eating
	3-bushel	50/–	certified seed
	acre	£140-150	
Lemons	bushel	10/– to 20/–	
Plums	„	18/– to 28/–	Victoria Market
	ton	£22-25	poorer grades
Apples	bushel	10/– to 15/–	
Cherries	„	24/– to 30/–	40/– maximum
Strawberries	lb	1/11 to 2/6	inferior; to cannery
	„	3/6	marketed by grower
	„	2/9	marketed by agent
Other berries	„	10d to 1/2	10d jam fruit, 1/2 canning fruit
Tulips (flowers)	doz	6/–	Melbourne and roadside
Bulbs	1000	£25-30	tulip, hyacinth,
	„	£7-10	gladioli
Firewood	ton	£2	after clearing

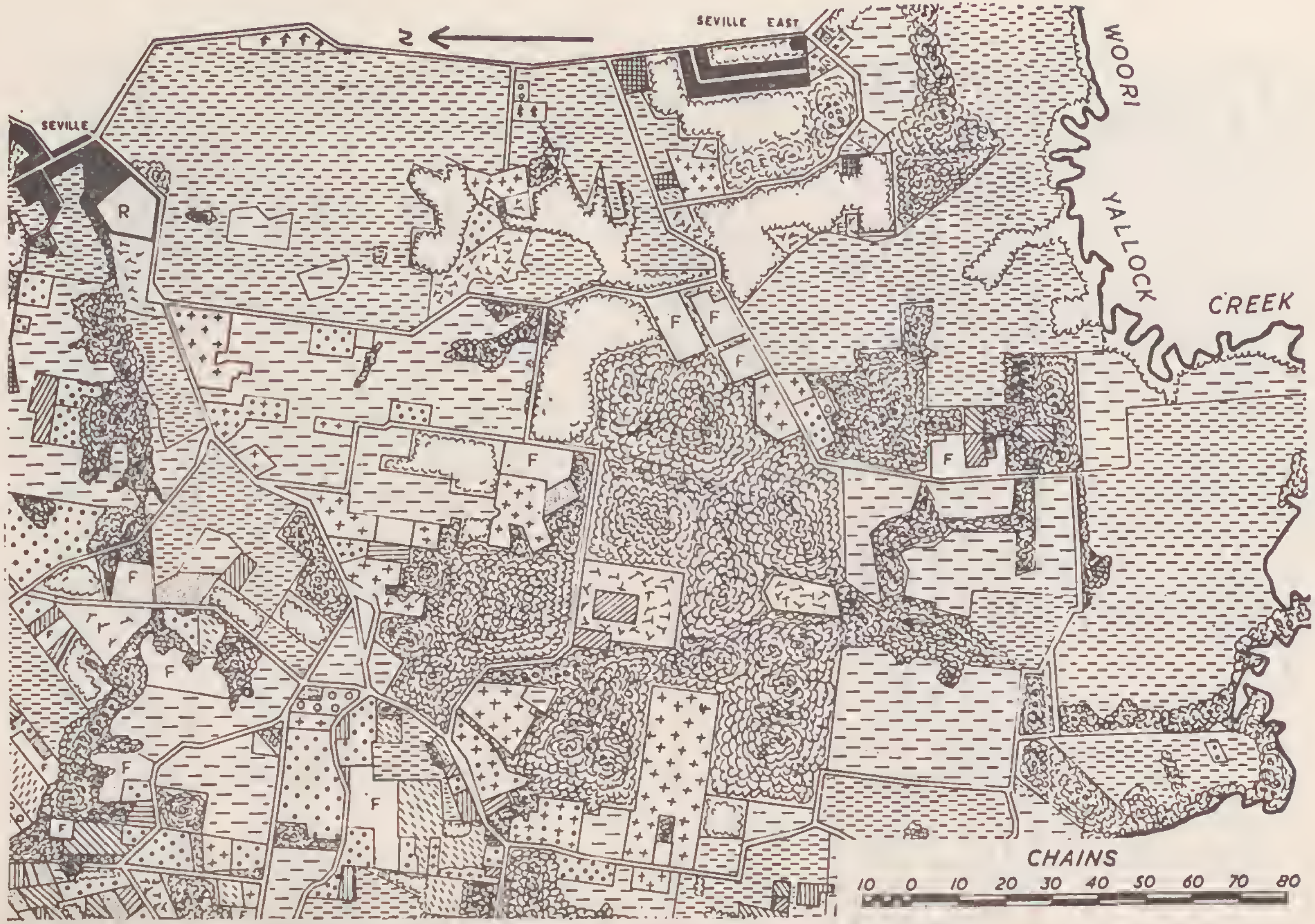

FIG. 4—Detailed land utilization map, June 1962, of the NE. of the Silvan-Monbulk region in the '*predominantly grazing and forest area*'. *See Fig. 3 for explanation of* symbols.

TABLE 9

Crop Yields 1960-2: Silvan-Monbulk Region

Crop	Yield
Tomatoes	800-900 bushels/acre
Carrots	1000 ,, ,,
Beans	150–200 ,, ,,
Potatoes	4–6 tons/acre
Lemons	3 bushels/tree
Plums	6½ ,, ,,
Apples	4–5 ,, ,,
Cherries	4 ,, ,,
Berry fruit	1–2 tons/acre

higher yields on individual farms, e.g. while the Victorian average potato yield (1961-62) was 5·38 tons/acre, a farm on basaltic soil N. of Silvan harvested 7·5 tons/acre. Similarly, a marked increase is possible in berry fruit production with the use of specially grown runners provided by the Victorian Department of Agriculture. Current berry yields average ¾-1 ton/acre for strawberries, and just over a ton for raspberries and other berries. Yet this has been raised in some cases to 5 tons/acre with the consistent use of virus-free strawberry runners supplied from Toolangi by the agricultural department. Whether this latter high yield can be maintained over any considerable period has yet to be ascertained.

Problems Associated with Land Use

ENVIRONMENTAL FACTORS

The adequacy of the water supply for farm purposes varies considerably within the Silvan-Monbulk region, and indeed from farm to farm. While the actual gross precipitation would be adequate for all but the most intensive land use (bulb nurseries are particularly demanding in this respect), the cumulative effect of run-off and evaporation means that irrigation is desirable and sometimes necessary for crop production. The steeper slopes of the red loams shed rainfall most readily, but the very nature of this relief hinders the provision of irrigation channels. The Yarra-Silvan conduit which traverses the area NE.-SW. can be drawn on for irrigation of crops at 2/- per 1,000 gallons, but may not be used to water pastures. Permission to irrigate from this source is restricted to properties downslope from the channel to minimize possible contamination from run-off and seepage. The Silvan Reservoir itself is reserved exclusively for Melbourne's domestic water supply network. Some farms, situated on transitional soils, have semi-permanent springs flowing from beneath the basaltic soils, and these are used to fill private dams from which the water is pumped or channelled as required. In most cases these continued to flow even during the dry period of 1961-2. A number of bores, notably NE. of Silvan, have been sunk in an attempt to tap this same water source. The total cost of boring (£800-£1,000 to drill 200 ft, or £500 after rains) would not seem, however, to be justified by the generally unsatisfactory results. Private dams are a more successful alternative, but there are two pre-requisites: a water source, whether run-off, spring, or creek; and a suitable soil. The free-draining basaltic soil is not suitable, although there are a number of dams in transitional areas where there is sufficient impermeable clay to inhibit the escape of water. In areas of podzolic soils, as in the

N. and E., dams must be sunk to considerable depth to minimize downward percolation; concrete construction of dams is the rather expensive alternative, but the two or three examples (all in the N.) have proved difficult to maintain from cracking.

Frosts and even 'cold snaps' cause considerable damage or the complete loss of certain crops. While the frosts are not usually severe, every season sees the loss of some strawberries, peas, beans, and to a lesser extent, orchard fruits. Frosts also affect plant and bulb nurseries E. of Silvan (Fig. 5, 6), but this has been minimized by the use of plastic sheeting. The fact that there are only one or two farmers who use 'smoke pots' would seem to indicate the infrequent occurrence of severe frosts. Severe hail storms, even less frequent, nevertheless cause great losses in all fruits when they do occur. Snowfalls are extremely rare but have marred or completely ruined some farmers' crops within the last 2-3 years.

In summer the combination of hot, dry northerly winds, and a northerly aspect, bring about the burning and withering of market garden and nursery crops; peas and strawberries are particularly prone. In contradistinction such aspects are favourable for the quick drying, during harvesting, of bulbs. Shelter belts are at least a partial answer also. The problem is most serious to the N. of the survey area, the Silvan Reservoir having at least a minimal alleviating influence in the centre and S., though, as mentioned, aspect is more significant than geographic location.

Soil fertility is a common though not universal problem. Even the krasnozems, basaltic or dacitic, are suited to cultivation because of their porous structure rather than their fertility; leaching accentuates the calcium deficiency, and the soil tends to fix phosphorus. In fertilizers recommended for the survey area (e.g. by officers of the Victorian Department of Agriculture, and by Commonwealth Fertilizers & Chemicals Ltd) the ratio of nitrogen, phosphorus and potash is fairly critical, as for all agricultural land. As with many Australian soils there is a notable phosphorus deficiency, but the water-soluble fertilizer superphosphate makes this immedaitely available to plants. Evidence suggests that the potassium deficiency also is becoming more serious in this area E. of the Dandenongs. A number of farmers are at present initiating or increasing the application of potash to counteract declining yields, particularly with orchards on podzolic or transitional soils. Up to 4 cwt/acre of potash as muriate is being applied in orchards.

Soil-slip is a common problem in the steeper areas of the basaltic soils. The red loams become 'greasy' after heavy rains and, if the slope is sufficient, tend to move downhill; the resulting rippling and terracing makes ploughing difficult, and has been known to break fences and, in one case, to undermine a house. Immobilization of such soils is usually a long-term process; some steep sections have been left under natural forest, or grass cover may be used to stabilize the soil. Land use is minimal or postponed indefinitely where soil-slip is serious. Even with moderate slopes, cultivation may be difficult in winter as the soils become slippery.

Erosion, on the other hand, is not a serious problem though with steep slopes, such as those on the N. side of Emerald Ck (Fig. 5), heavy rain after cultivation causes a combination of soil-slip and erosion; in this case recent cultivation is the differentiating and pre-requisite factor. Erosion occurred on some of the longer-established farms due, in the main, to the technique of cultivating in long strips. This has been overcome with the use of shorter furrows, grass strips on headlands, cover crops and inter-cropping, cross-ploughing, contour planting as in orchards, and the now common use of agricultural pipes for subsoil drainage, particularly in the podzolic soils.

Weeds, bracken fern, and blackberries are a common problem; the Sassafras

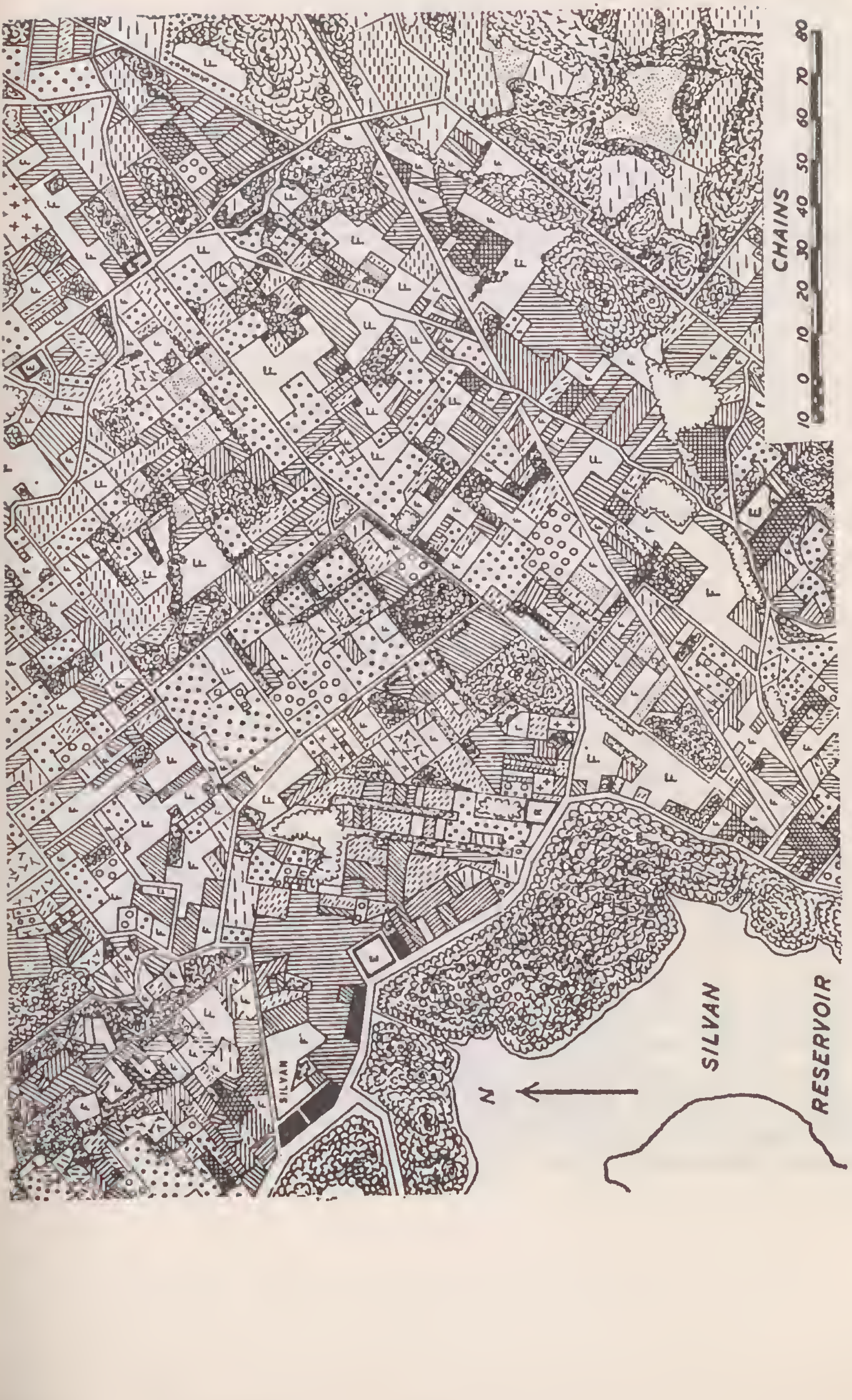

FIG. 5—Detailed land utilization map, June 1962, of the S. centre and the SE. of the Silvan-Monbulk Region. Parts of predominant land use areas shown are: (a) 'forest and grazing', flanking the E. and S.; (b) 'intensive market gardening', N. centre; (c) 'nurseries and market gardening', centre, to the E. and S. of Silvan Reservoir. See Fig. 3 for explanation of symbols.

Ck area is particularly bad in this respect (Fig. 7). The Patch Progress Association led a movement to have the problem attacked on a State-wide basis early in the 1920's. Hormone sprays and formulations like 2-4D are more successful than the original methods of eradication—cutting and burning. Bracken is not as widespread, except in wooded areas, and does not regenerate or spread as rapidly among growing crops on cultivated land as does the blackberry. Water-weed is prevalent on rejected land, and capeweed, Prince of Wales feather, and the wild radish also reach problem proportions.

Lindane, Dieldrin, and D.D.T. are the most commonly used insecticides in this area. Thrip on berries and nursery flowers, and aphis on cherries are particular problems; a number of orchards are sprayed with Bordeaux, and a kerosene weedicide is used at the rate of 40-70 gallons/acre on carrot crops (de Vaus 1956). Rootborer in cherries and other orchard trees is another insect pest.

Virus diseases have hit the growing of strawberries in particular, and even stocks of runners have on occasion had to be burnt. The variety 'Climax' was imported from Scotland, at first with little success, as growers had no method of preservation. The Department of Agriculture has been experimenting recently with several varieties at Toolangi—'Early Cambridge', 'Midland', 'Red Rich', 'Talisman', and 'Healthy Climax'. Such virus-free varieties, kept in cool stores, have enabled a considerable increase in yields, up to 5 tons/acre for 'Red Rich'.

From this brief survey of the environmental or physical problems of land use it can be seen that, while there are a number of difficulties or factors to be taken into account, nevertheless most if not all problems are being successfully combated.

PERSONAL FACTORS

Most of these have been mentioned already and probably apply to most persons engaged in this particular type of agriculture, at least throughout Victoria. Problems may be summarized as: (a) Lack of knowledge of intensive farming in general, and of market gardening, berry fruit growing, and orcharding under Victorian conditions in particular. This would apply on both the theoretically scientific and experimental levels, and especially, as mentioned previously, to Southern European migrant settlers. On the one hand there is often a complete lack of farm experience of any type and, on the other, a philosophy of 'anything goes'. Migrants' language problems tend to accentuate their isolation both from their Australian neighbours and from field officers available to advise them. Nevertheless, because some new Australian farmers are now, in fact, in regular contact with agricultural department officers (apart from the routine 12-18 monthly visit by the latter), it would seem that an increasing number of those who remain on the land will take advantage of this service. (b) To a lesser and decreasing extent, the lack of scientific farming knowledge applies to many other farmers in this area. A particular instance is the problem of soil fertility and maintenance of yields. Thus, on some older properties, fertilizer applications have not been adjusted for up to 25 years, despite recognized declines in yields and subsequent changes in the farm economy. Over the last 3-4 years, however, there has been an almost universal attack on this problem, and agricultural department officers, as a matter of course, visit all properties. (c) Lack of adequate initial working capital is again a particular problem of new Australian farmers; the prevalence of parallel, off-the-farm work, is one indication of this problem. The combination of inadequate initial capital, minimal farming knowledge, and possible early crop failure, sends a number of farmers back to the industrial suburbs of Melbourne each year.

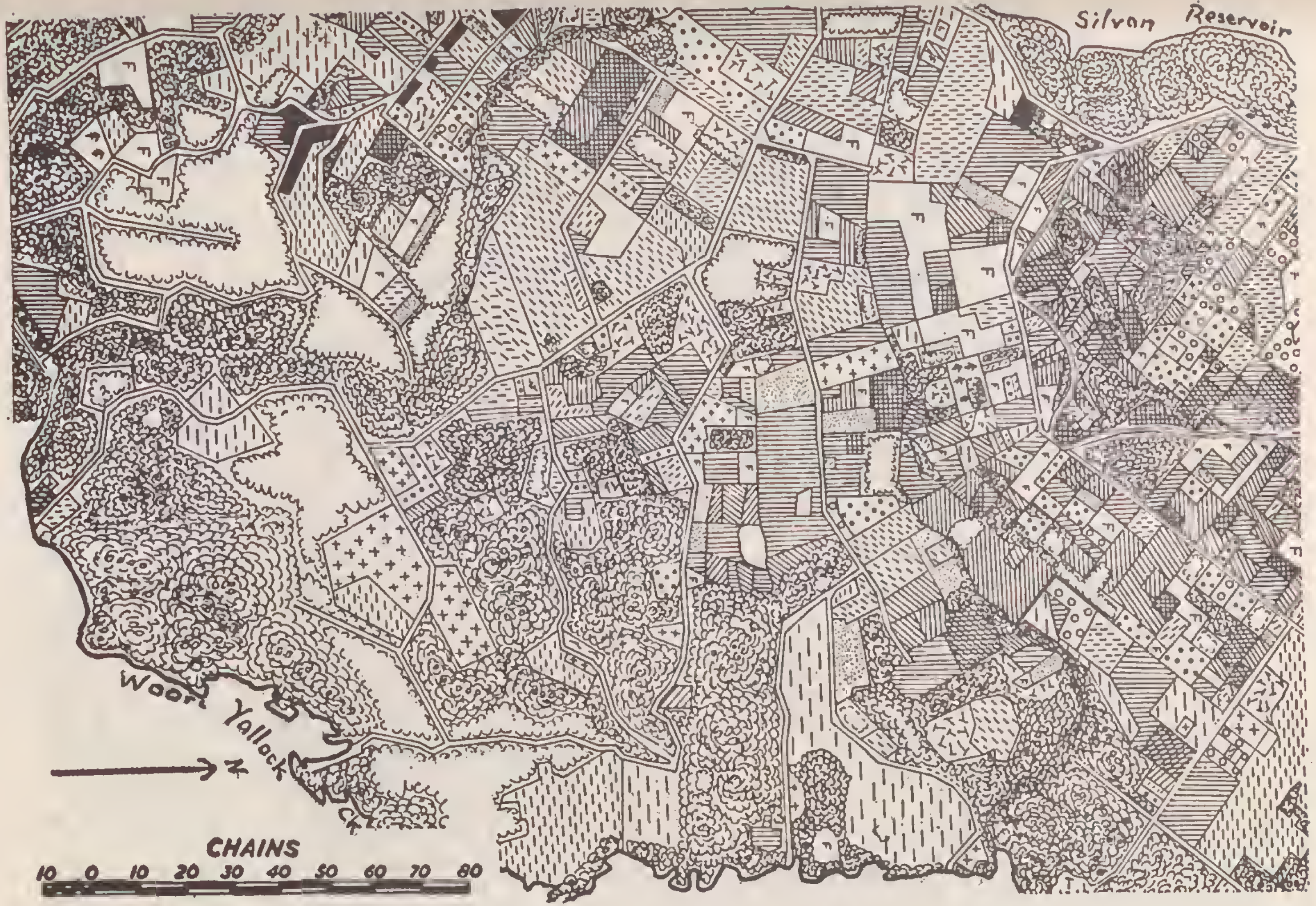

Fig. 6—Detailed land utilization map, June 1962, of the central area of the Silvan-Monbulk Region. Parts of predominant land use areas shown are: (a) 'forest', flanking the Silvan Reservoir; (b) 'market gardens and orchards', N. of Silvan; (c) 'orchard and market gardens', centre; (d) 'grazing and forest', on the E. flank. Note the concentration of berryfruit vines E. of Silvan. See Fig. 3 for explanation of symbols.

ECONOMIC FACTORS

As already pointed out, this paper does not intend to provide a detailed analysis of the economic structure of land utilization, but certain recurring economic problems can at least be outlined:

1. Competition in production and marketing is present in both the local and wider spheres. There is evidence of the existence of the age-old problem of large landholders 'squeezing out' the small (usually single-enterprise) farmers; e.g. berry fruit buyers pay less attention to small market gardeners than to larger mixed-economy farms. It is not clear whether this is a result of the latter being recognized as producing better-quality, more uniform crops. The larger landholders are finding less freedom on interstate markets than in the past, and are being increasingly confined to their home State.

2. Instability of prices is closely related to growing competition and here again more seriously affects the small farmers. Some have stored products such as potatoes, carrots, and lemons until prices rise, and it seems certain that this was the main factor in the change over from the berry fruit predominance of The Patch area 50-60 years ago to its present root-crops emphasis (de Vaus 1956). Also strawberry yields are lower on The Patch soils than at Silvan-Monbulk. Fluctuating prices do not always recoup labour and other costs and the result in both the larger and smaller properties in this area is for a gradual diversification. Some farmers experience intermittent difficulties in selling fruit in particular because they look for higher prices in Melbourne, rather than turning to the easier but less profitable Monbulk Cannery. However, this factory stops buying completely at certain times, so returns, albeit lower, are still by no means assured.

3. Transport of produce by agents on the 15% commission mentioned earlier closely reflects the size of the farm enterprise, only the largest properties finding it economic to provide their own transport. On the other hand, the agents' commission is excessively high due in the main to the lack of competition in this field.

4. Labour and employment: labour costs constitute a difficult problem on the smaller properties, but it is doubtful whether such assistance is usually necessary; the berry fruit industry and market gardening notably place much reliance on unpaid family labour. The readiness of the larger, more diversified farms to employ considerable harvesting (or picking) labour reflects both crop size (too large for mere family labour) and financial ability to pay this labour. This latter fact is due to a combination of higher gross returns, and to the spread of enterprise reinforcing the farm economic structure. The less labour-intensive nature of orcharding is one motivating force in the increasing importance of this form of land use.

The Monbulk Preserves Company, which derives its labour from within approximately an 8-mile radius, provides mainly unskilled work, but is an important supplementary income source for the district. Year-round jam making provides employment for about 120, while the December-April canning period raises factory employment to over 300 (1961-2). Two-thirds of this labour is female. Two shifts are worked in the latter season, and approximately 200 pickers are employed to pick company berries, grown in part for research into varieties. The Melbourne & Metropolitan Board of Works provides employment for many men during winter and seasonal 'off-peak' periods.

5. Subdivision and proximity to the Dandenongs: reference has been made already to the 'urban sprawl' invading this area, closely associated with subdivision and rising land values. This latter factor is also related to the developing tourist industry of the Dandenongs in general. The 1959 Interim Development Order

FIG. 7—Detailed land utilization, June 1962, of the SW. of the Silvan-Monbulk Region. Cf. Fig. 2. Parts of predominant land use areas shown are: (a) 'market gardens; (b) nurseries and market gardens; (c) forest; (d) urban centres of Monbulk and The Patch; (e) grazing and forest'. See Fig. 3 for explanation of symbols.

FIG. 8—Detailed land utilization, June 1962, of the NW. of the Silvan-Monbulk Region. Parts of predominant land use areas shown are: (a) 'forest and mixed', NW.; (b) 'market gardens and orchards', S. centre; (c) 'orchards and market gardens', E.; (d) 'grazing', NE.; (e) 'urban'. See Fig. 3 for explanation of symbols.

'freeze', and to a lesser extent the 1961 'credit squeeze', have temporarily slowed or halted subdivision. In most cases subdivision has been carried out by private landowners rather than by real estate agents, as is the case in other areas peripheral to Melbourne. Shire councils have been forced to increase rates to meet growing demands for urban services, roads in particular; grazing and general agriculture have been most seriously affected in this regard; more intensive, higher-return land use is more resistant to such pressures. Property fragmentation has also allowed formerly cultivated, or at least cleared land, to revert to scrub, blackberries and bracken. On the other hand, it must be pointed out that sites most sought for modern homes, steep heavily wooded slopes overlooking some portion of the Dandenongs, are just those areas most avoided by agriculture, intensive and extensive alike. The 'Ridge' area near The Patch is one example of this tendency for urban utilization of otherwise virgin or little-used land (Fig. 7). Town services for the area as a whole are not really adequate, perhaps because of the proximity to Melbourne; also, the required 'population threshold' may not have been attained for many urban services.

TABLE 10

Evelyn County Data 1959-62

Evelyn County	1959-60	1960-61	1961-62	% change 1958-59 to 1961-62
Rural holdings	2,592	2,656	2,715	+ 4·75
No. of fruit growers	692	676	667	— 3·61
Fruit growing acreage	5,891	5,981	6,050	+ 2·69
FRUIT PRODUCTION—bushels:				
Apples	240,403	305,506	223,305	— 8·00
Canning pears	3,134	6,794	2,817	— 1·01 —58·52*
Other pears	47,132	45,356	62,282	+32·15
Canning peaches	3,652	4,666	5,655	+54·84
Other peaches	37,556	28,281	48,505	+29·16
Plums	42,127	26,487	54,022	+28·22
Cherries	72,833	57,446	103,866	+29·89
BERRY PRODUCTION—cwt:				
Strawberries	6,234	6,121	10,235	+64·18
Raspberries	2,813	2,574	2,873	+ 2·13
Loganberries	2,357	1,992	1,624	—31·10
Gooseberries	1,038	555	677	—34·77
Youngberries	3,755	4,069	4,532	+20·69
Other berries	1,504	615	759	—49·55
VEGETABLES—tons:				
Potatoes	21,938	16,531	16,015	—27·00
All other	5,917	5,941	8,746	+47·80
NURSERIES—acres:	809	797	888	+ 9·77
LIVESTOCK—total:				
Dairy cattle	24,821	23,959	25,548	+ 2·93
Beef cattle	16,616	19,522	21,084	+26·88
Horses	2,340	2,048	2,020	—13·68

* % change 1960-61 to 1961-62 season.

Trends in Production and Land Use

Many references have been made already in this paper to changes in areal distribution and intensity of farming, and Table 10 in part provides a summary of this material. As most of the figures in this table show production rather than acreages, seasonal fluctuations partly mask the trends. The figures (Comm. Bur. Cen. Stats Vict. 1958-62) refer to Evelyn County, which encompasses the area with which this report is concerned, and in most cases reveal trends parallel to those noted in the Silvan-Monbulk region.

Recommendations for Future Research

1. A study of the significance of environment (geology, soil, slope, vegetation, hydrology, etc.), country of origin, and labour demand, in settlement.
2. A detailed economic analysis of all types of farming to supplement the Bureau of Agricultural Economics Survey on berry fruit growing.
3. Comparable land use surveys in surrounding areas to establish the continuity or otherwise of patterns recognized by this report.
4. The role of service centres such as Mt Dandenong, Ringwood, Belgrave, Monbulk, and Lilydale.
5. Recording of climatic data for this area E. of the Dandenongs, and away from the Silvan Reservoir.

Conclusion

The Silvan-Monbulk region is characterized physically by inversion of relief, with basalt-capped ridges and lower dissected Silurian sediments, dry sclerophyll vegetation, and a climate wetter and cooler than Melbourne.

The land use pattern is an extremely varied one. Property acreage ranges from less than one acre to over 300 acres, and is closely related to geology and soil type, and hence to the intensity of utilization, ranging from extensive grazing through orcharding to market gardening and berry fruit growing. The larger the property and the more diversified the farm production, the more stable the economy of the individual holding; small-scale intensive agriculture appears to be in a somewhat depressed condition. Nevertheless, yields are above average in some sections with particularly suitable soil, or because of the artificial development of fertility, or with the introduction of, e.g. specially treated plants, bulbs, and runners.

Where labour is of importance, the problem is minimized by the use of unpaid family labour. Local factory and Melbourne markets are catered for by agents at a uniform but excessively high rate. Instability of prices and a widespread increase in competition are more serious economic problems, however, and on their resolution rests much of the future agricultural development of the area. Fortunately, strawberries, economically the most important crop in the Silvan area, have remained stable for many years.

Physical problems are being overcome or held in check with (a) the use of irrigation, natural springs, and damming; (b) the addition of phosphorus, nitrogen and, latterly, potassium; (c) non-use or immobilization of steeper sections of basalt soil; and (d) the increasingly successful attack on the virus diseases of berries in particular.

Finally, maximum use is yet to be made of the professional advice available to all farmers, and at present there is a close correlation between the frequent depression of intensive farming, inexperience of new farmers, and inadequacy of initial working capital.

Acknowledgement

The authors wish to thank Mr W. Martindale, and Mr N. K. de Vaus, Horticultural Officer, both of the Victorian Department of Agriculture, for valuable criticism of the initial manuscript.

References

AVENT, K. L., 1954-60. Berryfruit growing in Victoria. *J. Agric. Vict.* 54-58.

BUREAU OF AGRICULTURAL ECONOMICS, 1962. *The Berry Fruit growing Industry: Victoria. An Economic Survey.* (Canberra)

CLIFFORD, H. T., 1953. On the distribution of the species of *Eucalyptus* in the region of the Dandenong Range, Victoria. *Proc. Roy. Soc. Vict.* 65: 30-55.

COCHRANE, G. ROSS, 1963. Vegetation studies in forest fire areas of the Mount Lofty Ranges, South Australia. *Ecology* 44: 41-52.

COMMONWEALTH BUREAU, CENSUS AND STATISTICS, 1962. *Victorian Rural Statistics Season 1961-62.* (Victorian office)

COMMONWEALTH BUREAU OF METEOROLOGY, 1958. *50 Years of Weather: Victoria 1908-1957.*

COULSON, HELEN, 1959. *Story of the Dandenongs.* (F. W. Cheshire)

EASTON, J. G., 1908. The geological boundaries in the Woori Yallock Basin. *Rec. Geol. Surv. Vict.* 2 (4): 198-199.

EDWARDS, A. B., 1940. A note on the physiography of the Woori Yallock Basin. *Proc. Roy. Soc. Vict.* 52: 336-341.

————, 1955. The rhyolite-dacite-granodiorite association of the Dandenong Ranges. *Proc. Roy. Soc. Vict.* 68: 111-149.

GENTILLI, J., 1948. Two climatic systems applied to Australia. *Aust. J. Sci.* 11: 13-16.

GREGORY, J. W., 1912. *The Geography of Victoria.* 2nd ed. (Whitcombe & Tombs)

LEEPER, G. W., 1955. Climate, in *Introducing Victoria* (Ed.) G. W. Leeper (Melbourne) 19-24.

SUMMERHAYES, J., 1958. The Australian berryfruit industry. *Quart. Rev. Agric. Econ.* 9: 44-58.

TRUMBLE, H. C., 1939. Climatic factors in relation to agricultural regions in Southern Australia. *Trans. Roy. Soc. S. Aust.* 63: 36.

VAUS, N. K., de, 1956. Carrot growing in the Dandenongs. *J. Agric. Vict.* 54: 155-158.

————, 1962. *Vegetable Growers' Digest*, 5, No. 2.

Explanation of Plate

PLATE XLVI

Representative landscape in the 'market gardens and orchards' area E. of Silvan, Silvan-Monbulk Region. Note the varied land use, small holdings, numerous farm buildings and the micro-pattern of strips of different market garden crops. Photo: Lands and Survey: Melbourne Metropolitan 1960, 1096/80.

9

SUPERPOSED FOLDING IN THE BEECHWORTH CONTACT AUREOLE

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Abstract

Analysis of the geometry and style of mesocopic structures developed in the hornfels of the Beechworth contact aureole suggest three periods of folding on the west flank of the North East Victorian Metamorphic complex. A microscopic form of rodding structure, developed in B2 folds, and deformed by the B3 folding, is described.

Introduction

A recent note (Beavis 1963) recorded evidence of at least two periods of folding in Ordovician slates near Mitta Mitta, on the E. margin of the Metamorphic Complex of North East Victoria. Evidence of three periods of folding, in beds of approximately the same age as those at Mitta Mitta, has now been obtained near Beechworth, on the W. flank of the Complex. Between Myrtleford and Beechworth the evidence of multiple deformation is abundant, but the advanced weathering and poor exposures over much of the area make detailed regional analysis almost impossible. In the contact aureole between the Murmungee Basin and Beechworth granites, however, some small but excellent exposures of fresh pelitic hornfelses occur. The study reported in this paper was restricted to one such exposure on the Lower Three Mile Ck. Because of the restriction, conclusions drawn from the study may not be generally applicable; they are intended to serve as a basis for the extension of the studies by others currently working in the area.

The folds of the first phase (B1 folds) are relatively large similar types, comparatively tight, with hinges spaced at intervals varying between 1 to 20 chains. Samples for detailed analysis were selected from a limb of one of these folds, at which scale the B1 folds are represented only as lineations (L_1). The samples show the lineations, L_1, L_2, L_3, of the three deformations; bedding S; and the strain slip cleavages S_2' and S_3' imposed during the second and third folding respectively. Any cleavage developed during the first deformation is not visible mesoscopically at the locality studied, but can be observed in metapelites elsewhere in the area. The B2 and B3 folds are strongly developed, but are rarely greater than 10 cm in size.

The writer acknowledges with gratitude the help received from the following:

Mr M. D. Leggo, of the University of Melbourne, who made available some of the samples studied, and prepared both Fig. 1 and the locality geology for this paper; and Mrs F. C. Beavis and Miss Elizabeth Carroll who assisted with the preparation of the figures.

Locality Geology

(By M. D. Leggo)

The locality examined, and from which the samples for detailed analysis were obtained, is situated on the Lower Three Mile Ck, ¾ mile below the junction of this stream with Two Mile Ck, and 2¾ miles SSW. of Beechworth township. The locality lies in a composite contact metamorphic aureole associated with the main Beechworth granite, an adamellite intrusion at the SW. of this granite, and the Murmungee Basin granite. The age of the parent sediments is not known with certainty since the nearest recorded fossils occur at Myrtleford, 15 miles S. of Beechworth, where Hall (1908) recorded *Dicellograptus*. The sediments consist of thin, finely laminated shales, alternating with thicker greywackes and occasional beds

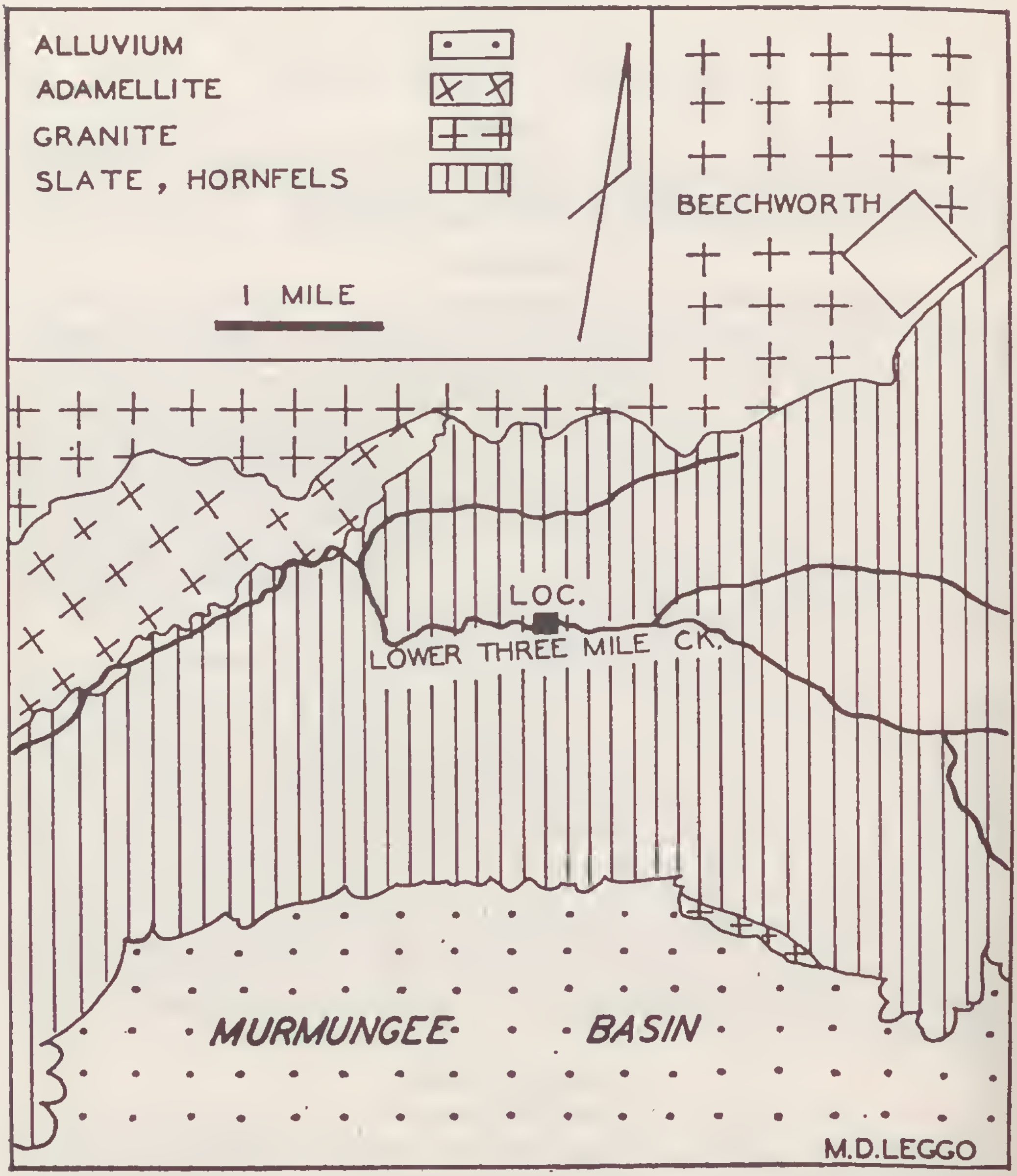

Fig. 1—Locality Map.

of grit. The strike of the bedding between Myrtleford and Beechworth varies between N.40° W. and N.10° W. Dips are steeply E., or more usually, W.

In thin section, the hornfels from the locality under discussion, is seen to consist of alterating bands of pelite and psammopelite with respective thicknesses of 1 mm and 2 mm. The differences between the two types are marked: the pelitic bands are conspicuously iron stained with less quartz and more mica than the psammopelitic bands.

The pelitic bands consist chiefly of mica, with muscovite predominating: the muscovite flakes are well developed, and have a larger size than the other minerals. Trains of sericite shreds, and a pleochroic colourless to light dirty green mica are also present. Quartz, chlorite, and opaque grains are the other main constituents. Yellow-brown iron oxide stains are pronounced.

The psammopelitic beds are composed mainly of strained quartz: the quartz has bubble-like inclusions. Shreds of sericite and small flakes of colourless to light brown pleochroic biotites are present. Felspar and opaque grains are minor constituents.

Structural Analysis

MESOSCOPIC ANALYSIS

Folding of the first (B1) phase:

The B1 folding which, from mesoscopic field observations had a style combining both parallel and similar elements, involved a foliation, S, formed by fine alternating dark and light bands 1 to 2 mm thick. This foliation represents a primary lamination emphasized by mimetic recrystallization during contact metamorphism. The lineation, L_1, developed on S during the B1 deformation, is represented by fine wrinkles or plications of S. The subsequent deformation of L_1 makes the determination of its general orientation difficult, but it seems to plunge very steeply to the S.

At and near the locality studied, axial plane cleavage (S_1') of this stage is not visible mesoscopically. This seems to be a feature of the area generally, S_1' being observed only very locally. The pelitic sediments involved in the B1 folding show the geometry of similar folds, but shear does not appear to have been a mechanism of significance in their deformation.

Folding of the second (B2) phase:

Since B2 structures have been deformed by the B3 folds, analysis was possible only by dividing the samples studied into domains in which the B2 folds were cylindrical and in which the axial surfaces, S_2', and axes, L_2, of these folds, displayed orientation homogeneity. The B2 folds are small antiforms and synforms, with rounded hinges; individual folds are rarely larger than 5 cm. These folds have developed in zones 12 to 25 cm wide, between which S remained planar during this phase. The axial surfaces are defined by a strain slip cleavage; the style of the folding is 'similar' and shear seems to have been the dominant mechanism. Profiles of these folds are illustrated by Fig. 2a.

The lineation, L_2, formed during B2, is defined by the hinges of the folds and by the intersection of S and S_2'. While L_2 is rectilinear over domains in which the B2 folds are cylindrical, the B3 deformation has produced an overall curvilinear form for L_2.

The analysis of B2 folds for two domains in which these folds are cylindrical, i.e. domains bounded by axial surfaces of B3 folds, is shown in Fig. 2b and 2c. For field A, the axial surfaces S_2' dip steeply SE. and strike north easterly. The fold axes, L_2, plunge 80° S. This field has apparent monoclinic symmetry. The

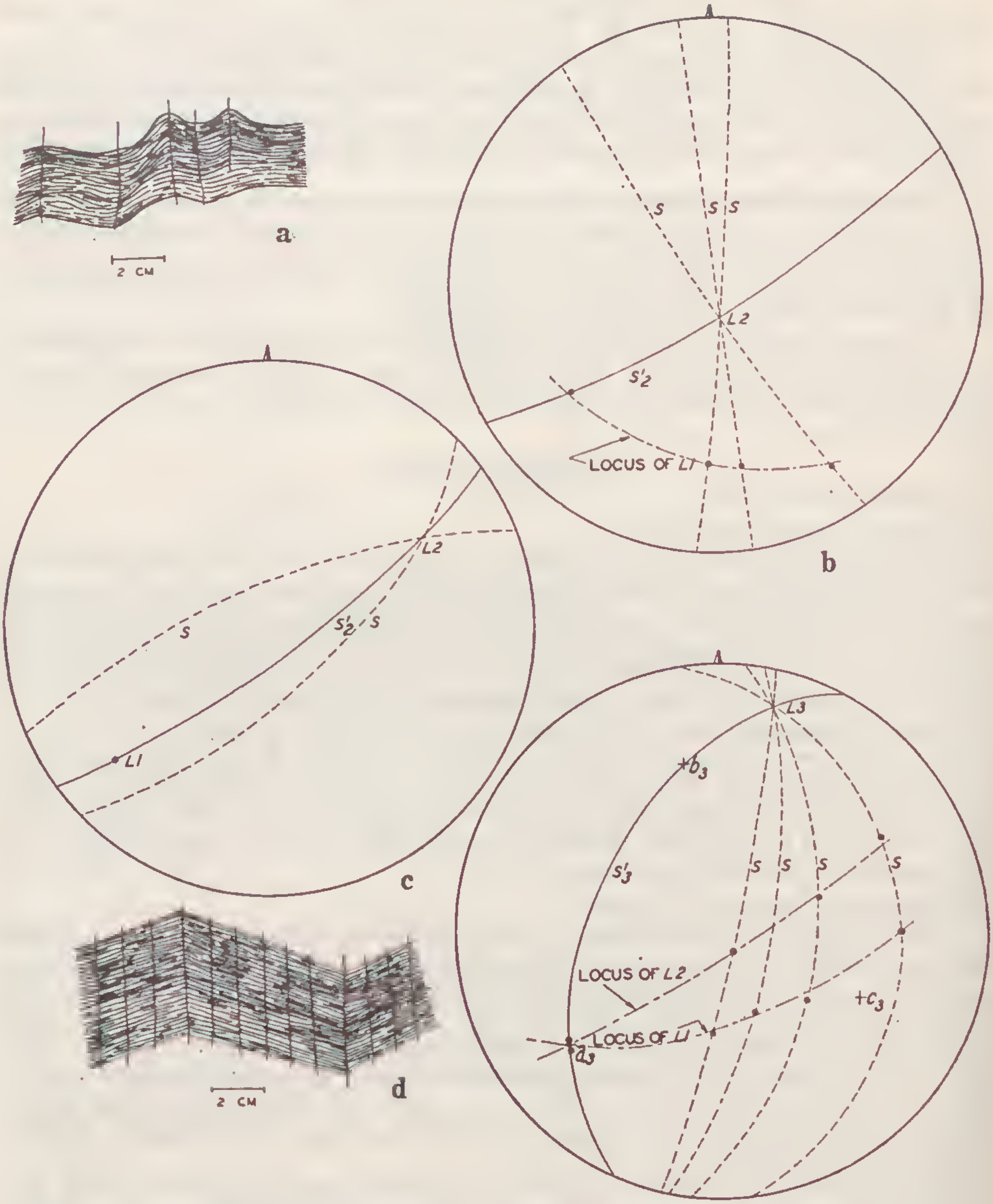

FIG. 2—Mesoscopic geometry of B2 and B3 folds.

a. Profile of B2 folds.
b. Analysis of B2 folds, field A.
c. Analysis of B2 folds, field B.
d. Profile of B3 folds.
e. Analysis of B3 folds.

orientation of L_1, deformed during the B2 phase, measured on limbs and hinges of the B2 folds, make angles with L_2 ranging between 49° and 62°, and lie on a great circle of the projection. Using the criteria of Ramsay (1960), these data support the observation that B2 folding was by a mechanism of shear.

The intersection of the locus of L_1 and the axial surfaces S_2' defines the direction of movement, i.e. the *a* tectonic axis of the B2 folding. Because of the B3 deformations, however, the orientation of *a*2 is apparent only, and, because of the uncertainty regarding the attitudes of S before B3, 'unrolling' about L_3 may not give the true orientation of *a*2.

Within field B, the axial surface S_2' shows a rotation with respect to its orientation in field A, while the folds themselves plunge to the NE. In this field, no sample showed a sufficiently clear definition of L_1 on B2 folds for the study of the deformation of the former to be attempted with any degree of confidence in the result.

Folding of the third (B3) phase:

Whereas the B2 folds are rounded, relatively appressed types, the B3 folds have a different style; they are broad, open, chevron-like antiforms and synforms, the hinges of the folds being spaced regularly at intervals of about 5 cm. The profile of these folds is shown in Fig. 2d. The axial surfaces, S_3', are planes of strain slip cleavage; these planes are spaced at 1 to 1·5 cm but are restricted to the hinges and, in some cases, one set of limbs. The lineation, L_3, is formed by the intersection of S and S_3' and of S_2' and S_3'. It is marked by ridges, 2 mm high, on S. This, again, is a contrast in style to the B2 folds, where S_2' was restricted to the actual axial planes. S_3' dips 50° WNW. and strikes NNE. L_3 plunges 12° in the direction N.16° E.

On the limbs and hinges of the B3 folds L_1 and L_2, deformed by the B3 phase, can be observed. These have been plotted in Fig. 2e. The loci of both sets lie on great circles of the projection: the angles which each makes with L_3 vary. For L_2, these are 45°, 82°, 122°, and for L_1, 70°, 93°, 100°, 108° and 122°. The geometry, then, confirms the mesoscopic data suggesting slip on cleavage planes as the mechanism of B3 fold development.

The loci of both L_1 and L_2 intersect S_3' in *a*3, the direction of movement in the B3 deformation. The *b*3 tectonic axis, which lies in S_3' can be found by construction. It will be noted that *b*3 and L_3 are not coincident. The B3 folds have been formed by slip on strain slip cleavage (*a*3 *b*3), and bedding planes. Hence, both from the structural and analytical viewpoints, these planes are of considerably greater significance than the fold axes which lie in these planes. This aspect becomes most important when, as in the case of the B3 deformation, the folds have developed in a surface with varying attitudes.

Microscopic Analysis

As stated above, the B1 deformation is represented in the samples by the mesoscopic L_1 and S. The latter appears in thin section as alternating quartz rich and mica rich laminae. For this study, thin sections were cut in two planes: one subnormal to L_2, the other subnormal to L_3. These sections show arrays of quartz domains not visible mesoscopically. The domains, which are restricted to the quartz-rich laminae, terminate abruptly against the micaceous laminae in the section $\perp L_3$. In the $\perp L_2$ section, the quartz domains lie parallel to S, and are restricted to the hinge zones of the B2 folds. In the $\perp L_3$ section, the domains lie *en echelon* in the plane of S_3' (Fig. 3a) while the long axes lie in S_2'. The domains are clearly linear structures on a microscopic scale, formed in the B2 folds parallel to L_2 and which were deformed by the B3 phase. They may be compared to the 'rodding structures' of Wilson (1953) but, because of their small size, some distinction should be drawn, and the term 'spindle structure' is suggested. Since these structures are restricted to the quartz-rich bands, it seems likely that they formed by segregation of quartz during the B2 folding. Kinking of the spindle structures where they abut on the micaceous bands argues some slip on S during the B3 folding (Fig. 3c).

FIG. 3—Spindle structures in hornfels.

a. Spindle structures in $\perp L_3$ section, prepared from composite photomicrograph.
b. Spindle structures in $\perp L_2$ section, prepared from composite photomicrograph.
c. Details of spindle structures in $\perp L_3$ section.

Analysis of [0001] quartz orientation has been made with two aims: one, to confirm the deformation of the spindle structures, the other, to attempt an assessment of the effects, if any, on the microfabric, of the B1 deformation.

Fig. 4a shows the [0001] orientation of quartz crystals which constitute the spindle structures: two partial girdles have been developed, one in S_2', the other in S_3'. The 7% maximum in the latter girdle is coincident with L_3, while the 4% maximum which lies in the S_2' girdle is coincident with L_2 in this field. Clearly, both B1 and B2 influenced the orientation of the quartz in the spindle structures.

The orientation of the matrix quartz (Fig. 4b) is more complex, as would be anticipated. Again, the strongest concentration of [0001] is in L_3, with the two partial girdles in S_2' and S_3'. There is, additionally, evidence of a third girdle containing three maxima (4%, 5%, 7%); the question arises as to whether or not this girdle represents S_1', the axial surface of B1 folds, not visible mesoscopically. Support for this idea is gained from the fact that the trend of this girdle approximates to that of the intersection of the plane containing the deformed L_1 and the plane of the thin section.

FIG. 4—Microscopic Analysis of Hornfels.

a. 193 [0001] quartz in spindle structure section ⊥ L_3.
Contours 7 – 6 – 5 – 4 – 3 – 2 – 1%.

b. 271 [0001] quartz in quartz-rich bands (matrix) of hornfels. Section ⊥ L_3.
Contours 10 – 9 – 8 – 4 – 3 – 2 – 1%.

Discussion

Bryhni (1962) stated that the distinction between different tectonic phases on the sole basis of differently oriented fold axes may not always be justified since one set of movements might be able to form linear structures of highly variable trend. It is not so much the trends of lineations which indicate more than one phase of folding '. . . it is rather the style of folding and the geometric harmony between structures of the same style'. A similar idea has been expressed by Ramsay (op. cit.). The tendency in recent years has been to concentrate purely on the geometric analysis of the structural elements, without adequate regard to the style of the elements themselves. In the present case, the geometric analysis certainly indicates three periods of folding. The B1 folds apparently developed by flexure, slip on S, and flow, without significant slip on cleavage planes. That some slip on cleavage S_1' did occur is suggested by the microscopic data. The B2 folds have a 'similar' style, and were developed by slip on cleavage planes which form the axial surfaces of these folds. Folding during the third deformation was again by slip on cleavage planes, although there is microscopic evidence of slip on S. These B3 folds have a chevron style, and, as previously noted, the cleavage planes are more highly developed and more closely spaced than the comparable B2 structures. There is a strong concordance of the geometry of the structures of the same style.

Initial deformation of the Upper Ordovician sediments from which the schists of the metamorphic complex were derived occurred during the epi-Ordovician Benambran Orogeny. Where the structure of the complex has been studied in detail, it has been found that the post-Benambran orogenies imposed discrete fault and joint structures, but not folds, on the schists. It has been concluded that, by the time the Bowning and Tabberabberan Orogenies were effective, the rocks of the complex were in such a tectonic environment and in such a physical condition that strain could only be expressed by discrete fracturing (Beavis 1962).

This leads to the idea that the superposed folding observed in slates and hornfelses on the flanks of the complex is not necessarily to be regarded as the result of more than one orogeny. Rather, it may be considered the result of separate phases of movement during the same orogeny. By virtue of the constantly changing environment and physical condition of the rocks, as well as the imposition of penetrative heterogeneities, and hence the varying orientation and intensity of the principal stresses, small folds of varying style and geometry could be imposed on the earlier major folds.

References

Beavis, F. C., 1962. The geology of the Kiewa Area. *Proc. Roy. Soc. Vict.* 75: 349-410.

————, 1963. Superposed folds in the Metamorphic Complex, North East Victoria. *Aust. J. Sci.* 26: 23-24.

Bryhni, I., 1962. Structural analysis of the Gr neheia area. *Norsk. Geol. Tidss.* 42: 331-371.

Hall, T. S., 1908. Report on graptolites. *Rec. Geol. Surv. Vict.* 2: 221.

Ramsay, J. G., 1960. The deformation of early linear structures. *J. Geol.* 68: 75-93.

Wilson, G., 1953. Mullion and rodding structures in the Moine Series of Scotland. *Proc. Geol. Assoc., London* 64: 118-151.

10

THE GEOLOGY OF THE KINGLAKE DISTRICT, CENTRAL VICTORIA

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Abstract

The Siluro-Devonian sediments of the Kinglake district, Central Victoria, are described and subdivided into two formations, the rich fauna allowing correlation with other Victorian Siluro-Devonian sequences. It is shown that the vascular land plant *Baragwanathia longifolia* occurs in mudstones of Lower Devonian age, well above its hitherto accepted Lower Ludlow horizon. A lateral change in facies within the area investigated is postulated, with deeper water to the E. and N.

Petrological study indicates that the sediments were derived from both granitic and sedimentary rocks; an ancient folded and intruded terrain, contributing detritus to the Central Victorian Lower Palaeozoic trough, is envisaged. Directional sedimentary structures suggest that the sediments of the Kinglake district had a westerly source, and discussion follows on the palaeogeography of Central Victoria in Siluro-Devonian times.

The structural geology of the Kinglake district is described and a mechanism given for the genesis of the arcuate folds present. Experimental evidence indicates that this mechanism, involving basement sinistral shear-zones, would account for the arcuate fold patterns of the Silurian and Lower Devonian sediments of Central Victoria.

Finally, the petrology of the igneous rocks of the Kinglake district is briefly described.

Introduction

The rocks described in this paper occur near the W. margin of the great Central Victorian belt of Silurian and Lower Devonian sediments (Fig. 1), forming part of a complete Victorian marine sequence from the Lower Cambrian to the Lower Devonian. The sediments studied have been subjected to only one period of orogenesis, the Tabberabberan Orogeny, of late Middle or Epi-Middle Devonian time.

The area investigated is approximately 30 miles long by 20 miles wide, the S. boundary being about 15 miles N. of Melbourne. The Great Dividing Range of Central Victoria, dividing the area roughly in two, averages about 1,800 ft above sea level, and rises to 2,601 ft at Mt Disappointment. S. of the Divide is the undulating Nillumbik Terrain varying between 400 and 600 ft above sea level, while to the N. the countryside is youthfully to maturely dissected, the main streams having lower gradients than their S.-flowing counterparts.

Most exposures of rock, limited in the main to creek sections and road cuttings, were examined. Mapping was done on military contour maps, scales 1 in. to 1 mile and 2 in. to 1 mile, while air-photos proved useful in rugged country. Laboratory work was carried out at the Geology Department, University of Melbourne, where the fossils and thin sections described are lodged.

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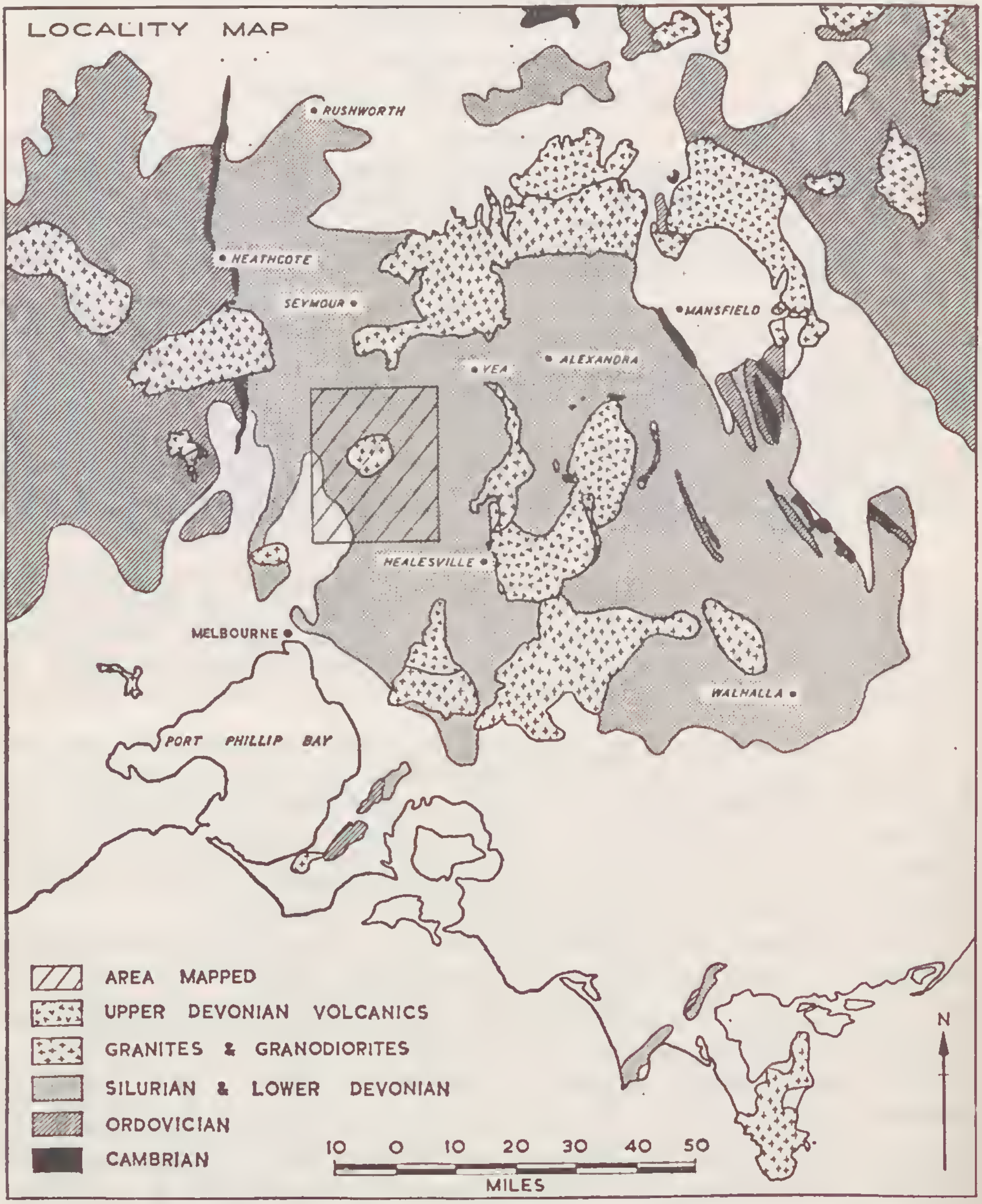


FIG. 1—Geological Map of the Lower Palaeozoic Rocks of Central Victoria.

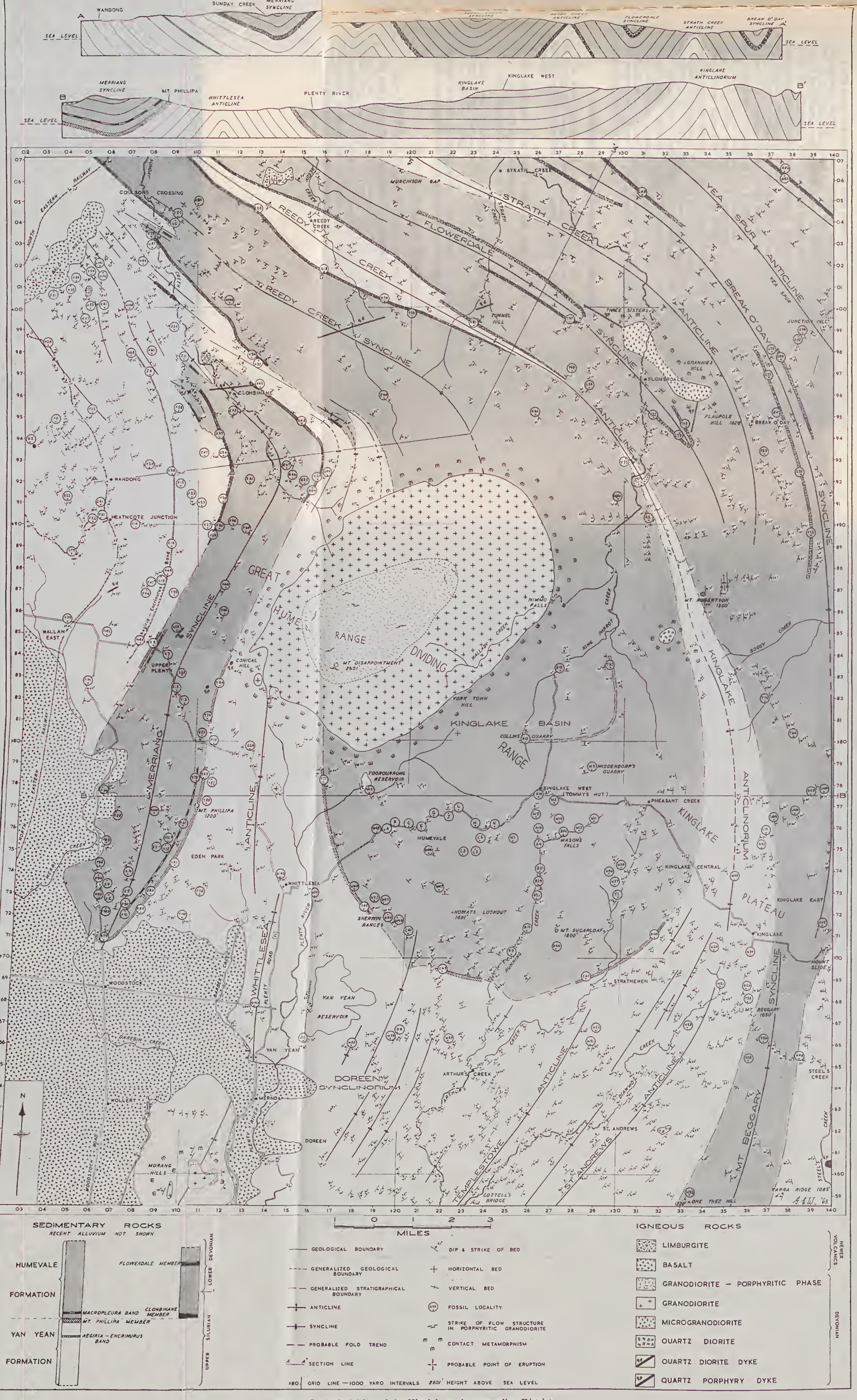


FIG. 2—Geological Map of the Kinglake and surrounding Districts.

Previous Literature

Little work had previously been done on the sedimentary rocks within the area investigated. Murray (1884) described, with map, the Reedy Ck goldfield to the NW. of Kinglake. He noted that the fold trend at Reedy Ck was at right angles to that at Melbourne, and suggested that N. of Melbourne, the folds described a curve to the W. Chapman (1904) listed fossils found near the Yan Yean Reservoir, concluding that the sediments were of Melbournian age. Jutson (1908) described the Silurian sediments at Eden Park, W. of Whittlesea, recognizing two major folds, which he named the Merriang Syncline and the Whittlesea Anticline. In an appendix, Chapman identified the fossils found by Jutson, giving a Melbournian age to the beds contained in the Whittlesea Anticline, and a Yeringian age to those in the core of the Merriang Syncline. On the basis of the chonetid brachiopod fauna, Gill (1945b) ascribed a Lower Devonian age to the siltstones at Kinglake West; further papers by Gill (1947, 1948b, 1948d) and Gill and Caster (1960) described several species of trilobites and carpoids from these beds.

Most of the igneous rocks had likewise received little attention. Whitelaw (1899) described gold-bearing dykes at Clonbinane and Steel's Ck, a further note on the gold and antimony occurrences at Clonbinane being given by Jenkins (1902). Junner (1914) included a detailed petrological study of the Yow Yow quartz diorite intrusion, Queenstown. Edwards and Baker (1944) described the petrology of the Morang Granodiorite and associated metamorphic rocks, concluding that the porphyritic phase of the intrusion was probably due to contamination by potash-rich country-rock.

Stratigraphy of the Kinglake and Surrounding Districts

The total thickness of rocks exposed is of the order of 14,000 ft, although the general monotonous lithology made subdivision difficult. The extremes of grain size are usually not great, with siltstones being by far the most common rock type present.

The sediments have been subdivided into the following two formations:

1. The Yan Yean Formation	5,000 + ft
2. The Humevale Formation	9,000 + ft

These two formations are described below in general terms. More detailed accounts of their palaeontology, petrography and sedimentary structures are given in later sections. Table 1 shows the distribution of identifiable fossils from the Kinglake district. Stratigraphical relationships are given in Table 2, while the detailed stratigraphy and structure of the area mapped is shown in Fig. 2.

THE YAN YEAN FORMATION

Age—? Middle to Upper Silurian. Estimated thickness—5,000 + ft.

The name Yan Yean Formation is proposed for strata typically exposed at Yan Yean, S. of Whittlesea, and also developed in the Wandong, Clonbinane and Kinglake East districts, the formation consisting of rhythmically bedded sandstones and mudstones in the type area. This formation, the base of which is not seen, is conformably overlain by the Humevale Formation, and its development in a number of districts is discussed below.

YAN YEAN DISTRICT

The maximum thickness exposed here is approximately 5,000 ft on the flanks of the Whittlesea Anticline, the sediments being evenly-bedded, and often laminated sandstones, mudstones and siltstones (Pl. XLVII, fig. 1). The sandstones, generally a pale yellow-brown, often exhibit cross-bedding, ripple-drift bedding, and flute casts. Grading is occasionally present in these beds, but only within the range of sand-size particles. The mudstones and siltstones, mainly light blue-grey to brown in colour, often contain fine sandstone laminae which may become impregnated with iron oxide and stand out as thin bands on weathering. Several large slump structures are present, the mudstones being greatly contorted between the competent sandstone strata.

The sediments are poorly fossiliferous, with most of the fossils occurring sporadically in the mudstones. At the Yan Yean Reservoir dark mudstones contain a distinctive fauna of numerous *Encrinurus* sp. and *Aegiria* sp.; N. of Whittlesea is a band containing abundant monograptids.

An assemblage of micaceous sandstones is taken to represent the top of the Yan Yean Formation at Eden Park and Whittlesea. The sandstones are symmetrically developed on each side of the Whittlesea Anticline, and were first noted as a possible marker horizon by Jutson (1908). The beds, containing numerous *Nucleospira* sp. and small rhynchonellids, are important because they show the relative ages of the fossiliferous siltstones at Eden Park and Kinglake West. Being typically developed at Mt Phillipa, W. of Whittlesea, the sandstones are named the Mt Phillipa Member.

The sediments of the Yan Yean district have been thrown into a number of N.-S.-trending folds. Dips from 40° to 70° are common, with occasional vertical beds and crush-zones, although none of the mudstones has been converted into slate.

UPPER PLENTY DISTRICT

At Upper Plenty about 4,000 ft of easterly-dipping sandstones and siltstones are developed. The lower 2,000 ft, predominantly siltstones, have produced several specimens of *Dalmanites wandongensis* Gill. The upper beds contain poorly preserved graptolites, while a mudstone band containing *Encrinurus* sp. and *Aegiria* sp. has been traced N. for about 6 miles to the Wandong district. This band is probably on the same horizon as the *Encrinurus-Aegiria* beds at Yan Yean. The top of the formation is marked by sandstones containing abundant small rhynchonellids, almost certainly equivalent to the Mt Phillipa Member.

WANDONG DISTRICT

In the Heathcote Junction-Wandong district, the Yan Yean Formation is represented by over 5,000 ft of tightly folded mudstones, siltstones and occasional sandstones.

The lower 2,000 ft in the Heathcote Junction district are similar lithologically to the rocks at Yan Yean, and contain few fossils. S. of Bald Hills, at Locality F31, a sandstone horizon above these lower beds contains an abundant fauna, noteworthy for the great number of starfish, carpoids and graptolites. This is Locality Bb23, Quarter Sheet No. 4 NW., of the Geological Survey of Victoria.

About 2,000 ft of rhythmically-bedded siltstones and very thin ripple-bedded sandstones follow, typically developed at Broadhurst's Ck and the Wandong railway quarries. At the Wandong quarries the beds are low-dipping as they occur in the centre of a NW.-plunging syncline, and are characterized by the presence of

Dalmanites wandongensis Gill, locally abundant. It is considered that these siltstones are in part equivalent to the lower beds at Upper Plenty.

The upper 1,000 ft of the Yan Yean Formation are composed of siltstones and sandstones containing *Encrinurus* sp. and *Phacops* sp., the abundance of *Encrinurus* suggesting part equivalence with the *Encrinurus* beds at Upper Plenty and the Yan Yean Reservoir.

OTHER DISTRICTS

Siltstones and sandstones stratigraphically equivalent to the Yan Yean Formation are present in the crests of the major anticlines at Reedy Ck and Kinglake, but have proven poorly fossiliferous. However, at locality Y73 about 2 miles S. of Flowerdale, mudstones contain numerous *Encrinurus* sp. and small rhynchonellids.

THE HUMEVALE FORMATION

Age—Upper Silurian to Lower Devonian. Estimated thickness—8,500-9,000 ft.

The name Humevale Formation is proposed for the great thickness of siltstones, and rare sandstones and conglomerate conformably overlying the Yan Yean Formation. Massive siltstones comprise most of the formation, and are typically exposed at Humevale, about 3 miles SW. of Tommy's Hut. The formation is extremely widespread, being developed at Eden Park, Kinglake West, the Clonbinane-Flowerdale-Yea district, and W. of Steel's Ck.

Two arenaceous members are recognized in the Humevale Formation, the Clonbinane Member at the base and the Flowerdale Member near the top. The siltstones forming the greater part of the formation will be referred to as the Humevale siltstones.

THE CLONBINANE MEMBER

Maximum thickness—400 ft; average thickness—200 ft.

The Clonbinane Member is composed mainly of yellow-brown micaceous sandstones typically exposed in cuttings along Spur Rd and Quarry Rd, Clonbinane. The sandstones are medium to fine-grained, averaging about 1 ft to 18 in. in thickness (Pl. XLVII, fig. 2). They are often well laminated, and occasionally show graded bedding with mud-pellets along the base of some beds, cross-bedding, ripple-drift bedding, and flute casts. Fossils are locally abundant in narrow bands. Interbedded blue-grey siltstones and mudstones are generally only a few inches thick, having either a sharp or a gradational contact with the underlying sandstones.

The member outcrops within about 200 square miles in the NW. of the area mapped, with both grain size of the sandstones and thickness of the member increasing to the NW. S. and E. of Clonbinane the relative proportion of interbedded siltstones increases until the sandstones are no longer mappable. Thus the Clonbinane Member may be regarded as lenticular, wedging out to the S. and E. Near Broadford to the NW., the rock has been quarried for building material, and is known locally as 'Broadford stone'.

The Clonbinane Member is moderately to steeply dipping, averaging about 50°-60°. The beds are repeated five times from W. to E. by the major folding, and generally strike NW., although S. of Clonbinane the trend is NNE. Crush zones are present at Tunnel Hill and Coulson's Crossing, while auriferous quartz veins and unmineralized joints are widespread. The sandstones often form prominent strike ridges, such helping greatly in their mapping.

THE HUMEVALE SILTSTONES

Estimated thickness—8,500 ft.

These beds are extremely widespread and form the bulk of the sediments of the Humevale Formation. The conglomerates and grits of the Flowerdale Member are interbedded with these siltstones high in the sequence.

The lithology is very monotonous, the beds at Kinglake West being fine-grained siltstones and mudstones from 2 ft to 8 ft thick (Pl. XLVII, fig. 3), with a few interbedded sandstones. The siltstones are dark blue-black in colour when fresh, weathering to a grey or yellowish-brown. Sedimentary structures are rare, cross-bedding occurring in only the coarser-grained strata.

HUMEVALE-KINGLAKE WEST

The siltstones at Kinglake West form a broad synclinal structure, with most beds dipping about 10° N. The sequence has been divided into four, each division representing about 2,000 ft of sediments.

Lower 2,000 ft:

These beds directly overlie the sandstones of the Mt Phillipa Member and are poorly fossiliferous, with shelly fossils occurring sporadically in the thick siltstones.

2,000-4,000 ft:

Here fossils begin to be more plentiful with the entry of many new species, although there is no change in lithology. Characteristic forms are *Notanoplia australis* (Gill) and *Chonetes ruddockensis* Gill.

4,000-6,000 ft:

Exposure is poor, but the few fossil localities have produced an abundant fauna.

Middendorp's Quarry, on Stony Ck, about 1½ miles NE. of Tommy's Hut, lies a few hundred feet above the base of this division. Gill (1947) recognized three main fossiliferous bands at this locality, one rich in trilobites, one in corals, and the third containing mainly echinoderms. The lithologies of the bands are similar, being blue to grey fine-grained siltstones with a few thin current-bedded sandstones. Due to the poor exposure, these fossiliferous bands have not been traced further in the field.

Nearly 1,000 ft above the Middendorp's Quarry horizon are the sandstones and siltstones of Collins's Quarry, at the headwaters of King Parrot Ck. The sandstones are yellow to grey in colour, show graded bedding, occasional crossbedding and contain an abundant fauna. They have been traced to the N. and E. in Stony Ck and Mathieson's Ck, but poor exposure did not permit their total thickness to be calculated.

6,000 ft to top of sequence:

There is little change in lithology to the top of the sequence, although the siltstones generally are not as fossiliferous as those of the previous division. The top of the Humevale Formation is not seen, the upper beds having been intruded by the Mt Disappointment Granodiorite.

EDEN PARK-UPPER PLENTY

At Eden Park, W. of Whittlesea, about 3,000 ft of coarse siltstones and fine sandstones overlie the Mt Phillipa Member in the Merriang Syncline, and are considered equivalent to the lower 3,000 ft of the Humevale Formation at Humevale-Kinglake West.

0-2,000 ft:

These beds are coarser-grained and contain a much more abundant fauna than equivalent strata at Humevale. The lowest fossiliferous beds occur about 400 ft above the base of the Humevale Formation, and belong to the 4 ft thick 'limestone band' of Jutson (1908). This band contains an abundant brachiopod fauna, and at Cemetery Lane much of the original calcareous material of the shells is preserved. The band is characterized by a large spiriferid, *Macropleura densilineata* (Chapman), and has been traced from Cemetery Lane for over 4 miles to the N., also being found on the W. limb of the syncline at Upper Plenty. However, in the N. outcrops the calcareous material has been leached away, leaving the impressions of the fossils in the silty matrix. The *Macropleura* Band, shown in Fig. 2, is considered to be on a similar horizon to the Clonbinane Member outcropping to the N.; brachiopod faunas are comparable, although the Clonbinane Member is relatively richer in echinoderms, and the *Macropleura* Band in trilobites. This is probably a reflection of facies.

Except for *Macropleura*, similar fossils to those of the *Macropleura* Band are found in the remaining 1,600 ft of this division.

2,000-3,000 ft:

The top 1,000 ft are contained in the core of the Merriang Syncline at Upper Plenty. The lithology is slightly different from the lower beds at Eden Park, with the thick, indurated siltstones gradually giving way to thinner bedded siltstones, mudstones and occasional sandstones. There is also a change in fauna, with the presence of *Notanoplia, Plectodonta*, and *Chonetes ruddockensis* further emphasizing the equivalence of these beds with those of the second lowest division at Kinglake West.

CLONBINANE-FLOWERDALE-YEA

Over 6,000 ft of siltstone in beds 6 in. to 18 in. thick overlies the sandstones of the Clonbinane Member in the major synclines of the Clonbinane-Flowerdale-Yea district, being interbedded with the conglomerate of the Flowerdale Member near the top of the sequence.

0-2,000 ft:

These beds are generally poorly fossiliferous, but have yielded a single specimen of *Monograptus dubius* cf. *thuringicus* Jaeger only a few hundred feet above the top of the Clonbinane Member, and *M.* cf. *uncinatus* at Break-o'-Day.

2,000-4,000 ft:

Probably equivalent to the second lowest division at Kinglake West, and the upper beds at Eden Park.

4,000-6,000 ft:

The horizon of the Flowerdale Member is taken as the top of this division. These upper beds, now represented by slates, occur near the axes of the major synclines. The cleavage is rarely parallel to the bedding and consequently no fossils have been found in these beds, which appear to be slightly finer-grained than the underlying siltstones. However, the cleavage decreases in intensity to the E., and numerous fossils, notably *Baragwanathia longifolia* Lang and Cookson and *Panenka* sp., have been found in fine siltstones in a road-cutting about 4 miles SW. of Yea (Locality A82). As this locality underlies the Flowerdale Member by only about 200 ft, it is considered to be on approximately the same horizon as Collins's Quarry at Kinglake West.

Siltstones above the Flowerdale Member show intense cleavage, and so far have not yielded any fossils.

STEEL'S CK-KINGLAKE EAST

A large syncline running from W. of Steel's Ck through Kinglake East and N. towards Break-o'-Day contains approximately 6,000 ft of siltstones and mudstones, most referable to the Humevale Formation, although absence of marker horizons makes exact correlation difficult.

W. of Steel's Ck, fine blue-grey siltstones and occasional sandstones have yielded a small fauna. At Kinglake East the beds are finer grained and less fossiliferous than those at Kinglake West. It was not possible to mark an exact boundary here between the Yan Yean and Humevale Formations, but the lowest fossil localities (L109, L111) are probably on approximately the same horizon as the Mt Phillipa Member of the Yan Yean Formation. The upper 3,000 ft of siltstones and mudstones contain a similar fauna to the upper 3,000 ft at Kinglake West.

THE FLOWERDALE MEMBER

Maximum thickness—approximately 200 ft.

The Flowerdale Member consists of a persistent horizon of conglomerate, grits and sandstones present in the cores of three major synclines in the Flowerdale-Yea district, although not developed in beds of equivalent age at Kinglake West. However, this member is considered to be on a similar horizon to the sandy beds at Collins's Quarry, Kinglake West (see Table 2).

The Flowerdale Member has been divided into two lithological units, a lower conglomerate phase, and an upper sandstone-grit phase.

Conglomerate Phase: Maximum thickness—50 ft.

The conglomerate is not as extensive as the grits and sandstones, but where present, almost invariably forms the base of the member, except where locally underlain by a few feet of coarse sandstone. The pebbles, mainly of reef quartz and quartzite, and occasionally slate, chert and sandstone, range in size from a fraction of an inch to 1 ft in diameter, in most cases being poorly sorted. The great majority are well-rounded, although the smaller ones of less than an inch diameter are often angular or only slightly worn (Pl. XLVIII, fig. 1). The matrix of the conglomerate varies in texture from fine siltstone to coarse sandstone, much of the siltstone now being represented by slate. The largest pebbles occur at Locality Y97 in the SW.

Abundant crinoid columnals and small, poorly preserved brachiopods are ubiquitous in the conglomerate, but at localities Y97 and A85 numerous well-preserved fossils are present in the muddy matrix, many of the species not having been found elsewhere in the Kinglake district. These two widely spaced localitis with similar faunas suggest equivalence of all outcrops of conglomerate within the area investigated.

Sandstone-Grit Phase: Average thickness—100-150 ft.

This phase overlies the conglomerate and locally comprises the whole of the Flowerdale Member. The sandstones and grits, of grey to light-brown colour, occur in beds 1 to 3 ft thick often containing small quartz pebbles and calcareous shell fragments. Graded beds and flute casts are common, although cross-bedding is not well developed. Fossils are numerous and comparable with those from the upper beds at Kinglake West.

TABLE I

Distribution of Fossils from the Kinglake and surrounding Districts

SPECIES	YAN YEAN FORMATION							HUMEVALE FORMATION														
		Upper Plenty		Wandong District					Kinglake West					Eden Park		Clonbinane-Flowerdale-Yea					Flowerdale Member	
											4,000′–6,000′											
	Yan Yean	0–2,000′	2,000′–4,000′	0–2,000′	F31	2,000–4,000′	4,000′–5,000′	Clonbinane Member	0–2,000′	2,000–4,000″	Midd. Q.	Coll. Q.	6,000′→	0–2,000′	2,000′–3,000′	0–2,000′	2,000′–4,000′	4,000′–6,000′	Steel's Creek	Kinglake East	Conglomerate	Sandstone
Tabulata																						
Pleurodictyum megastoma McCoy								c		c	c	c		c	c	r	o		r		c	c
P. sp.								c	r	c	c	c	o		c						o	
Favosites cf. *forbesi* Edwards and Haime																					r	
F. sp.								r			o	o									o	
Rugosa																						
'*Lindstroemia*' *scalaris* Chapman	r				o								r							r		
'*L.*' *parva* Chapman	r	r					o													r		
'*L.*' *conspicua* Chapman	r	r					o	o	r	o				c	c		o					
'*L.*' *yeringae* Chapman										o	c	c	o									
'*L.*' *ampla* Chapman										o	c	c								r		o
Rhizophyllum sp.																					o	
cf. *Syringaxon*																					o	
Annelida																						
Keilorites sp.	o	r				r		o	r	o			r			r			r			
Polyzoa																						
Fenestella sp.												o									o	o
Polyzoa indet.					c			c	o					c	o							
Brachiopoda																						
Chonetes melbournensis Chapman	r																					
C. ruddockensis Gill										o	o	o	r		c		r			o		r
C. cresswelli Chapman											o	o										r
C. cf. *psiloplia* Gill										r									r			
C. sp. nov.										r						r						
Macropleura densilineata (Chapman)														c								
Eospirifer aff. *togatus* (Barrande)																					c	
Howellella sp.								o			o	c									o	o
Nucleospira sp.	o	r			a		o	c	o	o	o	o				r			r			
Isorthis sp.								a		o	o			a	c				c			
I. festiva Philip																					r	
Tyersella sp.																					r	
Dalmanellids indet.		r	o				o	a	o	o			r	a	c	o			c	o	c	
Leptaena '*rhomboidalis*' (Wilckens)														a								
L. sp.								o		o	o									r	o	
Notoleptaena sp.										o	o						r					r
Leptostrophia sp.								o						c	o					r	o	o
Atrypa '*reticularis*' (Linnaeus)								c						a								
Lissatrypa sp.								o				o		o						o	o	
L. lenticulata Philip									o	c	c											o
Notanoplia australis (Gill)										c	c	c	o		c		o			o	o	c
N. withersi (Gill)										o	c	o										o
Plectodonta bipartita (Chapman)								r	r	o	c		o		c	r	o		o	o		o
Aegiria sp.	o		c	r	o		o															
Stegerhynchus sp.			c		c			a	o	o				a	c				c			
Rhynchonellids indet.	c		c		c		c	a	o			c		a	c	o			c	c		
Notoconchidium sp.															o							
Lingula sp.	r						o	o		o	o	o		o			r					
Lamellibranchiata																						
Ctenodonta sp.	r	r							r	c	o		o	o	c					o		
Nuculites sp.	r	r					o							o	o							
N. maccoyianus Chapman									r	o	o									r	o	
Panenka sp.																		o				
Actinopteria boydi (Conrad)								r						o								
cf. *Parallelodon*																				r		
cf. *Lunulicardium*													r							r		
Gastropoda																						
Bellerophon sp.										o		o		o			r					
Straparollus sp.								o									r				o	
Loxonema sp											o										o	
cf. *Platyceras*										r												
Cephalopoda																						
Orthoceracones indet.	r	r		r					r	r		o			r	r		o				
Mollusca Incertae Sedis																						
Hyolithes sp.	r	o		o		o			r	c	o	o	o		o		o			o		
Crinoidea																						
Crinoids spp. nov.				r	c			c				c							r			
Crinoid columnals	o	o	o		a	o	o	a	o	c	o	a	o	c	o	r	o		o	o	a	a
Carpoidea																						
Victoriacystis aff. *wilkinsi* Gill and Caster											r											
Rutroclypeus victoriae Gill and Caster											r											
R. junori Withers											r	r										
R. ? *withersi* Gill and Caster											r											
Carpoids spp. nov.					o			o														
Blastoidea																						
Blastoids spp. nov.											r	r										
Cystoidea																						
Cystoids spp. nov.											r	r										
Asteroidia																						
Lepidaster australis (Withers and Keble)	r																					
Phillipsaster selwyni (McCoy)					c		o	o														
Ulrichaster biradialis (Withers and Keble)					c																	
Schuchertia junori Withers and Keble												o										
Petraster sp.											r											
Asteroids spp. nov.					c		o	o			r											
Ophiuroidia																						
Lapworthura miltoni (Salter)								o			r	o										
L. pulcherrima Withers and Keble								o														
Furcaster kilmorensis Withers and Keble								o														
Crepidosoma kinglakensis Withers and Keble												c								r		
Urosoma parvus (Withers and Keble)												c										
Eospondylus cf. *tenuis* Withers and Keble												o										
Sturtzura sp.											r											
Ophiuroids spp. nov.	r				c			o			r											
Graptolithina																						
Monograptus colonus	o																					
M. chimaera var. *salweyi* (Barrande)				r	c																	
M. bohemicus (Barrande)	r																					
M. dubius? (Suess)	r		r	r																		
M. dubius cf. *thuringicus* Jaeger																r						
M. varians var. *pumilus* Wood					o																	
M. '*uncinatus*'																r						
Trilobita																						
Encrinurus sp.	o		c		o		a															
Otarion sp.											r	r		o								
Ampyx yarraensis Chapman	r																					
Dalmanites sp.	r						o															
D. wandongensis Gill		o				c																
Odontochile sp.								r	r			r		c		o						r
O. formosa Gill										c	c						r			r		
Phacops sp.	r								r	c	c	r		c							o	
P. cf. *crossleii* Etheridge fil. and Mitchell							o															
Proetus euryceps (McCoy)											o											
Calymene sp.										o				o						r	o	
C. bowiei Gill			r																			
Gravicalymene angustior (Chapman)												o										o
Trimerus vomer (Chapman)						r																
T. kinglakensis Gill											c											
cf. *T. lilydalensis* Gill																	r					
Homalonotids					r									c	c							
Dicranurus kinglakensis Gill											o	r										
Scutellum sp.											r											
Ostracoda																						
Beyrichiacea	r				r	r	r		r	r	o	r	r							r		r
Phylum Incertae Sedis																						
Conularia sp.						r	r		r	r		r		r						r		
Plantae																						
Baragwanathia longifolia Lang and Cookson																		c				
Hostimella sp.																		o				a
cf. *Psilophyton*																		o				
Plant fragments indet.											c	c								c		a

a = abundant; c = common; o = occasional; r = rare.

Palaeontology

The main groups of organisms are reviewed, emphasis being placed on local stratigraphical use. However, many species remain unidentified.

TABULATE CORALS

Only two genera of tabulate corals, *Pleurodictyum* and *Favosites*, have been identified, both being restricted to the Humevale Formation. *Pleurodictyum megastoma* McCoy is common in the Clonbinane Member, and also in the lower beds of the Humevale Formation at Eden Park, although here the average cell diameter is smaller than most specimens from the Clonbinane Member. *P. megastoma* becomes abundant in the upper beds at Kinglake West where it attains its greatest corallite diameter, thus confirming Philip's (1962) observation that the diameter tends to increase at progressively younger horizons. However, facies seems also to exercise some control in this respect. The small-celled species of *Pleurodictyum* generally has a similar distribution to that of *P. megastoma*, although absent from the lower beds at Eden Park. The tabulate corals are almost invariably associated with an abundant shelly fauna, suggesting they preferred a shallow water environment.

RUGOSE CORALS

Rugose corals are widely distributed, most being referable to species of *'Lindstroemia'* (Chapman 1924). *L. parva* Chapman and *L. scalaris* Chapman, the two smallest forms, are almost entirely restricted to the Yan Yean Formation, occurring sporadically in the mudstone. *L. conspicua* Chapman, of moderate size up to 15 mm long, is common in the siltstones of the Yan Yean Formation in the Wandong district and the lower beds of the Humevale Formation at Eden Park, but rare at higher horizons. The largest forms, *L. yeringae* and *L. ampla*, attain a length of 20 mm and 25 mm respectively, being common in the upper beds at Kinglake West.

The conglomerate phase of the Flowerdale Member contains a distinctive rugose coral fauna, with *Rhizophyllum* sp., *Syringaxon* sp. and Rugosa indet. being similar to forms described by Talent (1959) from E. Victoria.

ANNELIDS

Worm tunnels and tracks, some referable to the genus *Keilorites*, occur occasionally in the siltstones. Gill plumes are rare, being found only in the shales interbedded with the sandstones of the Clonbinane Member.

POLYZOA

Small trepostome and cyclostome polyzoa occur throughout the sequence, although they have not proven of stratigraphical value. *Fenestella* sp. is restricted to the sandstones of the Collins's Quarry horizon, Kinglake West, and the Flowerdale Member.

BRACHIOPODS

Brachiopods are by far the most abundant fossils, occurring in all lithologies from mudstone to conglomerate.

Chonetids are stratigraphically useful, with *Chonetes melbournensis* Chapman being restricted to the Yan Yean Formation, while *C. ruddockensis* Gill, *C. cresswelli* Chapman, *C.* cf. *psiloplia* Gill, and a number of new species of *Chonetes* are found only in the middle to upper beds of the Humevale Formation.

Macropleura densilineata (Chapman) has a very restricted range, being found only at Eden Park-Upper Plenty, and it is likely that its distribution has been controlled by facies. Similarly, *Eospirifer* aff. *togatus* (Barrande) occurs only in the conglomerate phase of the Flowerdale Member.

Atrypa 'recticularis' (Linnaeus), although having a wide range elsewhere in Victoria, is here restricted to the Clonbinane Member and the lower beds at Eden Park. *Lissatrypa lenticulata* Philip and *Plectodonta bipartita* (Chapman) enter at the base of the Humevale Formation, although both species become more common higher in the sequence. *Aegiria* sp., similar to *Plectodonta bipartita* but lacking the strong median septa, is almost entirely restricted to the *Aegiria-Encrinurus* Band high in the Yan Yean Formation.

Notanoplia australis (Gill) and *N. withersi* (Gill) do not enter till the second lowest division of the Humevale Formation, being most common in the upper beds at Kinglake West where they are associated with *Lissatrypa, Plectodonta* and *Chonetes.*

Isorthis sp. is abundant with other dalmanellids in the lower beds at Eden Park and the Clonbinane Member. Dalmanellids are not common higher in the sequence at Kinglake West, although in the conglomerate of the Flowerdale Member *Isorthis festiva* Philip and *Tyersella* sp. have been identified.

Leptaena 'rhomboidalis' (Wilckens) is characteristic of the lower beds at Eden Park, while leptaenids are found occasionally throughout the whole of the Humevale Formation. *Leptostrophia* sp. first appears in the Clonbinane Member, being quite common at Eden Park and in the Flowerdale Member. No doubt a number of different species of this genus are represented.

'Camarotoechia decemplicata', now identified as *Stegerhynchus* sp. (Dr J. Talent pers. com.) is common with numerous poorly preserved rhynchonellids in the upper beds of the Yan Yean Formation, and continues into the lower portion of the Humevale Formation. Two specimens of *Notoconchidium* sp. have been found at Locality F12, Upper Plenty.

LAMELLIBRANCHS

Most forms are long ranging and of little use stratigraphically. *Actinopteria boydi* (Conrad) is restricted to the Clonbinane Member and the lower beds at Eden Park, while specimens comparable with *Parallelodon* and *Lunulicardium* have been found in the fine mudstones at Kinglake East, these two genera being common in the rocks of the Warburton area. *Panenka* sp. showing fine radial striations occurs in mudstones high in the Humevale Formation at Locality A82, in the NE. corner of the area mapped.

GASTROPODS

Gastropods occur sporadically throughout the entire sequence. The doubtful gastropod *Hyolithes* is most common, and several species appear to be present.

CEPHALOPODS

Fragments of orthoceracones are found occasionally in the mudstones and siltstones, consistent with their probable pelagic existence.

CRINOIDS

Crinoid columnals are extremely common, although complete crinoids are almost entirely restricted to the sandstones and associated with an abundant shelly fauna. Specimens from Locality F31, Yan Yean Formation; the Clonbinane Member; and Collins's Quarry, Kinglake West, show beautiful preservation, but have not been studied in detail.

CARPOIDS

Four species of carpoid from Collins's and Middendorp's Quarries, Kinglake West, have been described by Gill and Caster (1960). Several new genera found at Locality F31 and in the Clonbinane Member were given to Mr E. D. Gill of the National Museum, Melbourne.

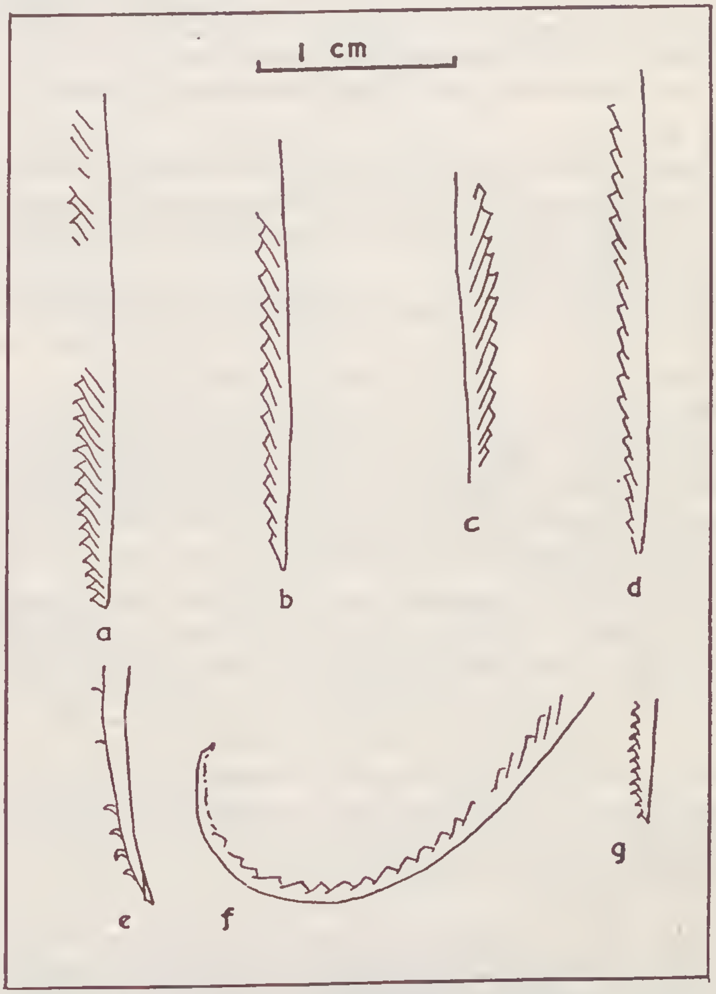


FIG. 3—Graptolites from the Kinglake and surrounding districts:
a. *Monograptus colonus*, Locality D143
b. *M. dubius* ? (Suess), Locality D140
c. *M. dubius* ? (Suess), Locality H87
d. *M.* cf. *dubius thuringicus* Jaeger, Locality X50
e. *M.* sp. indet., Locality E56
f. *M. bohemicus* (Barrande), Locality F10
g. *M. varians* var. *pumilis* Wood, Locality F31

BLASTOIDS AND CYSTOIDS

Blastoids and cystoids are very rare, only fragmentary remains having been found at Middendorp's and Collins's Quarries, Kinglake West.

ASTEROIDS AND OPHIUROIDS

As with the crinoids, asteroids and ophiuroids are restricted to the sandstones, being most common in the Clonbinane Member, Locality F31, and Collins's Quarry, Kinglake West. It thus seems that most enchinoderms preferred a clear-water environment. The Collins's Quarry horizon is characterized by *Crepidosoma kinglakensis* Withers and Keble and *Urosoma parvus* (Withers and Keble). Several of the generic names for the starfish and brittlestars given by Withers and Keble (1933, 1934) have been altered according to suggestions by Spencer (1950).

GRAPTOLITES

Although rare, graptolites are by far the most useful fossils stratigraphically. They are almost entirely restricted to the mudstones, and rarely were more than one or two specimens found at the one locality. The better-preserved graptolites, shown in Fig. 3, include the following:

Monograptus colonus (Fig. 3a), at Locality D143 in mudstones of the Yan Yan Yean Formation, 141,737 Yan Yean Military Map.

Monograptus varians var. *pumilus* Wood (Fig. 3g), common at Locality F31, Yan Yean Formation, 033,008 Kinglake Military Map.

Monograptus bohemicus (Barrande) (Fig. 3f) at Locality F10 in mudstones of the Yan Yean Formation, 109,798 Kinglake Military Map.

Monograptus dubius ? (Suess) (Fig. 3b & c) at Locality Q2, Broadhurst's Ck, 023,937 Lancefield Military Map; Locality D140, 133,678 Yan Yean Military Map; Locality H87, 077,028 Kinglake Military Map; Locality G39, Heathcote Junction, 044,887 Kinglake Military Map; all localities in the Yan Yean Formation.

Monograptus dubius cf. *thuringicus* Jaeger (Fig. 3d), found singly in siltstones of the Humevale Formation, Locality X50, Stony Ck, 090,043 Kinglake Military Map, a few hundred ft above the top of the Clonbinane Member.

Monograptus sp. (Fig. 3e). Several incomplete specimens were found in mudstones low in the Humevale Formation W. of Junction Hill, Locality E56, 384,989 Glenburn Military Map. The hooked thecae, long sicular and broken-backed appearance suggest *Monograptus uncinatus* var. *orbatus* Wood. However, many Upper Ludlow graptolites show proximal thecae of the '*uncinatus*' type (Jaeger 1959), so no definite identification can be given in the absence of a complete specimen.

TRILOBITES

Trilobites are widely distributed throughout the mudstones and siltstones of both formations, although rare in the sandstones, indicating their preference for a muddy sea floor. Complete specimens are rare, the most common fragments being pygidia and to a lesser extent cephalons.

Encrinurus sp. is a characteristic fossil of the Yan Yean Formation, being most common in the upper beds where it forms a mappable horizon with the brachiopod *Aegiria*.

Dalmanitid trilobites are abundant and the most useful stratigraphically. *Dalmanites wandongensis* Gill is found only within the Yan Yean Formation in the siltstones at Wandong and Upper Plenty. *Odontochile* sp. enters at the base of the Humevale Formation, being most common in the beds at Eden Park. Here, all dalmanitids with 16 or more pygorachial segments have been classified as *Odontochile*, hypostomes not being available for study. *Odontochile formosa* Gill enters in the second lowest division of the Humevale Formation at Kinglake West. Thus, Gill's (1948d) sequence, *Dalmanites wandongensis* → *Odontochile meridianus* → *Odontochile formosa* is in part confirmed.

Phacopiid trilobites are common but of little use stratigraphically, with the possible exception of *Phacops* cf. *crossleii* Etheridge fil. and Mitchell, which appears to be restricted to the upper beds of the Yan Yean Formation. Calymenids are not common, with *Gravicalymene angustior* (Chapman) being found mainly in the Collins's Quarry horizon, Kinglake West, and the Flowerdale Member.

Homalonotid trilobites are not widespread although common locally. *Trimerus vomer* (Chapman) occurs at Wandong in siltstones of the Yan Yean Formation, while *Trimerus kinglakensis* Gill has been found only at Middendorp's Quarry, Kinglake West, thus supporting Gill's (1948b, p. 72) opinion 'that *T. kinglakensis* is genetically related to, and probably a little later in time than, *T. vomer*'. Poorly preserved homalonotids common in the lower beds at Eden Park do not appear to be referable to either of the above species. A single pygidium similar to that of *Trimerus lilydalensis* Gill was found at Locality F41, Clonbinane, in siltstones of the Humevale Formation.

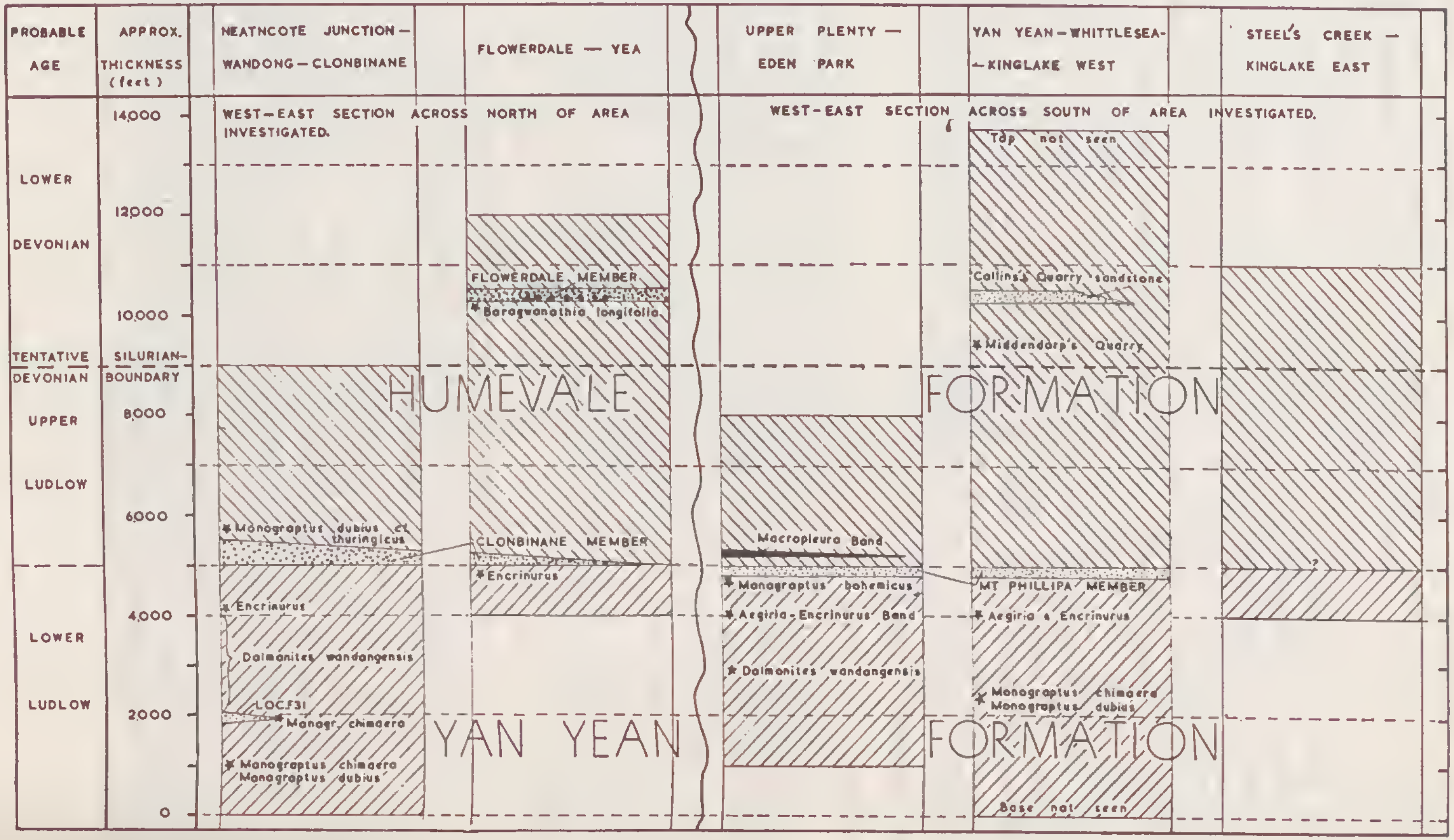
PLANTS

Land plants are found only in the upper beds of the Humevale Formation, entering about the horizon of Middendorp's Quarry, Kinglake West. *Hostimella* sp. and abundant fragmentary remains occur in narrow bands in the sandstones of the Flowerdale Member. Many beautifully preserved specimens of *Baragwanathia longifolia* Lang & Cookson are present in fine siltstone (Locality A82, 376,064 Yea Military Map) high in the Humevale Formation, just below the conglomerate of the Flowerdale Member (Pl. XLVIII, fig. 2). Thus, the *Baragwanathia* spp. are considered to occur on a similar horizon to that of Collins's Quarry, Kinglake West (see Table 2). Several spiny plants found at Locality A82 resemble species of *Psilophyton* found in the Lower Devonian of Maine, U.S.A. (Dorf and Rankin 1962).

FAUNAL SUCCESSION AND PALAEO-ECOLOGY

Fossils are generally rare in the Yan Yean Formation, and although sandstones at Localities F31 and X56 have yielded an abundant fauna, these beds are certainly not typical of the formation as a whole. Fossils first become common over a wide area in the Mt Phillipa and Clonbinane Members, and the lower 2,000 ft of the Humevale Formation at Eden Park contain an abundant shelly fauna in siltstones and fine sandstones. The notable feature of the Humevale siltstones is the lateral and vertical variation in abundance of fossils and grain size of the sediments. The strata at Eden Park are slightly coarser gained and much more fossiliferous than the stratigraphically equivalent lower 2,000 ft of siltstones at Humevale. Similarly, the upper beds at Kinglake West are richly fossiliferous while the sediments at Kinglake East are finer grained and contain an impoverished fauna. There is also a slight decrease in grain size and fossil content of the sediments to the N., but the differences are not as marked as those to the E.

TABLE 2
Correlation Chart



A general shallowing of the sea is the most likely explanation for the great increase in shelly fossils from the Yan Yean to the Humevale formation. The lateral variations in abundance of fauna and grain size of the Humevale siltstones indicate deeper water to the E., and to a lesser extent, the N. Thus, with continued shallowing the shelly faunas were able to migrate to the E. The conglomerate of the Flowerdale Member does not indicate shallow water conditions; evidence will be given in a later section that it is a slump conglomerate.

AGE OF THE SEDIMENTS

Table 2 shows correlation and probable age of the important sections within the area mapped. An attempt is here made at correlation with other Victorian Siluro-Devonian sequences, and also with the European type section.

YAN YEAN FORMATION

The Yan Yean Formation may be confidently correlated with the Lower Ludlovian, based on the graptolites *Monograptus colonus, M. varians* var. *pumilus*, and *M. bohemicus*, these forms being most common in the *Monograptus nilssoni* Zone of the Ludlow Shales (Elles and Wood 1918). *M. bohemicus* has been found only a few hundred feet below the base of the Humevale Formation, indicating that the Yan Yean Formation probably is not younger than the Middle Lower Ludlovian, although it may extend down into the Wenlockian in the St Andrews-Hurstbridge district. Thus, the Yan Yean Formation may be regarded as Melbournian in age (Jones 1927, Thomas and Keble 1933).

The sequence in the Wandong district—lower mudstones containing graptolites; sandstones and siltstones with starfish, *Dalmanites*, and numerous other shelly fossils; and finally mudstones with *Encrinurus* and *Aegiria*—is similar lithologically and palaeontologically to the Dargile Beds at Heathcote, which Thomas (1937) showed to be also of Lower Ludlovian or Melbournian age. Future mapping may eventually link the Wandong and Dargile beds by means of the Chintin Beds of the Kilmore district.

HUMEVALE FORMATION

Since the Humevale Formation directly overlies the Yan Yean Formation, its lower beds must represent the Upper Ludlovian. If the graptolite found at Locality X50 just above the Clonbinane Member is *Monograptus dubius* var. *thuringicus*, it would mean that the Clonbinane Member is not younger than the Middle Ludlow. This fits well with the proximity of Lower Ludlow graptolites to the base of the member.

The lower 2,000 ft of siltstones at Eden Park, and the Clonbinane Member contain several species common in the Yeringian sediments at Lilydale, Gill (1942) regarding *Pleurodictyum megastoma* as indicating a Lower Devonian age. However, Hill (1943) does not discount the possibility of the genus *Pleurodictyum* extending down into the Silurian, while Philip (1962, p. 166) notes that *Pleurodictyum* has been found in the Silurian of North America. *Atrypa 'reticularis', Leptaena 'rhomboidalis', Plectodonta bipartita* and *Actinopteria boydi* are also present in the Lower Devonian sediments at Lilydale, and there has been a tendency to regard several of these forms as characteristic Yeringian fossils. Their presence in the lower beds of the Humevale Formation has thus extended their local range down into the Ludlovian. The specimens of *Monograptus* showing *'uncinatus'* type thecae, found low in the Humevale Formation at Break-o'-Day, are probably the proximal portions of biform Upper Ludlow graptolites.

The two upper divisions of the Humevale Formation at Kinglake West have the following species in common with the type Yeringian strata (Gill 1942, 1945b) considered Lower Devonian in age:

Chonetes ruddockensis Gill, *Plectodonta bipartita* (Chapman), *Notanoplia australis* (Gill), *Gravicalymene angustior* (Chapman), *Pleurodictyum megastoma* McCoy, *'Lindstroemia' yeringae* Chapman, and *L. ampla* Chapman.

The following species from Middendorp's and Collins's Quarries, Kinglake West (which both occur within a stratigraphic thickness of 800 ft), are found in the upper portions of the Boola Beds at Tyers, Gippsland, regarded by Philip (1962) as Lower Devonian in age:

Pleurodictyum megastoma McCoy, *Plectodonta bipartita* (Chapman), *Notanoplia australis* (Gill), *Chonetes cresswelli* Chapman, *Lissatrypa lenticulata* Philip, *Gravicalymene angustior* (Chapman), *Crepidosoma kinglakensis* Withers and Keble, and *Notoleptaena* sp.

The Flowerdale Member, considered to be on a similar horizon to that of Collins's Quarry, has the following species in common with the Boola Beds:

Favosites aff. *forbesi* Edwards and Haime, *Pleurodictyum megastoma* McCoy, *Chonetes cresswelli* Chapman, *Eospirifer* aff. *togatus* (Barrande), *Isorthis festiva* Philip, *Lissatrypa lenticulata* Philip, *Notanoplia australis* (Gill), *Plectodonta bipartita* (Chapman), *Gravicalymene angustior* (Chapman), *Tyersella* sp., and *Notoleptaena* sp.

Thus the two upper divisions of the Humevale Formation are probably of Lower Devonian age, with the Silurian-Devonian boundary between 2,000 ft and 4,000 ft above the top of the Yan Yean Formation.

The following corals and brachiopods from the conglomerate of the Flowerdale Member—*Syringaxon, Favosites* cf. *forbesi, Eospirifer* aff. *togatus, Isorthis festiva, Tyersella, Delthyris*, and *Rhizophyllum*—have not been found elsewhere in the Humevale Formation. Philip (1962, p. 137) noted that *Tyersella* and *Eospirifer* survived the facies change from mudstone to conglomerate in the Tyers area, and it is probably the distinctive facies which restricts the above forms to the conglomerate of the Flowerdale Member.

The occurrence of *Baragwanathia longifolia* at Locality A82 immediately below the conglomerate of the Flowerdale Member means that this plant, believed to be the world's oldest vascular land plant (Lang and Cookson 1934), ranges up into the Lower Devonian, a conclusion also reached by Philip (1962), who found a solitary specimen of *Baragwanathia* high in the Boola Beds at Tyers. Thus, together with Jaeger's (1959) study, evidence is accumulating that *Baragwanathia* is not solely a Lower Ludlow plant and that the commonly associated *Monograptus 'uncinatus'* of the Yea-Alexandra district has been wrongly identified, being in reality an Upper Ludlow graptolite. Jaeger (in Philip, p. 246) considers that the graptolite associated with *Baragwanathia* is his *Monograptus praehercynicus*, which possibly extends into the Lower Devonian. If this identification is upheld, it will be necessary to postulate a lateral variation in facies during the Upper Ludlow from shelly in the Whittlesea-Kinglake West district to graptolitic in the Yea district. As mentioned above, there is evidence within the Kinglake district that the sea did deepen to the E. and N., and this will be further supported below.

Sediments

PETROGRAPHY

For purposes of description the sediments have been divided into three groups—Lutites, Arenites, and Rudites.

LUTITES

Siltstones and mudstones form over 80% of the total sequence. A detailed petrological and micrometric study was made of the siltstones exposed in Running Ck, Kinglake West, in the hope of finding a gradation in composition, diagenesis or grain size throughout a thickness of over 3,000 ft. Although local variations were present, no systematic change of any sort was detected, and the thin sections were indistinguishable from those of siltstones from elsewhere in the Humevale and Yan Yean formations.

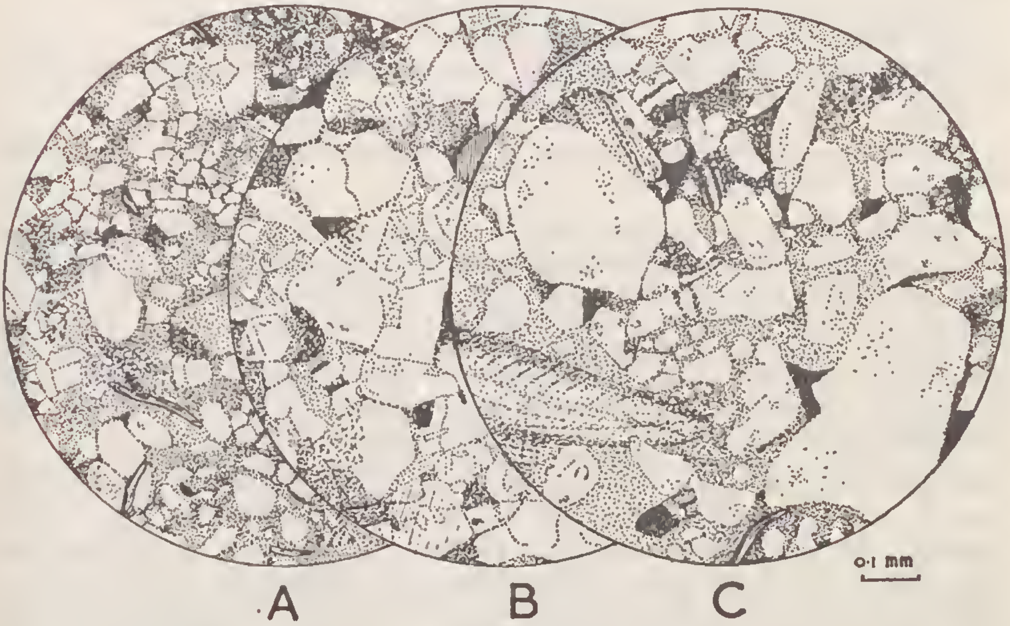


FIG. 4—a. Siltstone from Running Ck, Kinglake West.
b. Sandstone from the Clonbinane Member.
c. Poorly sorted greywacke from the Flowerdale Member.

Sections 8476-8482 from Running Ck, Kinglake West (arranged in stratigraphical order), Section 8483 from Wandong Quarry, and Sections 8484 and 8485 from Pheasant Ck, Kinglake Central, show that the siltstones consist predominantly of angular quartz, with occasional felspar grains and plates of mica, set in a greeny-brown slightly pleochroic groundmass (Fig. 4a). The following minerals have been identified in thin section:

Quartz—by far the most common detrital mineral, in small angular grains, and only rarely water-rounded; often contains small bubbles and needle-like inclusions, probably rutile; rarely shows strain extinction.

Felspar—occasionally as angular grains about the same size as the quartz, and rarely as small, tabular crystals. Varieties include microline, showing cross-hatched twinning; orthoclase, relatively common in some sections, and occasionally exhibiting perthitic intergrowth; plagioclase ranging from albite to andesine, with oligoclase being most common.

Biotite—as fresh or partially bleached plates and laths arranged roughly parallel to the bedding; local alteration to chlorite.

Muscovite—in ragged laths, similar in size and orientation to the biotite.

Sericite—probably partly authigenic, and partly allogenic, as an alteration product of some felspar grains, and an important constituent of the groundmass.

Iron ore—common as small grains, occasionally with euhedral outline. Ilmenite predominates over magnetite, while pyrite is rare.

Leucoxene—scattered grains as an alteration product after ilmenite.

Zircon—in minute prisms, most water-rounded.

Tourmaline—in small, green-brown prisms.

Chlorite—the greeny-brown, slightly pleochroic material of the groundmass is probably a variety of chlorite.

Calcite—in irregular patches in the groundmass of some sections.

? Kaolin—as an alteration product of the felspar grains, and also a probable constituent of the groundmass.

Even though the sections were cut from blue-black, fresh looking rocks, most show some alteration due to diagenesis or surface weathering. Quartz grains have been occasionally embayed and replaced at their borders by the chloritic matrix and calcite, small neighbouring grains with the same optical orientation suggesting replacement by the groundmass along fractures in a larger grain. Some of the felspars have been partially to completely altered to sericite and kaolin, biotite partly bleached or chloritized, and occasional pseudomorphs of chlorite and iron ore have possibly been derived from detrital amphibole or pyroxene.

Some patches or bands within the siltstones contain many quartz grains, while other patches are composed mainly of the chloritic matrix, although generally the rocks are of a remarkably even texture. A micrometric analysis was carried out to determine the ratio of clastic grains to matrix in the siltstone, the method used being that employed by Crook (1956). This involved measuring linearly the ratio of clastic grains to matrix along random traverses of sections seen under high power. The average results were 50·9% clastic grains, 49·1% matrix. Sections cut parallel to the bedding gave a slightly higher percentage clastic grains than did sections cut at right angles from the same hand specimen, probably due to the settling of tabular grains along the bedding.

The average diameter of several hundred clastic grains in Sections 8478 and 8479 was measured with a micrometer slide. Krumbein and Pettijohn (1938, p. 130) found that the apparent mean diameter of grains measured in thin section is approximately 24% smaller than the actual mean diameter. The measurements were corrected by this amount and plotted against their relative frequencies. The curves were closely symmetrical about the mode, in both cases 57 microns, which falls within the range of 'coarse silt' in the modified Wentworth Scale, given in Dunbar and Rodgers (1957, p. 161). Thus, the field classification of these rocks as siltstones is confirmed, as Dunbar and Rodgers, p. 163, state that a sediment as a whole is 'ordinarily assigned to that class containing either the mode, the median, or the geometric mean of the size distribution'.

Two fresh samples from the 'limestone' at Eden Park yielded 22·9% and 26·0% carbonate, and as the size of the detrital quartz grains is similar to that of the surrounding sediments, these beds are best described as calcareous siltstones.

Arenites

Fine-grained sandstones are common in the Yan Yean Formation and form the bulk of the Clonbinane Member, while coarse-grained, poorly sorted sandstones and grits occur in the Flowerdale Member high in the sequence.

Section 8488 is typical of the sandstones of the Clonbinane Member (Fig. 4b), the rock coming from a quarry at Reedy Ck. Angular quartz grains predominate, with occasional grains of orthoclase and twinned oligoclase. Muscovite and biotite are common as laths and plates which lie along the bedding and give the rock its characteristic flaggy split. The matrix of chlorite and sericite is not as common as in the siltstones; small zircon prisms and grains of secondary limonite are also present. Using the method described above, the average diameter of the quartz and felspar grains was calculated to be 132 microns, i.e. within the 'fine sand' range of the modified Wentworth Scale. Thus, although the sediments of this average grain size have some chloritic matrix, they contain no rock fragments and are best described as argillaceous sandstones.

Section 8490 (Fig. 4c) is typical of the grits at Kangaroo Ck, about 3 miles N. of Flowerdale. The rock is poorly sorted, some rounded quartz grains being over 1mm in diameter, although most of the quartz is angular and of sand particle size. Felspar grains are also present, together with rock fragments, often water worn, of quartzite and slate. Fossil remains are preserved as crystalline calcite surrounded by a border of limonite; interstitial calcite is also common in the groundmass and appears to have locally replaced quartz and felspar in embayments and fractures. Laths of muscovite and biotite are often ragged and distorted, indicating that the rock has undergone shearing. The groundmass is composed of a very fine mosaic of quartz grains, with some sericite and calcite. The poor sorting of the detrital grains, the included rock fragments and fine groundmass are consistent with the definition of a greywacke given by Pettijohn (1957); thus most of the arenites of the Flowerdale Member may be classed as gritty greywackes.

Rudites

The single conglomerate horizon at the base of the Flowerdale Member has been described above in reasonable detail. All the pebbles are of extremely stable rock types, reef quartz and quartzite being the most common. Section 8491 of a quartzite pebble is composed mainly of a mosaic of quartz grains, with a few grains of acid plagioclase, flakes of biotite, and a small amount of chloritic matrix. The absence of any siliceous cement and the interlocking nature of many of the quartz grains suggest that the rock has undergone a certain amount of thermal metamorphism.

Heavy Mineral Analysis

Samples from a wide variety of rock types were anlysed for their heavy minerals, in the hope of throwing some light on the origin of the sediments. Samples were taken from: siltstones of the Humevale Formation at Kinglake West and Upper Plenty; sandstone at Collins's Quarry, Kinglake West; and the conglomerate and gritty phases of the Flowerdale Member.

Zircon, rutile and tourmaline were present in all the sediments analysed, being of similar dimensions and relative proportions, although owing to their very small size they were more common in the siltstones than the sandstones and grits. The heavy minerals shown in Slides 8492 to 8498 are described below.

Zircon—typically prismatic, mainly short and stumpy, and terminated by pyramids; colourless to pale blue or pale green, often slightly pleochroic, containing fine needle-like inclusions, iron ore grains and occasional small bubbles; most water-worn to some degree, some being elliptical to almost circular in outline.

Rutile—present in two varieties, although never as abundant as zircon. Most commonly as slender, honey-brown, pleochroic prisms, showing pinacoidal terminations; all slightly water-worn, containing few inclusions. The other variety is smaller, yellow-brown in colour, and more water-worn, being in some cases subspherical in outline.

Tourmaline—commonly as green-brown, strongly pleochroic, stumpy and occasionally slender prisms, terminated with pinacoids; most contain bubbles, with the more slender prisms enclosing dust-like particles of iron ore drawn out in line; generally rounded slightly, occasional grains being elliptical in outline. Krynine (1946) considers this green-brown variety of tourmaline, containing many bubbles and cavities, to be derived from granitic rocks.

Several of the tourmalines show light coloured outgrowths in optical continuity with the main crystal at one end only of the c-axis. Krynine (1946) regards such outgrowths to be of authigenic tourmaline. The small outgrowths on a nearly spherical grain have a somewhat rounded outline and may be water-worn. If this is so it means that the grain is second cycle, which seems likely from its greatly water-worn appearance.

Iron ore—grains of magnetite and ilmenite are common, many having octagonal or prismatic outline. Irregular grains of limonite are abundant in the sandstones from Collins's Quarry.

Micas—Plate of muscovite and biotite are found occasionally in all rock types, being particularly common in the sandstones from Collins's Quarry and the Clonbinane Member.

NATURE OF THE SOURCE ROCKS

The uniformity of the constituent minerals of the sediments suggests similar source rocks were being eroded during the whole time of deposition. Several writers have previously given their opinions as to the nature of the source rocks for the Silurian sediments of the Melbourne district. Jutson (1911) suggested a source composed both of igneous and sedimentary rocks, as did Langford (1916), while Junner (1913) believed that the predominant source rock was igneous, probably granitic.

The following reasons suggest that the sediments were derived in part from granitic igneous rocks:

1. The abundance of muscovite in the sandstones, and fresh biotite in the siltstones.
2. The presence of fresh acid plagioclase, orthoclase and perthite grains in all the sediments.
3. The occurrence of the heavy minerals zircon, rutile and especially tourmaline indicates an ultimate, but does not necessarily prove an immediate, granitic source. However, the heavy minerals showing little or no rounding are likely to be first cycle.
4. The abundance of reef quartz pebbles in the conglomerate of the Flowerdale Member indicates that the source rocks had been subjected to some igneous activity, with the injection of many quartz veins, commonly associated with granitic intrusions.

The absence of metamorphic minerals and the lack of strain extinction in the quartz grains suggest that metamorphic rocks were not an important source for the sediments.

The following points indicate that sedimentary rocks were present in the source terrain:

1. The great rounding of some of the heavy minerals, and the possible water-worn authigenic tourmaline outgrowth suggest second cycle deposition.
2. The great number of quartzite pebbles in the conglomerate is positive proof of the sedimentary nature of at least some of the source rocks.

Thus, a terrain of sedimentary rocks, intruded by granites and associated quartz veins, seems the likely source for the sediments of the Kinglake district, rapid erosion having allowed deposition of fresh felspar and micas in the neighbouring Siluro-Devonian sea.

Sedimentary Structures

Bedding Features

Structures within this division include graded bedding, cross-bedding, ripple-drift bedding, sole markings and scour-and-fill.

Graded Bedding

In the Yan Yean Formation, occasional sandstone beds from 6 to 18 in. thick have sharp junctions with the overlying and underlying siltstones, but show slight vertical grading, as do some of the thin sandy laminae in the siltstones and mudstones. The sandstones of the Clonbinane Member are also occasionally graded, gradually passing from fine sand up into thin shale beds, the grading often being increased by the presence of flat mud pellets lying along the base of the sandstones. The greywackes and grits of the Flowerdale Member afford the best examples of graded bedding, with beds about one foot thick being gritty at the base and grading up into medium to fine sandstone.

However, the many thousands of feet of mudstones and siltstones, about 80% of the total sequence, are not graded at all. Thus, graded bedding must be regarded as the exception rather than the rule.

Laminated Bedding

Many of the sandstones of the Yan Yean Formation and Clonbinane Member are well laminated (Pl. XLVIII, fig. 3), due either to slight changes in grain size, or layers of organic fragments. However, laminated bedding is not common in the greywackes and grits of the Flowerdale Member.

Cross-bedding and Ripple Bedding

Cross-bedding is common in the sandstones of the Yan Yean Formation (Pl. XLVIII, fig. 3), the tops of the cross-laminae generally being truncated by the overlying bed, while the lower portions show a sigmoidal curvature. The cross-bedding at any one exposure has similar directions of dip, and this was recorded at many localities. The sandstones of the Clonbinane Member also show cross-bedding, although it is not as common as in the Yan Yean Formation. Few good examples of cross-bedding were observed in the gritty beds of the Flowerdale Member. In general, cross-stratified beds are seldom more than 2 in. thick. The average of 76 foreset inclinations was 25°.

Current ripple bedding is often associated with cross-bedding, although ripple-mark is not common, due in part to limited suitable exposure, and also probably to the erosion of the crests prior to the deposition of the following bed.

SOLE MARKINGS

Sole markings, consisting mainly of flute casts and occasionally worm tracks, are restricted to the sandstones and grits, although seldom observed in situ. The base of a sandstone block from the Yan Yean Formation, Whittlesea, contains many small flute casts and grooves showing a definite direction of elongation (indicated by the pen in Pl. XLIX, fig. 1), there also being a tendency for the flute casts to be arranged in diagonal rows, making an angle of approximately 50° with the direction of elongation. This pattern is similar to that illustrated by Kuenen (1957, p. 237). Larger and smoother flute casts occur in the sandstones of the Clonbinane Member, as shown in Pl. XLIX, fig. 2. Cross-bedding in this block indicates a current direction parallel to the long axis of the grooves (arrow), confirming that such sole markings are due to scouring of the sea floor by current action prior to the deposition of the sandstone beds. Flute casts and grooves were also observed in the greywackes of the Flowerdale Member.

SCOURS

The smallest scours are associated with current ripple bedding, being common in the sandstones of the Yan Yean Formation. However, only one large scour involving several beds was observed in sandstones of the Clonbinane Member.

SOFT SEDIMENT DEFORMATION

A wide variety of structures due to soft sediment deformation in sandstones and mudstones of the Yan Yean Formation are exposed in a road cutting at Doreen, S. of Whittlesea. Large diapyric injections of mudstone have entirely broken through the overlying sandstones and appear to have a faulted contact with neighbouring beds. Smaller mudstone injections which have not completely pierced the sandstone above are associated with downward projecting sandstone lobes, commonly referred to as load casts. Small folds at right angles to the tectonic strike of the district indicate that some lateral movement or sliding of the sediments has taken place, while greatly contorted bedding (Pl. XLIX, fig. 3) is proof of the highly mobile nature of the mudstones during deformation.

The best explanation for the development of load casts (Hills 1940, Kuenen 1953, Kelling and Walton 1957) is the settling of pockets of sandstone under gravity into the fine, unconsolidated sediments below, tongues of mudstone being simultaneously injected up into the sandstone. The asymmetry of several of these mudstone injections suggests differential horizontal movement of the sediments while still unconsolidated (Hills 1940).

Several laminated sandstone beds of the Yan Yean Formation show a series of cuspate anticlines in the upper laminae which gradually diminish in size towards the base of the bed. These distortions are similar to the 'convolute bedding' of Kuenen (1953, p. 1057-58), who considered they were due to gradual deformation of a bed in a quicksand condition but which had not undergone horizontal movement. This convolute bedding contrasts sharply with the chaotic disturbances in some of the mudstones at Doreen.

MECHANISM OF DEPOSITION OF ARENITES AND RUDITES

Kuenen and Migliorini (1950) postulated turbidity currents as a mechanism by which graded arenaceous beds could be deposited amid pelagic clay in the deeper

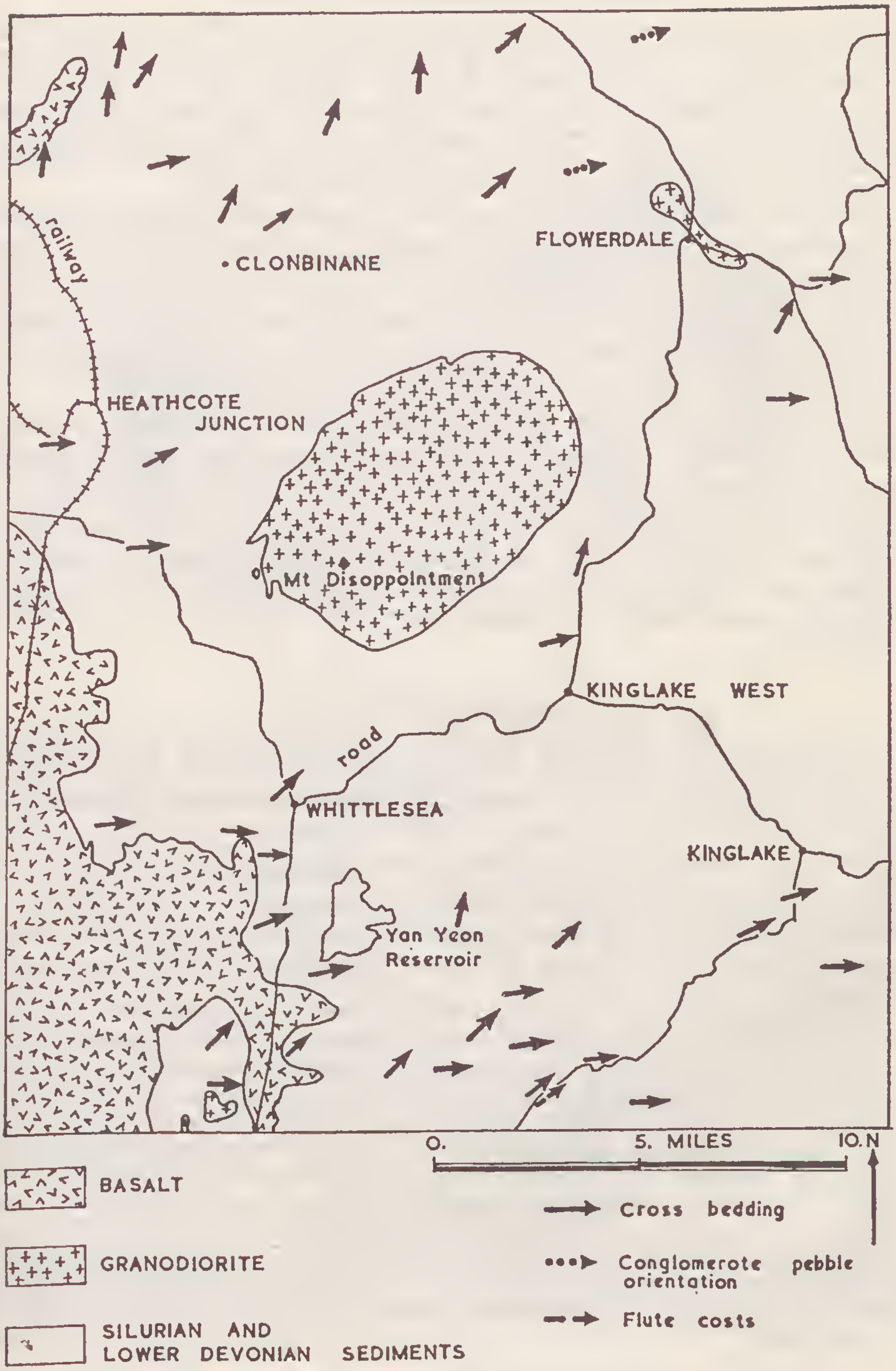


FIG. 5—Palaeocurrent directions within the area investigated. Vector mean of 77 cross-bedding measurements strikes 50°; vector magnitude 70%.

portions of ocean basins. Further work by Kuenen (1953, 1957, etc.) revealed that many sedimentary structures, such as cross-bedding, flute casts, load casts, convolute bedding, etc., were common in graded sequences, and he attributed them to the action of turbidity currents. However, Murphy and Schlanger (1962) showed that a number of the above structures, especially cross-bedding, convolute bedding, and load casts may occur in a non-turbidite sequence. Hence, regular graded bedding appears to be the only criterion for turbidity current deposition.

Thus, the graded arenites of the Yan Yean Formation and Clonbinane Member are tentatively regarded as having been deposited by strong sediment-laden bottom currents, and the interbedded mudstones and shales in still waters between periods of current action. However, the excellent preservation of delicate crinoids and brittlestars in the sandstones of the Clonbinane Member and also at Collins's Quarry, Kinglake West, does not appear to support the theory of deposition by turbulent bottom currents. It is possible that some of these finer sandstone beds were deposited by currents that flowed over a long period of time.

The beds of the Flowerdale Member appear to be the only sediments studied to have been deposited by large-scale slumping and turbidity currents. The conglomerate, which generally overlies fine siltstones presumably of fairly deep water origin and often contains a muddy matrix, may be best explained by slumping and re-deposition in a deeper part of the basin, as suggested for the Lower Silurian conglomerate at Keilor by Hills and Thomas (1954). Incorporated mud fragments indicate erosion of consolidated sediments during the slumping. A turbidity current origin also seems likely for the strongly graded grits and greywackes overlying the conglomerate.

PALAEOCURRENT DIRECTIONS

Cross-bedding was the most useful palaeocurrent indicator. The attitudes of the cross-laminae were measured, and their original directions of dip calculated by means of a stereogram. Fig. 5 shows that the overall movement of currents was to the E. or NE., with the southerly component becoming more evident to the N. In returning the beds to the horizontal, corrections were made for plunge of the folds, although none for possible rotation of the beds around a vertical axis, which may have occurred in the N. portion of the area mapped.

Flute casts and grooves where observed in situ indicated a current direction consistent with the cross-bedding, the apices of the flute casts being taken to point up current.

Kopstein (1954) found that in the Harlech Dome conglomerates of slump or turbidity current origin, the longest axes of elongated pebbles lay parallel to the current direction indicated by cross-bedding and sole markings of associated beds. There was also a tendency for the coarsest fraction of elongated pebbles to slant downcurrent at angles up to 45°, with plunges of 25° or less being most frequent. This method of current measurement was applied to the conglomerate of the Flowerdale Member. The orientations of the long axes of 57 elongated pebbles from ½ in. to 3 in. in length were recorded from four widely separated localities, plotted on an equal area projection, and restored to their attitudes at the time of deposition. The final contoured diagram (Fig. 6) shows a strong E.-W. lineation of the pebbles, with the maximum striking 82° and plunging 3° E. This is consistent with the other palaeocurrent directions and the occurrence of the largest pebbles at Locality Y97.

FIG. 6—Orientation of the long axes of 57 elongated pebbles from the Flowerdale Member.

PALAEOSLOPE AND SOURCE OF SEDIMENTS

Since sediment-laden currents or slumps act under gravity, it is reasonable to assume that they would flow down the steepest slope of the sea floor. If momentum were great enough a current might possibly flow obliquely across the sloping sea floor where uneven topography existed, but it is hard to envisage this happening over great distances. Hence it seems likely that the sea floor sloped to the NE. within the area investigated. This is supported by the lateral variation in facies of the Humevale Formation, as noted above.

As stated previously, the terrain which supplied the sediments of the Kinglake district probably consisted both of granitic and sedimentary rocks. The easterly slope of the Siluro-Devonian sea floor suggests that this ancient terrain lay to the W. of the area investigated.

SEDIMENTARY HISTORY

The great thickness of sediments (approximately 14,000 ft) deposited within the Kinglake district in the relatively short time range from the Lower Ludlovian to the Lower Devonian indicates both rapid erosion and deposition in a subsiding geosyncline.

Fairly deep water conditions appear to have prevailed in the Lower Ludlovian, with the deposition, possibly from turbidity currents, of cross-bedded and occasionally graded arenites in the Yan Yean district. However, at Wandong the absence of thick arenites and the presence of numerous mud-burrowing trilobites suggest that shallower conditions prevailed.

During the Upper Ludlovian, shallowing of the sea is indicated by the more numerous fossils and change in lithology. The beds at Eden Park were probably deposited in shallow water, shelly fossils being abundant enough to form a 'limestone' band, while to the N. the sandstones of the Clonbinane Member were deposited with the aid of currents from the SW.

The thick, monotonous siltstones of the Humevale Formation suggest rapid deposition in a shelf environment during the Lower Devonian, with shallow water in the SW. indicated by the abundant fauna of the Kinglake West district. These sediments are similar to the massive siltstones of the Mesozoic and Tertiary of New Zealand, considered by Kingma (1960) to be marine shelf deposits. The finer siltstones and mudstones of the Flowerdale-Yea district containing excellently preserved land plants, and the presence of the slump conglomerate suggest deeper water conditions to the NE. during the Lower Devonian.

These shallowing movements were possibly associated with the Bowning Orogeny, although the uniformity of the current directions indicates that the major folding of the Tabberabberan Orogeny had not yet commenced.

PALAEOGEOGRAPHY OF CENTRAL VICTORIA IN SILURO-DEVONIAN TIME

As the tectonic strike of the sediments of Central Victoria is roughly N.-S., it is likely that the trough was elongated meridionally. No Silurian or Lower Devonian sediments have been recognized W. of the Cambrian Heathcote Axis, and it is interesting to speculate on the position of the W. shore-line in Lower Devonian time. Packham (1960) considered that the 'western margin of sedimentation must have been some distance to the west of Heathcote, since the Silurian and Devonian sediments there are over 24,000 ft thick'. However, the upper 10,000 ft of sediments at Heathcote, represented by the McIvor and Mt Ida Formations (Thomas 1937), consist predominantly of abundantly fossiliferous sandstones, suggesting near-shore conditions.

Although Kuenen has stressed the importance of longitudinal filling of oblong sedimentary basins, the W. portion of the Victorian Siluro-Devonian trough appears to have been filled transversely from the W.

The terrain from which the sediments of the Kinglake district were derived is not evident, although the deformed Proterozoic and Cambrian deposits of the Adelaide Geosyncline probably contributed much detritus to the Victorian trough from the Ordovician to the Devonian. Hills and Thomas (1954, p. 131) stated that 'the considerable lithological change from the top of the Silurian to the Lower Devonian, with the incoming of conglomerates, is perhaps to be correlated with the Bowning Orogeny. . .'. The source of the conglomerates, at least within the area investigated, being from the W., suggests that the Bowning Orogeny extended its influence to W. Victoria, with the possible uplift of further potential source rocks.

The restriction of *Baragwanathia* to the central portions of the trough is probably due to the facies there having been favourable for its preservation. This is consistent with the findings of Kingma (1960), who showed that the sediments of the New Zealand geosynclinal basins are most coarse grained and strongly

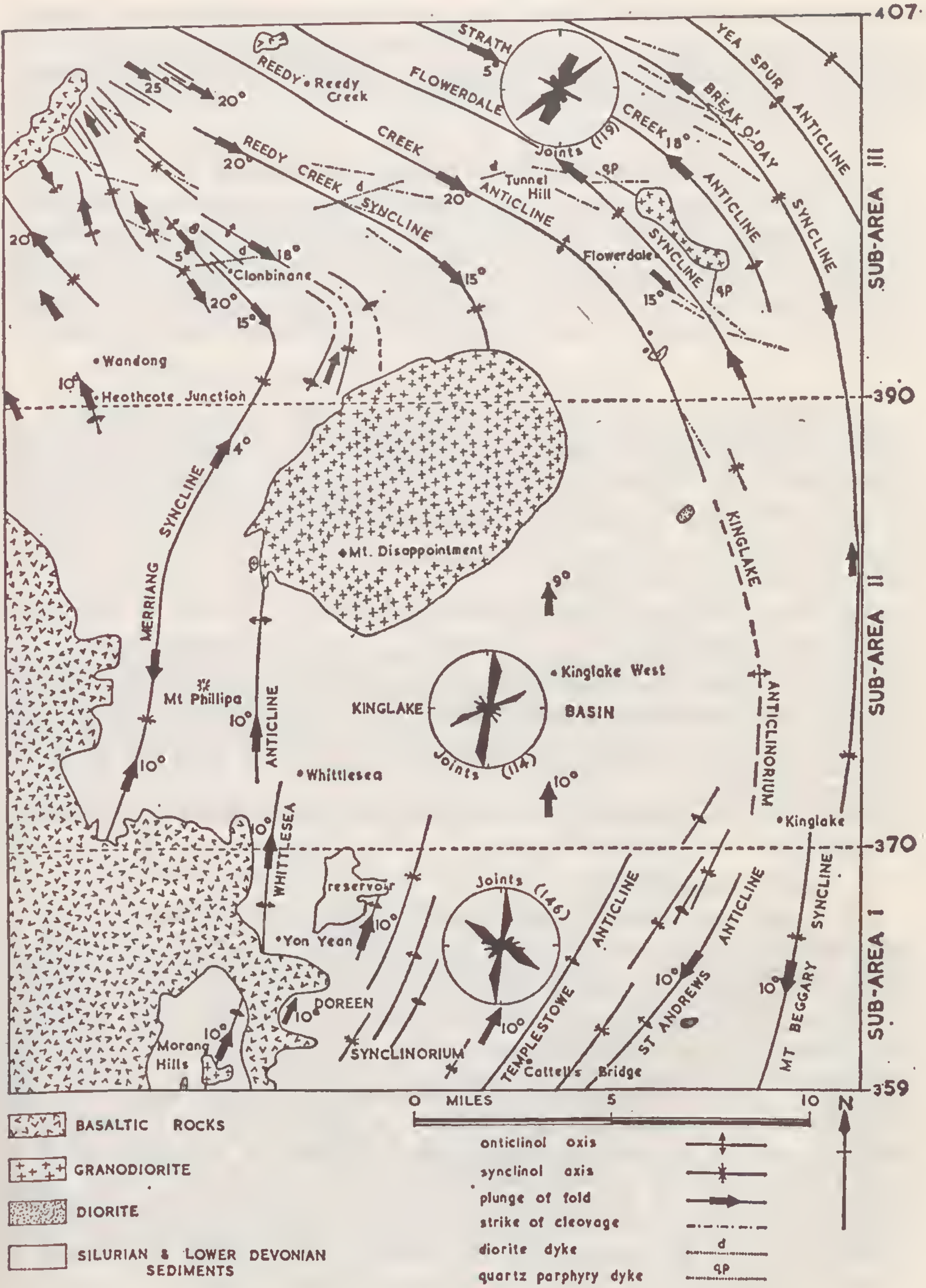


FIG. 7—Synoptic Structure Plan of the Kinglake and surrounding Districts.

scoured nearest the probable source, while plant material is most abundant in those areas farthest from the probable source. Similarly, Banks (1962) considered that the deep-water Mathinna Beds of NE. Tasmania, containing abundant plant remains including *Hostimella*, are probably equivalent to the Siluro-Devonian shelf deposits of the Eldon Group to the W.

Structural Geology of the Kinglake District

The Silurian and Lower Devonian sediments of Central Victoria were moderately to strongly folded in Middle Devonian times during the Tabberabberan Orogeny. The folds are mainly sub-meridional in trend, although locally strongly arcuate, as noted by Thomas (1939). The structure of the area investigated is summarized in Fig. 7, the notable feature being the 90° change in trend of the folds from approximately N. 25°E. at Yan Yean to E. 25°S. at Reedy Ck.

FOLDING

The general lack of cleavage in the sediments, the uniform thickness of individual beds across small folds and crush-zones, and occasional slickensided bedding planes indicate that the strata have been bent into concentric or parallel folds. This appears to be the dominant type of folding developed in the Silurian and Lower Devonian sediments of West-Central Victoria (Jutson 1911, Junner 1913, Hills 1941), contrasting sharply with the shear folding in the Ordovician rocks W. of the Heathcote Axis.

The major structural features are described below, starting in the W. of the area and working from S. to N.

W. and N. of Heathcote Junction, the mudstones and sandstones of the Yan Yean Formation have been thrown into a series of tight, asymmetric folds, striking N. 30°W. and plunging approximately 10°NW. The W. limbs of the anticlines are generally the steeper, while locally there is evidence of overfolding to the W. However, E. of Heathcote Junction the strata dip constantly to the E. as far as the Clonbinane district.

Most of the area remaining may be divided into four persistent major folds or 'fold-zones':

1. The Merriang Syncline:

The S. portion of this fold was first mapped and named by Jutson (1908) in the Eden Park district. Here it is broad and asymmetrical, the steeper dips being on the E. limb, while gently dipping beds in the centre of the fold indicate a northerly plunge of about 10°. N. of Mt Phillipa the syncline narrows and plunges to the S., thus forming an elongated basin structure with the beds at Eden Park. At Upper Plenty the trend changes from N.-S. to N. 30°E., the fold running for about 6 miles roughly parallel to the NW. boundary of the Mt Disappointment Granodiorite and plunging about 5°NE. Two miles S. of Clonbinane the Merriang Syncline suddenly swings to the W. through 70° to a trend of N. 40°W., while the plunge again reverses to 10°SE. The syncline at this bend is asymmetric, having dips of up to 45° on the E. limb; few greater than 20° occur for over 2 miles to the W. of the axis. At Clonbinane, the syncline breaks down into numerous tight folds trending NW. and plunging either NW. or SE. This type of close folding is typical of the NW. corner of the area mapped, the anticlines often having near-vertical E. limbs, so exposing with each fold progressively older beds to the W.

2. The Whittlesea Anticline:

The anticline passing through the Morang inlier is probably a southerly extension of this fold. N. of the Morang basalt, the Whittlesea Anticline runs almost due N. for about 4 miles with dips seldom exceeding 60° on either limb, the crest indicating a plunge of 10°N. At Whittlesea, the apparent displacement of the fold over ½ mile to the W. suggests faulting, although scarcity of exposure makes interpretation difficult. To the W., a number of minor S.-plunging folds indicate some complexity to structure, but they do not persist far to the N. After displacement the Whittlesea Anticline continues due N., still with a plunge of 10°N., until truncated by the Mt Disappointment Granodiorite, a small apophysis intruding S. along the fold axis for about ½ mile. N. of the granodiorite the fold emerges as an anticlinorium, which follows the Merriang Syncline around the sharp bend to the W. and merges with the tight folding N. of Clonbinane.

3. The Doreen-Kinglake West-Reedy Ck 'Synclinal':

E. of the Whittlesea Anticline in the Yan Yean district is a large synclinorium about 5 miles wide and trending approximately N. 28°E., composed of at least 6 small folds each less than a mile apart. This structure has been named the Doreen Synclinorium after the nearby township of Doreen. Dips of 65° are common, numerous small drag folds and crush-zones indicating a northerly plunge of 10° or more.

The synclinorium continues NE. for about 5 miles, the folds gradually dying out, until E. of the Yan Yean Reservoir it is represented by a single broad syncline. This synclinal structure, over 12 miles wide and continuing N. for more than 15 miles, has been named the Kinglake Basin. Within the greater part of this structural basin the thick siltstones of the Humevale Formation are low-dipping, generally preserving only the northerly plunge of about 10°. A notable feature is that the Mt Disappointment Granodiorite lies almost entirely within the Kinglake Basin, just cutting across the Whittlesea Anticline on the W.

N. of Kinglake West the strike swings gradually to the W. and the basin narrows until it merges into the NW.-trending Reedy Ck Syncline, named after the creek which flows for several miles within this fold. The syncline plunges from 15° to 20° SE., narrowing to the NW. where it breaks down into several smaller SE.-plunging folds, similar to those of the Clonbinane district.

4. The Cottell's Bridge-Kinglake-Flowerdale 'Anticlinal':

E. of the Doreen Synclinorium there is much close folding and puckering, indicating a northerly plunge, but the predominant dip is to the W. until at Cottell's Bridge the northerly extension of the Templestowe Anticline (Jutson 1911) is reached. Further minor folds occur between the Templestowe Anticline and another major fold to the E., here named the St Andrews Anticline, which plunges from 10° to 15°S., the synclinal area between the anticlines possibly representing the northerly continuation of Jutson's Bulleen Syncline. E. of the St Andrews Anticline is the broad, asymmetric Mt Beggary Syncline plunging at 10°-15° to the S.

Proceeding N. towards Kinglake, the Templestowe and St Andrews Anticlines merge into an anticlinorium, containing many smaller folds showing a great variation in strike and plunge. Areas of puckering, curvature of strike, reverse faults, slaty cleavage, strong jointing, and numerous small quartz reefs are all characteristic of the structure, named the Kinglake Anticlinorium. This structure continues in a northerly direction for about 6 miles, with strikes gradually swinging to the W., until it merges into the NW.-trending folds of the Flowerdale district. A large syncline containing the fossiliferous beds at Kinglake East has been traced to the N. just inside the E. boundary of the area mapped, and appears to be a continuation of the Break-o'-Day Syncline.

NE. from the Reedy Ck Syncline a remarkably simple type of folding extends well beyond the area investigated. These folds trend in a north-westerly direction, varying from E. 30°S. at the Reedy Ck Anticline to E. 45°S. at the Yea Spur Anticline, and are evenly spaced about 2 miles apart. With the exception of the Reedy Ck Anticline at Tunnel Hill, these folds have simple, relatively sharp turnovers, with about 6,000 ft of sediment, dipping between 60° and 70°, on each limb. The anticlines of this series often show signs of tension, while slates are present in the cores of the synclines. Plunges are shown in Fig. 7.

Fold Analysis

The area investigated may be divided into three sub-areas, each with its own characteristic fold pattern. The boundary lines of these sub-areas, shown in Fig. 7, are the E.-W. grids 359, 370, 390 and 407.

Fig. 8—ΠS diagram for the Yan Yean district (Sub-area i).

Sub-area (i):

The Yan Yean-St Andrews district, between E.-W. grids 359 and 370. Here the general trend is NNE., the folds being close together with moderately to steeply dipping limbs. Many of the folds are not persistent, dying out, to be replaced *en echelon*, with displacements of up to one mile.

Fig. 8 is the ΠS diagram for the folds between the Whittlesea and St Andrews Anticline, β plunging 16° on a bearing of 26°. This is consistent with the regional fold trend and the few observed values of B. The maximum on the R.H.S. of the diagram indicates the predominance of westerly dipping beds, due to most of the measurements being taken on the E. limb of the Doreen Synclinorium. Local deviations in fold trend probably account for the S girdle not intersecting the maxima at both ends of the diagram.

Sub-area (ii):

The Whittlesea-Kinglake district, between E.-W. grids 370 and 390. The folding here is characterized by N.-S. trending anticlines and broad synclines, section BB′ (Fig. 2) from the Merriang Syncline to the Kinglake Anticlinorium illustrating the magnitude of the Kinglake Basin.

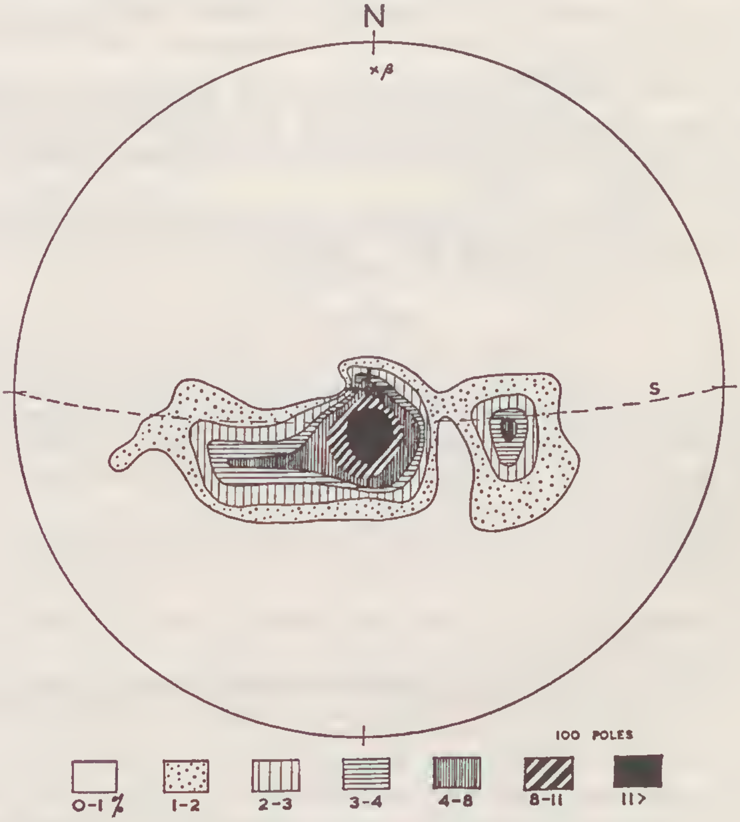


FIG. 9—ΠS diagram for the Kinglake district (Sub-area ii).

The ΠS diagram for the Kinglake Basin (Fig. 9) shows β plunging 9° due N., the maximum in the centre of the diagram being due to the great expanse of unfolded beds present. Here the regional northerly plunge is half that in the Yan Yean district, and continues to decrease until N. of the Mt Disappointment Granodiorite the Kinglake Basin plunges to the S.

Sub-area (iii):

The Clonbinane-Reedy Ck-Flowerdale district, between E.-W. grids 390 and 407. Here the folds trend NW., are equally spaced and of simple structure as described above, section AA′ in Fig. 2 illustrating their uniformity.

No ΠS diagram was drawn for this sub-area, because of the general sharpness and change of plunge of the folds.

FAULTING

Although occasional brecciation and drag of beds were observed, there was no evidence of any large-scale faulting within the area investigated.

Jutson (1908) postulated a N.-trending normal fault along the small anticline E. of the Merriang Syncline at Eden Park. A great complication of dips and strikes occurs in gullies N. of Cemetery Lane, but as the Mt Phillipa Member of the Yan Yean Formation is symmetrically disposed on each side of the Whittlesea Anticline, strike faulting in this district on a large scale is unlikely. However, it is possible that a cross-fault with some sinistral movement displaces the axis of the Whittlesea Anticline just W. of Whittlesea.

Numerous minor faults, both normal and reverse, are exposed in cuttings, but displacements are seldom more than a few feet. Two excellent examples of small reverse faults may be seen in an old cutting near the Whittlesea Cemetery, close to the axis of the Whittlesea Anticline.

Faulting or fracturing on a fairly large scale is indicated by the presence of quartz diorite and quartz porphyry dykes in the N. half of the area, and the linear boundaries of the Mt Disappointment Granodiorite.

JOINTING

Joints occur in all the sediments, but are best developed in the thick, low dipping siltstones as at Humevale and Wandong. Owing to the generally thick soil cover it was not possible to trace individual joint planes beyond a single exposure; however, that major joint sets do persist for miles is indicated by the local control of drainage by joints, e.g. Running Ck, Kinglake West. Most joints are steeply dipping, many being vertical.

To see if there is any relationship between folding and jointing, the same sub-areas used in the fold analysis are adopted. The joint rosettes are shown in Fig. 7.

Sub-area (i):

Most of the joints fall into two sets, one striking between 5° and 15°, the other between 120° and 125°.

The set striking 120°-125° is almost perpendicular to the average fold axis for the sub-area as indicated by the ΠS diagram, and may be classified as 'ac' or cross joints.

The set striking 5°-15°, although deviating by about 10° from the average fold axis, probably represents longitudinal or 'bc' joints.

A third, minor set of joints, striking approximately 85° and making an angle of 59° with the average fold axis, may be regarded as diagonal joints.

Sub-area (ii):

The predominant set of joints strikes between 5° and 15°, deviating by about 10° from the mean fold axis, which strikes N.-S. These are referable to 'bc' or longitudinal joints. The second well-defined set strikes 65°, and are best considered diagonal joints.

No other prominent joint sets are present, although the three remaining maxima may represent poorly developed cross joints and the other set of diagonal joints.

Sub-area (iii):

The joint pattern differs from those of the previous two sub-areas in that there appears to be only a minor development of 'bc' or longitudinal joints, although the deviation from the average fold trend is very slight. However, the close parallelism between auriferous quartz reefs and the trend of the Reedy Ck Anticline, and the fact that the reefs wedge out suddenly with depth (Murray 1884), suggest that the quartz fills longitudinal tension fractures caused by bending of the strata at the anticline.

A major set of 'ac' or cross-joints strikes between 25° and 35° at right angles to the average fold trend. The set striking 55° and making an angle of 63° with the average fold trend may be regarded as diagonal joints.

ORIGIN OF JOINTS

All major sets of joints closely fit the folding within the respective sub-areas and may be classified as either 'bc', 'ac', or diagonal joints.

The cross or 'ac' joints are probably due to tension resulting from slight elongation parallel to the axes of the folds. These have been termed 'extension joints' by Billings (1954).

The longitudinal or 'bc' joints have been described by Billings as 'release joints, similar to those that form at right angles to the axis of compression when the load is released. Other joints with this attitude may be due to tension on the convex side of a bent stratum.' The longitudinal joints of the Kinglake Basin are probably release joints, while those in tightly folded areas are most likely due to direct tension, as at Reedy Ck.

The diagonal joints are probably due to shearing. Ideally, shear joints should occur in two vertical, perpendicular sets lying at 45° to the axis of compression 'a'. This angle, known as β (not to be confused with the pole β of ΠS diagrams) is usually less than 45°, many geologists preferring 30°-35° based on the work of Hubbert (1951), while Moody and Hill (1956) assumed a value of 30°. In sub-areas (i), (ii), and (iii), the values for β (i.e. angle between diagonal or shear joints and the a-axis of the folds) are respectively 31°, 25° and 27°, the average of 28° being comparable with many world-wide field observations. Williams (1959) showed that, at Girvan, β ranges from 10° to 53°, his average of 29° being consistent with results here. Only one of the two possible sets of shear joints is developed in each sub-area, and is probably due to the set which formed first hindering the development of the other by relieving the stresses responsible. No consistent differences were observed between the surfaces of joints due to shear and tension.

Thus the joints within the area investigated were probably formed at the same time as the folding, and indicate that the sediments have been subjected to only one main period of deformation.

CLEAVAGE

Cleavage is almost totally absent in sub-areas (i) and (ii), with only local development of a rough fracture cleavage in the Kinglake Anticlinorium.

However, cleavage is well developed in sub-area (iii), as shown in Fig. 7. In the tight folding of the Clonbinane district, a rough, near-vertical cleavage is present in both anticlines and synclines, and strikes approximately 110°, making an angle of up to 30° with the axial planes of the folds.

Progressing to the E., strong cleavage occurs near the axes of the major synclines. This cleavage is of the true slaty type where the original rock was a fine siltstone or mudstone, but is not well developed in the thin interbedded sandstones where fracturing radial to the anticlinal axes prevails. The cleavage is either vertical or dips at no less than 70° away from the synclines, the strike often making an angle of about 10° with the fold axes, especially in the E. of the sub-area. Due north of the Mt Disappointment Granodiorite essentially axial plane cleavage is present, agreeing with the idea of simple compression along an azimuth of 28° suggested by the joint analysis. However, the deviation from axial plane cleavage to the E. and W. is possibly significant with regard to the origin of the unusual fold trend in sub-area (iii).

The restriction of the cleavage to the synclines and tension to the anticlines has been noted elsewhere. Junner (1913) observed that in the Diamond Ck district a few miles N. of Melbourne, the synclines were zones of compression, with crumpling and overthrusting, while the anticlines had been subjected to tension at some stage, when quartz veins were intruded.

Although cleavage is not developed in the Yan Yean district, the presence of boudinage in sandstones indicates that locally the sediments have undergone great compression, fine sandstone laminae in the mudstones giving evidence of flowage around the sandstone boudins.

Origin of the Fold Structures

There are three unusual fold structures developed in the area investigated: the major structure is the broad sweep of the folds through 92°, from an average trend to 26° at Yan Yean to 118° at Reedy Ck; secondly, the sharp bend in the Merriang Syncline and Whittlesea Anticline S. of Clonbinane; thirdly, the Kinglake Basin containing, amid regional tight folding, a wide expanse of unfolded sediments.

THE ARCUATE FOLD PATTERN

From Melbourne N. to Yan Yean, the trend of the folded bedrock is about N. 30°E. (Fig. 10). In the Tallarook-Seymour district the fold trend is also roughly meridional, so the regional trend may be taken as approximately N.-S., from which the folding of the Reedy Ck-Flowerdale district deviates.

As described above, the folds of the Melbourne-Yan Yean district (plotted in part from records at the Geology Department) are closely spaced, most not persisting for a great distance along the strike, while in the Reedy Ck-Flowerdale district the folds are about 2 miles apart and continue for many miles. The simple joint patterns obtained throughout the area investigated, and the general lack of cross-folding indicate that all the folds were formed during one main period of deformation. The only possible explanation for the arcuate fold pattern is that the sediments were subjected to a large scale sinistral rotation during regional compression from the E. and W. The probable cause of this rotational force is described below in the light of previous experimental work.

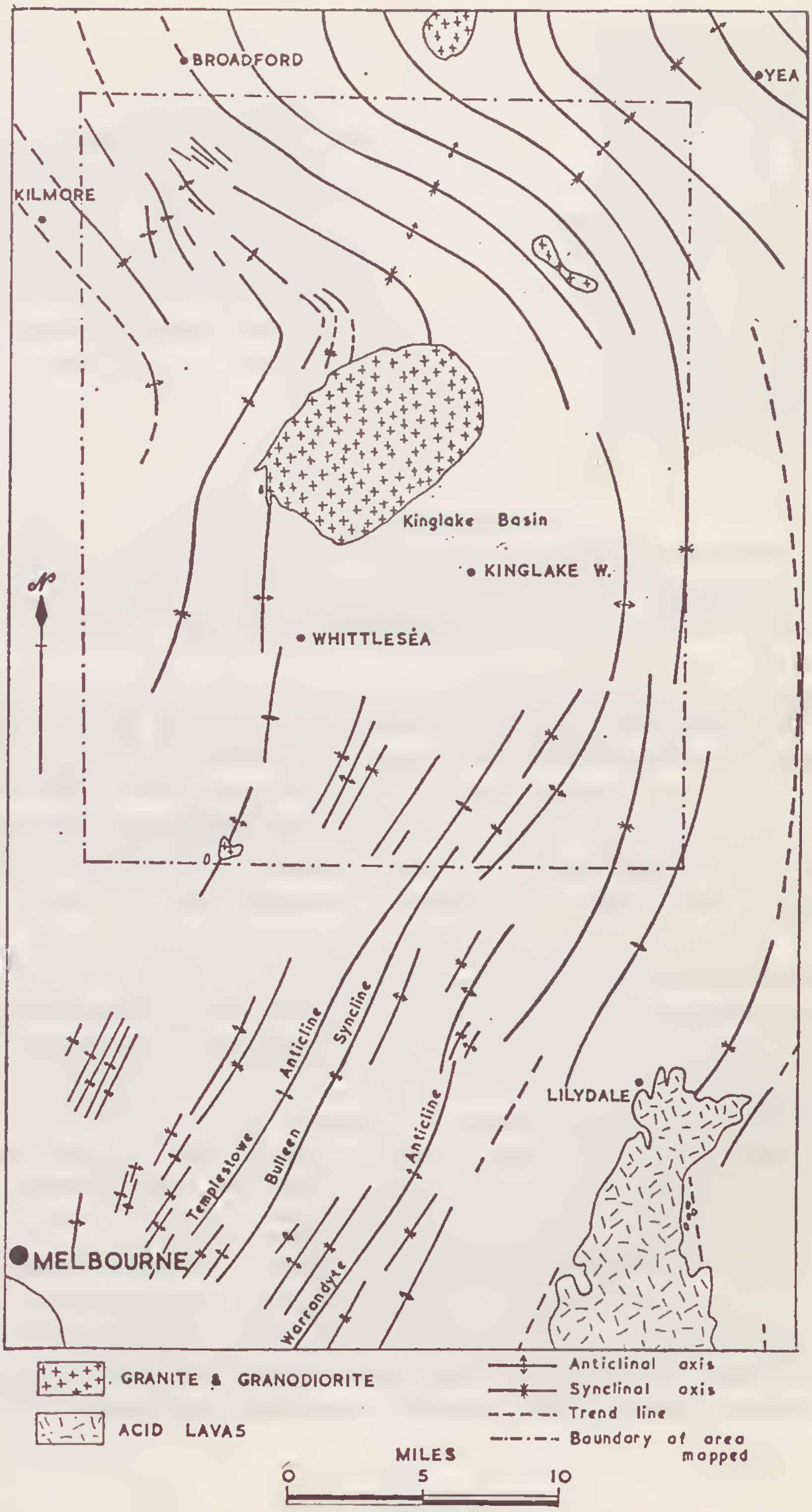


FIG. 10—Structural Map of the Silurian and Lower Devonian Sediments of South-Central Victoria.

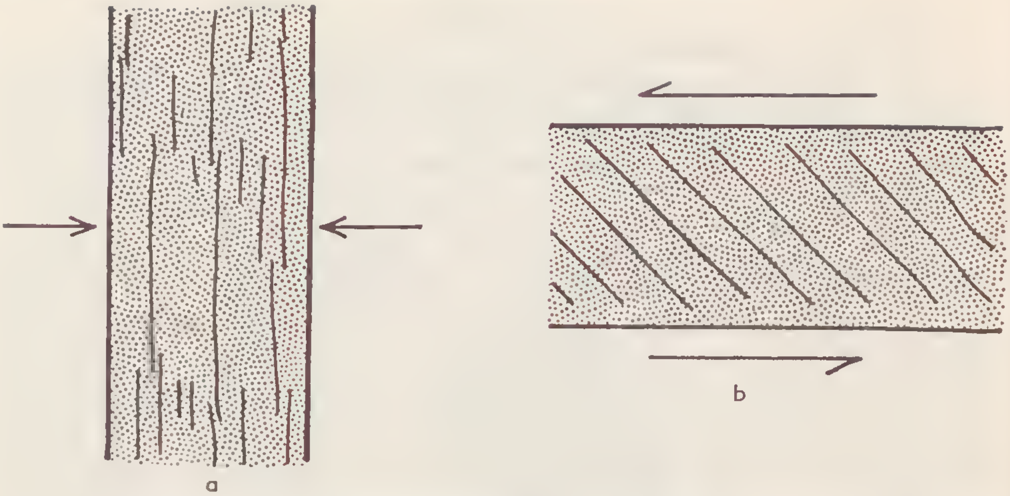


FIG. 11—Formation of folds in paraffin wax:

a. Under direct compression, an overlapping series of plunging folds is produced at right angles to the direction of compression.

b. Horizontal shearing produces a series of elongated folds making an angle of approximately 45 degrees with the direction of shear. (After Mead 1920)

Mead (1920) conducted a series of experiments on the fold patterns produced in layers of paraffin wax subjected to compression, torsion and shearing. He found that overlapping series of folds were produced by compression (Fig. 11a)—wherever a fold terminated by plunging, another fold appeared *en echelon* continuing the necessary amount of shortening. He concluded that plunging folds did not necessarily mean cross-folding, but that they could be 'developed in flat-lying beds, with perfectly even application of shortening stresses'. Mead also found that long, plunging folds parallel to the direction of elongation were caused by shear or rotational stress (Fig. 11b).

Brown (1928a) studied the folds formed when two adjacent wooden blocks covered with alternating layers of paraffin and vaseline were moved laterally with respect to each other. In the experiment where paper was used as the middle layer, folds, and thrust-, shear-, and normal-faults were produced. The long axes of the while the strike of the normal faults was parallel to the short axis of the strain ellipsoid, and formed an angle of 45° to the strike of the underlying shear zone, while the strike of the normal faults was parallel to the short avis of the strain ellipsoid. The folds were 3 to 5 times as long as they were wide, in spite of the fact that they were truncated by normal faults. Brown concluded that 'horizontal movement along buried faults may result in the development of shear faults or folds, and tension- and thrust-faults, the folds being greatly elongated . . .'.

In Mead's experiments, the overlapping folds due to direct compression may be compared with the fold pattern of the Melbourne-Yan Yean area, while the elongated folds due to rotational stress are similar to those of the Reedy Ck-Flowerdale district. Brown's experiment with shearing also produced a fold pattern similar to that at Flowerdale, and suggests a mechanism for the development of this anomalous trend. His conclusion that such basement movements may occur in nature is supported by Moody and Hill (1956) who, in a summary of the world's major wrench faults state, p. 1215, that 'the result of movement along these deep faults can be expressed in the overlying sedimentary veneer more commonly by a complex zone of wrench faults and generally complicated structure than by an individual fault trace. Some deep-seated wrenches appear to be indicated at the surface only by systems of small *en echelon* faults or anticlines'.

Thus, it is likely that the overlapping folds of the Melbourne-Yan Yean district are due to direct compression along a line striking approximately E. 30°S., while the elongated NW.-trending folds of the Flowerdale district were probably caused by drag from a basement sinistral wrench fault or shear zone, running roughly E.-W. between the Mt Disappointment and Trawool granite massifs. The only recognized major fractures or faults within the area investigated—those of the diorite dykes and the linear SE. boundary of the Mt Disappointment Granodiorite—all have a north-easterly trend, and are possibly analogous to the normal faults of Brown's experiment. The deviation of cleavage from the axial planes of the folds in the Clonbinane district suggests that the folds due to the basement movement post-date, in part, those due to E.-W. compression, although both were almost certainly connected with the same orogenic phase.

In Brown's experiment the drag folds made an angle of 45° with the shear plane. Moody and Hill defined γ as the angle between a basement wrench fault and the overlying drag folds, stating that 'the value of the critical angle γ has not yet been determined satisfactorily; generally it varies between 5° and 30°, with an average value of 15°. However, in some instances γ is apparently 0°, and the drag folds, in this situation called compression ridges, are parallel to the parent wrench fault.' Thus, it seems unlikely that a value of γ as high as 45° occurs in nature, and here the basement shear zone N. of Kinglake is considered to run E.-W., giving γ a value of 28° at Reedy Ck. Further evidence supporting this direction for the basement movement will be given below.

THE BEND IN THE MERRIANG SYNCLINE, CLONBINANE

The Merriang Syncline, extending for over 15 miles along the W. margin of the area investigated, undergoes several changes of trend, the most notable being the sharp bend just S. of Clonbinane. Such a bend is unusual for the Silurian sediments of Victoria, and may be termed 'axial plane folding' (Scotford 1956).

Scotford postulated compression from two different directions to account for axial plane folding in the metamorphic rocks of New York. However, as mentioned above, there is no evidence for cross-folding in the Kinglake district. If the bend were due to a direct thrust from the W., overfolding to the E. would be expected, but as the axial plane of the Merriang Syncline is here inclined to the W. this manner of formation of the bend also appears unlikely. Thus it seems probable that the sharp bend was caused by the same sinistral rotation that produced the anomalous fold trend of the Reedy Ck-Flowerdale district.

THE KINGLAKE BASIN

The third unusual feature of the folds within the area mapped is the Kinglake Basin, containing nearly 100 square miles of low-dipping beds and intruded in the NW. by the Mt Disappointment Granodiorite.

The Ordovician rocks of Central Victoria are very tightly folded, with widespread development of slates, but the Silurian sediments show little or no cleavage. However, there is no marked difference in structure between sediments of Lower and

Upper Silurian age in the Melbourne district, so a sudden decrease in fold intensity in sediments of Upper Ludlovian age does not seem likely. The sediments of the Humevale Formation in the Clonbinane-Reedy Ck district are just as tightly folded as those of the Yan Yean Formation, while the Lower Devonian sediments of the Lilydale district are strongly folded, with dips up to 70° (Gill 1942, p. 28). Thus, although there may well be a slight decrease in fold intensity from the Silurian to Lower Devonian sediments of Central Victoria, it does not seem sufficent alone to account for the formation of the Kinglake Basin.

The Kinglake Basin appears to be similar to the 'geosynclinettes' in the Eastern Geosyncline, New Zealand (Kingma 1958), which are basins from 15 to 20 miles long by 6 to 10 miles wide, containing up to 15,000 ft of sediments. Kingma, p. 270, stated that the geosynclinettes 'have been large enough to act as obstacles to the regional folding, and although they have been tilted, they have rarely suffered internal folding'. The close relationship between joint pattern and fold trend indicates that the massive siltstones of the Kinglake Basin have undergone compression, and it is probable that these sediments, in part at least, also resisted the regional folding. Such an origin for the Kinglake Basin is supported by Hills's (1945) observation that 'gliding along laminae. . .goes far toward accounting for the frequent development of close and acute folds in thin bedded rocks, as compared with broader and more open folds in massive strata'.

Structure of Central Victoria

Thomas (1939, 1958) made brief reference to the arcuate and persistent folds in the Silurian and Lower Devonian sediments between the Heathcote and Mt Wellington Cambrian belts in Central Victoria. He noted that the curves seemed to have their centre somewhere near Melbourne, but offered no explanation as to their origin.

Fig. 12 shows the structure of the Lower Palaeozoic rocks of Central Victoria. The map is based on Thomas (1939), but the structure of the Silurian and Lower Devonian has been much supplemented with recent work, and also by data in old mining reports. Three major fold arcs, all of similar sense, are present, most clearly shown at Kinglake, Heathcote and Rushworth. The arcuate folds continue E. from Kinglake, the strike gradually changing from 118° at Reedy Ck to 160° in the Walhalla Synclinorium; N. of the Cobaw Massif, the thrust-faulted Heathcote Axis and adjacent sediments make a large inflection to the W.; another great arc extends eastwards from Rushworth, the strike increasing from 100° at Rushworth to approximately 130° at Benalla. It is noteworthy that the Cambrian belts generally follow these trends.

Numerous experiments were carried out in an attempt to determine the mechanisms of formation of the various fold patterns present in Central Victoria.

EXPERIMENT 1: Folds due to simple compression.

A rubber strip about 5 in. wide and 18 in. long was stretched over a flat wooden board and firmly secured by pins. Soft grease was then spread over portion of the rubber, a thin tissue paper placed on the grease and the surface smoothed. The pins were then removed, and the rubber allowed to slowly contract.

The resultant close, overlapping folds (Pl. L, fig. 1) are similar to those produced under simple compression by Mead (1920), and may be compared with the fold pattern of the Yan Yean-Melbourne district. The folds in Pl. L, fig. 1 are rarely parallel for long and often, where *en echelon* displacement occurs, there is

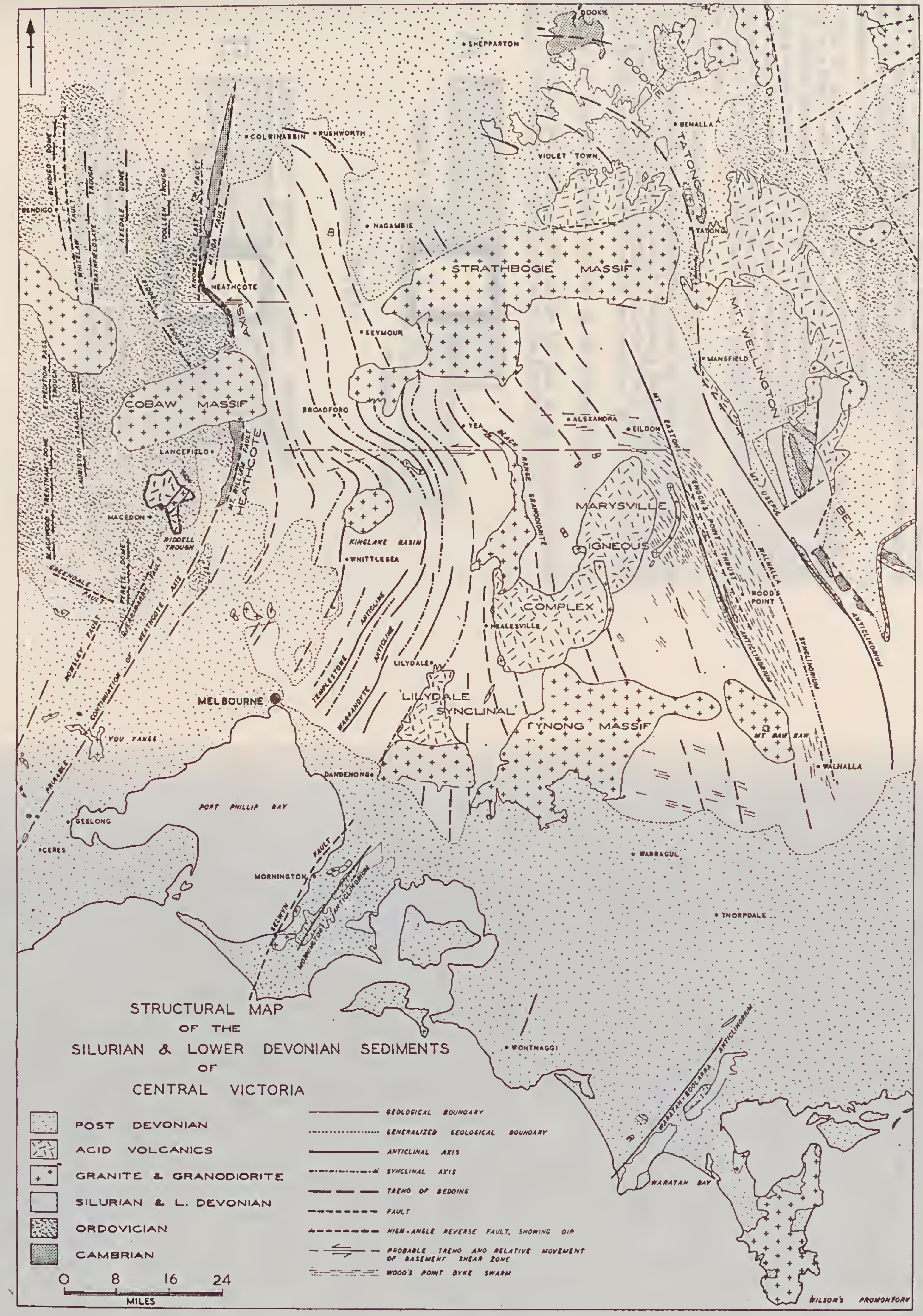

STRUCTURAL MAP
OF THE
SILURIAN & LOWER DEVONIAN SEDIMENTS
OF
CENTRAL VICTORIA
POST DEVONIAN
ACID VOLCANICS
GRANITE & GRANODIORITE
SILURIAN & L. DEVONIAN
ORDOVICIAN
CAMBRIAN
GEOLOGICAL BOUNDARY
GENERALIZED GEOLOGICAL BOUNDARY
ANTICLINAL AXIS
SYNCLINAL AXIS
TREND OF BEDDING
FAULT
HIGH-ANGLE REVERSE FAULT, SHOWING DIP
PROBABLE TREND AND RELATIVE MOVEMENT OF BASEMENT SHEAR ZONE
WOOD'S POINT DYKE SWARM
0
8
16
24
MILES
SHEPPARTON
DOOKIE
DOOKIE
BENALLA
TATONG
TATONG
VIOLET TOWN
COLBINABBIN
RUSHWORTH
NAGAMBIE
STRATHBOGIE MASSIF
MT. WELLINGTON
MANSFIELD
BELT
BENDIGO
BENDIGO DOME
WHITELAW FAULT
STRATHFIELDSAYE TROUGH
AYEDALE DOME
TOOLLEEN TROUGH
KNOWSLEY EAST FAULT
MT. IDA FAULT
HEATHCOTE
AXIS
RIDDELL TROUGH
SEYMOUR
EXPEDITION PASS TROUGH
LAURISTON - TARADALE DOME
COBAW MASSIF
BROADFORD
ALEXANDRA
EILDON
MT. EASTON
MT. USEFUL
YEA
BLACK RANGE GRANODIORITE
LANCEFIELD
MT. WILLIAM FAULT
HEATHCOTE
BLACKWOOD - TRENTHAM DOME
MACEDON
RIDDELL TROUGH
KINGLAKE BASIN
WHITTLESEA
MARYSVILLE
IGNEOUS
ENOCH'S POINT THRUST
WALHALLA
GREENDALE FAULT
PYRETE DOME
DJERRIWARRH FAULT
WOOD'S POINT
ANTICLINORIUM
COMPLEX
HEALESVILLE
TEMPLESTOWE ANTICLINE
WARRANDYTE ANTICLINE
LILYDALE
SYNCLINORIUM
ANTICLINORIUM
ROWSLEY FAULT
CONTINUATION OF HEATHCOTE AXIS
MELBOURNE
LILYDALE SYNCLINAL
TYNONG MASSIF
MT BAW BAW
YOU YANGS
WALHALLA
DANDENONG
PROBABLE
PORT PHILLIP BAY
GEELONG
CERES
WARRAGUL
MORNINGTON
FAULT
SELWYN
MORNINGTON ANTICLINORIUM
THORPDALE
WONTHAGGI
WARATAH - BOOLARRA ANTICLINORIUM
WARATAH BAY
WILSON'S PROMONTORY

FIG. 12

a swing in the trend. Consequently, areas of high fold density also tend to be areas where the folds deviate from the normal trend, and are probably due to inhomogeneity of the medium. These areas appear to be analogous to the crush-zones at Studley Park (Hills 1941) and Warrandyte (Jutson 1911).

Experiment 2: Folds due to horizontal sinistral shear.

Here the grease and tissue paper were mounted on two flat wooden blocks joined by a tongue and groove and free to move laterally with respect to each other.

A sinistral movement of the top block produced a series of drag folds in the overlying tissue paper (Pl. L, fig. 2). This confirms the work of Brown (1928a), and demonstrates that sinistral basement movement produces a fold pattern similar to that of the Flowerdale district. The folds shown here differ from those of Brown's experiment in that they are sigmoidally curved, probably due to drag in the softer grease medium.

Experiment 3: Compression followed by horizontal sinistral shear.

The two wooden blocks described above, grease and tissue paper were used. The 'N.-S.' folds (Pl. L, fig. 3) were formed by stretching the tissue paper lengthwise, as the soft grease did not allow the formation of even folds by pushing from the sides. The top block was then moved to the left, producing an 'E-W.' basement sinistral shear.

There are several noteworthy features of the resultant fold pattern (Pl. L, fig. 4).

1. The sharp bend of almost 90° on the left side of the stationary block is analogous to the sudden change of trend within the Kinglake district.

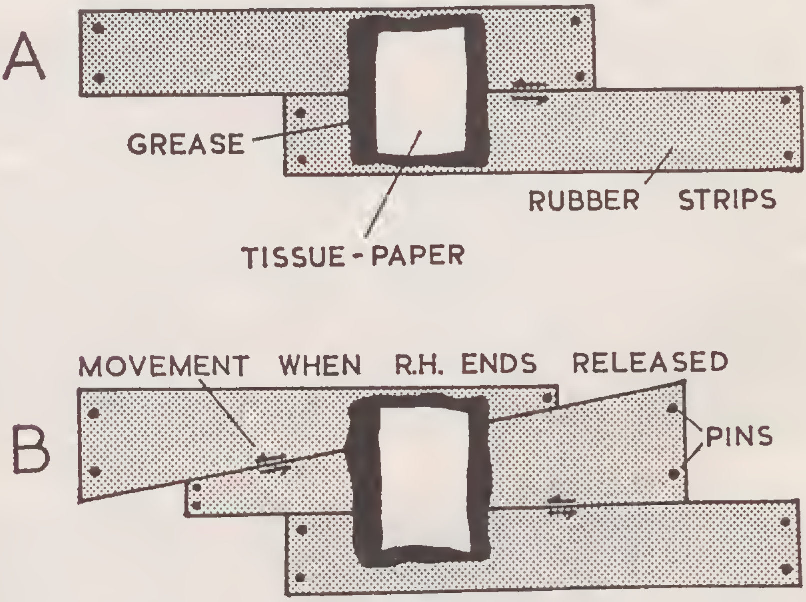


Fig. 13—a. Two stretched rubber strips arranged to produce simultaneously both compression and 'E.-W.' shear.
b. Three rubber strips arranged to produce simultaneously compression and two non-parallel shears.

2. The angle γ between the drag folds and the underlying shear increases from about 30° on the left to 50° on the right. Similarly, the folds at Reedy Ck strike approximately 120°, and in the Yea-Eildon district 150°-160°.

3. In the lower block the arcuate folds are not concentric and the radii of curvature increase to the right, as with the folds from Kinglake to the Walhalla Synclinorium.

Experiment 4: Simultaneous compression and horizontal sinistral shear.

Two strips of rubber each about 5 in. wide and 18 in. long were equally stretched and pinned side by side to a wooden board, with the lower strip displaced to the right (Fig. 13a).

Grease and tissue paper were applied across the two strips, the right hand ends released and both strips allowed to slowly contract. Although contraction was everywhere the same, the staggered positions caused lateral movement between the strips similar to that of a sinistral wrench fault.

The fold pattern produced by this simultaneous compression and shearing is shown in Pl. L, fig. 5. The angle γ and the radii of curvature of the fold arcs increase to the right as in experiment 3, and again compare with the folding in South-Central Victoria. The folds due to compression are small and overlapping, grading into the stronger, more persistent folds across the shear in analogous manner to the folds of the Kinglake district. Also, the folds on the left hand side are asymmetrical with axial planes inclined to the left, comparable with the asymmetry of the Merriang Syncline and the overfolding to the W. in the Heathcote Junction district. In the centre the folds are mostly symmetrical, while on the right the axial planes dip to the left.

Experiment 5: Compression with two horizontal sinistral shears.

Firstly, three rubber strips were stretched in staggered position to produce simultaneously both compression and two 'E.-W.' sinistral basement shears. The lower shear produced a fold pattern similar to that of the Kinglake-Eildon-Walhalla arc, but in no experiment was it possible to reproduce the E.-W. folds of the Rushworth district, no matter how far the top rubber strip was displaced to the left.

The trend of the upper shear was then altered from E.-W. to a strike of about 77° as shown in Fig. 13b, Pl. L, fig. 6 being typical of the fold patterns produced. The angle γ, although it increases to the right, is approximately the same for each shear, being about 30° on the far left. Consequently, on the left, the upper set of drag folds strikes approximately 107°, and the lower set 120°, consistent with the fold trends at Rushworth and Flowerdale respectively. Altering the strike of the upper shear to 65° would no doubt produce folds striking almost E.-W. The lateral variations in radii of curvature and angle γ of the drag folds result in much sharper changes of trend on the left, analogous to the sharp bends in the folds of the Kinglake and Rushworth districts.

Conclusions from Experimental Work

Experimental evidence supports the theory that the arcuate folds of South-Central Victoria were caused by sinistral movement along a basement shear zone trending approximately E.-W., and extending from Kinglake to the Walhalla Synclinorium (see Fig. 12). Such a shear zone would be parallel to the linear S. boundaries of the Strathbogie Granite Massif, which probably represent pre-granite faults.

It is possible that the Heathcote inflection is due to another, but much smaller basement shear zone, again showing sinistral movement and running E.-W. This shear zone would be aligned with the main linear S. boundary of the Strathbogie Granite, and possibly major basement movement exists along this line.

Experimental evidence also shows that sinistral movement along a basement shear zone striking between 65° and 75° could have produced the Rushworth-Benalla fold arc. Such a shear zone would be roughly parallel to a number of major Palaeozoic faults in the Beechworth-Kiewa area to the E., shown on the Tectonic Map of Australia.

The Heathcote Axis

The Heathcote Axis (Thomas 1937, 1939) is a narrow, thrust-faulted, submeridional inlier of Cambrian rocks marking the junction of the Ordovician and Silurian sediments of Central Victoria.

Thomas (1939, p. 62) stated that it was 'difficult to trace this belt (the Heathcote Axis) to the south, but it takes a twist to the south-west near Monegeetta and is lost under the basalt of the Keilor Plains'. However, Coulson (1929, 1932) showed that outcrops of diabase at the You Yangs, and at Dog Rocks and Ceres W. of Geelong, would lie on a line produced to the SW. from Monegeetta, and on Fig. 12 it may be seen that this extrapolated line is closely parallel to the fold trend of the Silurian rocks to the E.

Anderson (1951) noted the common association of folds, thrust faults, and wrench faults in deformed sediments, and considered they were formed simultaneously by the same compressive movements. He stated that 'any system of transcurrent faults should theoretically consist of two classes, whose members are complementary, and run in different directions. There may thus be four different types of structure in one area (folds, thrust faults, to transcurrent faults) which are evidently connected, but this association is seldom complete. In much of the Jura Mountains, and of the Scottish Highlands, only one of the two possible sets of transcurrent faults has been established . . .'.

The probable association between basement wrench faults and the folds of the Victorian Siluro-Devonian sediments has been indicated above, with only one of the two posible sets of wrench faults, those with sinistral movement, having developed. However, Hills and Thomas (1954) stated that during the Ordovician, the major anticlinal structures, such as the Heathcote Axis, 'were already developing as geanticlines within the trough, with thinner deposits forming on them . . .', suggesting that the Heathcote Axis was a major structure prior to the folding of the Tabberabberan Orogeny. Sinistral movement beneath the Silurian and Lower Denovian sediments would mean that, to the N., the basement blocks would be thrust progressively more to the W., possibly causing re-faulting along the axis, the relative movement being 'E. block under' rather than 'W. block over'. Such re-faulting would give the Heathcote Axis faults their greatest stratigraphic throw to the N., which is the actual case.

Thus, it seems likely that at the time of folding of the Silurian and Lower Devonian sediments of Central Victoria, the basement was divided into several large blocks by E.-W.-trending fractures or faults, while the major structural line of the Heathcote Axis was already partly developed. Following initiation of the folding by compression acting along an azimuth between 90° and 120°, sinistral movement between several of the basement blocks caused arcuate folds in the overlying sediments and deflection and re-faulting of the Heathcote Axis. The boundaries of the Strathbogie Granite were possibly later controlled by some of these basement fractures.

Igneous Rocks of the Kinglake District

DIORITES

At least 6 dykes and 2 stocks of quartz diorite intrude the sediments of the Kinglake district (Fig. 2). These were hard to map accurately owing to their deeply weathered state, so old mine diggings and reports proved very useful. Consequently there may be many undiscovered dykes within the area, particularly in the heavily timbered country.

1. Reedy Ck Quartz Diorite Dyke:

Murray (1884), who was first to record the presence of this dyke, considered it to be 50 to 200 ft wide and to run NE. from Sunday Ck to Strath Ck. However, 3 separate diorite dykes are present in this district, the largest being approximately 2 miles in length, striking 73°, about 3 miles S. of Reedy Ck. Murray reported that the dyke was locally intersected by auriferous quartz veins extending from wall to wall, which were worked for gold and antimony.

The dyke is a fine-grained, greenish, mesocratic rock, thin sections revealing that it has undergone extensive alteration. The least altered (Section 8499) contains large euhedral and occasionally twinned phenocrysts of green-brown hornblende, partially altered to chlorite. No cores of augite or enstatite were observed in the hornblende, although Edwards (1937, p. 98) noted the feature in this dyke. The groundmass consists of zoned plagioclase, probably andesine, the cores having been extensively altered to sericite, cloudy orthoclase, and interstitial quartz. Accessory minerals include ilmenite, apatite, sphene, and epidote.

In the more altered rock (Sections 8500, 8501) the hornblende is represented almost entirely by pseudomorphs of chlorite, often in large, irregular patches. Most of the felspar is very cloudy and of low refractive index, with occasional lamellar twinning suggesting some is albite. Epidote is common and fibrous tremolite has

TABLE 3

Chemical Analyses of Quartz Diorites

	(1)	(2)	(3)	(4)
SiO_2	54·66	53·60	52·53	49·65
Al_2O_3	18·05	16·28	18·78	16·73
Fe_2O_3	1·06	0·44	1·52	0·31
FeO	7·04	10·34	6·60	8·99
MgO	6·21	6·80	3·02	5·88
CaO	1·20	7·10	7·21	7·87
Na_2O	4·77	2·80	2·54	3·10
K_2O	2·64	1·70	1·73	0·80
H_2O+	3·48	0·44	2·24	2·50
H_2O-	0·26	0·15	0·53	0·14
CO_2			0·39	1·08
P_2O_5			0·32	0·04
MnO			0·14	0·14
TiO_2	1·15	1·14	2·16	2·81
	100·52	100·79	99·71	100·04

(1) Reedy Ck quartz diorite. (Analyst: V. Biskupsky)
(2) Mt Robertson quartz-hypersthene diorite. (Analyst: V. Biskupsky)
(3) St Andrews quartz diorite. (Analyst: N. R. Junner)
(4) Morning Star dyke, Wood's Point. (Analyst: A. W. Howitt 1887)

developed locally in radial clusters. Other common accessory minerals are sphene, leucoxene, pyrrhotite, pyrite, and apatite. Interstitial quartz is widespread, often in granophyric intergrowth with felspar.

A chemical analysis of the dyke rock is shown in Table 3, No. 1, together with an analysis of the Morning Star dyke, Wood's Point. The low percentage of lime and the high percentage of water in the Reedy Ck diorite are probably due to leaching of calcium carbonate, none of which was observed in thin section. Otherwise, the chemical composition is similar to the Wood's Point dyke.

2. Clonbinane Quartz Diorite Dyke:

The Clonbinane diorite dyke is at least 1½ miles long, striking 80° across Sunday Ck, and according to Whitelaw (1899) averaging about 80 ft in width. The rock is fine-grained and greenish, with a large amount of pyrite and arsenopyrite disseminated throughout, while towards the NE. it tends to be porphyritic. Sections 8502 and 8503 show that the dyke is a typical propylitized quartz diorite, containing irregular pseudomorphs of chlorite; partially chloritized hornblende; cloudy twinned felspar, probably albite; interstitial quartz; ilmenite grains; with alteration products pyrite, leucoxene, calcite, and epidote.

Whitelaw (1899) and Jenkins (1902) both noted that mineralized reefs composed of quartz, stibnite, pyrite, and breccia of the Silurian rocks cross the dyke at right angles every few yards, dying out a foot or so beyond the dyke. These reefs vary from 12 ft to a few inches in width, generally the wide spaces being filled with quartz and the narrow spaces with stibnite.

3. Tunnel Hill Dykes:

A large, weathered dioritic dyke, striking approximately 55°, is exposed in old mines and tunnels at Tunnel Hill, about 4 miles N. of the Mt Disappointment Granodiorite. Granodiorite porphyrite (Section 8504) occurs as float in Strath Ck, near Tunnel Hill, although it was not observed in situ.

4. Yow Yow Quartz Diorite:

About 1½ miles E. of St Andrews is an elliptical shaped intrusion of quartz diorite about ¼ mile long and trending approximately NE. This has been described in detail by Junner (1914), and a chemical analysis of the rock is included in Table 3.

5. Mt Robertson Quartz-Hypersthene Diorite:

A small, oval-shaped intrusion of diorite about ½ mile long and trending NE. occurs near Mt Robertson, 5 miles NE. of Kinglake West. The intrusion, which is deeply weathered, is almost completely surrounded by a narrow aureole of quartz-sericite-biotite hornfels, indicating that the adjacent siltstones have undergone low-grade thermal metamorphism.

The rock is medium to fine grained, mesocratic and slightly greenish when fresh. Sections 8506 to 8508 contain small tabular phenocrysts of twinned andesine partly altered to sericite, and occasionally zoned augite, enstatite and hypersthene. A few of the pyroxenes have been partially altered to a green, fibrous hornblende and sericite?; pseudomorphs of hornblende are probably after pyroxene. Biotite is interstitial to the felspar and pyroxene phenocrysts, occasionally forming jackets around the hypersthene and hornblende. Cloudy orthoclase and interstitial quartz are also present, with accessories iron ore, apatite, and zircon. The biotite rims to the hypersthene are similar to those noted by Edwards (1932b) in unmetamorphosed hypersthene dacites of the Warburton area, and ascribed by him to reaction between hypersthene and orthoclase.

The rock may be classified as a quartz-hypersthene diorite, and is petrologically similar to the hypersthene porphyrite at Tooborac (Singleton 1949). The chemical analysis is given in Table 3, No. 2.

6. Upper Plenty Dykes:

A road cutting ¼ mile E. of the North Eastern Railway (grid reference 061,869 Kinglake Military Map) exposes a dioritic dyke about 150 ft wide and striking 50°. The sedimentary rocks adjacent to the dyke are highly jointed and rubbly, having the appearance of weathered hornfels. Owing to its highly weathered state it was not possible to trace the dyke far.

A small weathered dyke, probably a porphyritic diorite, about ¼ mile long and averaging about 10 ft in width, occurs on a hill ½ mile N. of the Wallan Road, Upper Plenty (grid reference 091,850 Kinglake Military Map). The dyke strikes 25° parallel to the trend of the Silurian strata, bulging to a width of 60 ft at its NE. end.

E. of Upper Plenty, numerous fresh boulders of a porphyritic quartz diorite (Section 8509) are common at Conical Hill (grid reference 115,838 Kinglake Military Map). Another porphyritic dyke in this vicinity is recorded on the Quarter Sheet No. 4 SE., but neither has been traced far due to the thick soil and timber cover.

7. Steel's Ck Quartz-Felspar Porphyry:

At Steel's Ck in the SE. corner of the area mapped is an irregular shaped intrusion of quartz-felspar porphyry containing N.-trending veins of quartz and stibite (Whitelaw 1899, Threadgold 1958). The porphyry, which shows signs of intense shearing, is part of a larger intrusion extending beyond the area mapped.

AGE OF THE DYKES

It has been shown that within the Kinglake district there are a number of diorite dykes and 'dyke-bulges' which, in their petrology, chemical composition, alteration, structure, and mineralization, closely resemble those of the Wood's Point dyke swarm to the E.

Hills (1952) gave the age of the Wood's Point dyke swarm as late Middle or early Upper Devonian stating, p. 89, that 'the upper age limit to the swarm is afforded by its relationship to the Upper Devonian sedimentary and volcanic rocks of the Marysville Complex, which the dykes do not penetrate'. A similar age is likely for the diorites of the Kinglake district, and they probably pre-date the Mt Disappointment and other granodiorite intrusions.

Fig. 12 shows that the dykes of the Wood's Point swarm trend north-westerly at Walhalla, parallel to the regional strike of the folded sediments, but N. of Walhalla swing gradually to the W. until at Alexandra the trend is E.-W. All the diorite intrusions within the Kinglake district have a north-easterly trend, and possibly form a continuation of the arc W. of Alexandra.

GRANODIORITES

FLOWERDALE MICROGRANODIORITE

The microgranodiorite intrusion at Flowerdale is dumb-bell shaped, approximately 3 miles long with a maximum width of 1 mile, and lying parallel to the fold trend of the district. Two quartz porphyry dykes each at least 1 mile in length extend from the two main lobes of microgranodiorite, making the intrusion as a whole arcuate in outline. Both Break-o'-Day Ck and King Parrot Ck cross the microgranodiorite, which is deeply weathered and mostly covered with stream alluvium.

Contact Metamorphism:

The microgranodiorite is surrounded by a prominent aureole of thermally metamorphosed sediments, most strongly developed on the NE. side.

The siltstones approximately ½ mile from the contact have a spotted texture, while closer to the microgranodiorite a dark blue, tough hornfels is developed. Most of the inner zones of the aureole consist of quartz-biotite-sericite or quartz-biotite-muscovite hornfels. Section 8510 contains unaltered detrital quartz grains, although the chloritic groundmass has recrystallized into a fine intergrowth of biotite and sericite. At higher grades of metamorphism the hornfels is composed of anhedral, interlocking quartz grains and abundant laths of biotite and muscovite arranged in decussate texture, as shown in Section 8511 from Flagpole Hill. Other minerals include rare orthoclase, iron ore, apatite, and chlorite after biotite.

A true cordierite hornfels is present about ¼ mile from the contact 1 mile S. of the Three Sisters. Section 8512 contains anhedral porphyroblasts of cordierite poikiloblastically enclosing quartz, iron ore, muscovite, biotite, and fine rutile (?) needles. Between the cordierite porphyroblasts is a mosaic of quartz and rare orthoclase, biotite and muscovite laths, and iron ore.

Quartz Porphyry Dykes:

S. of the Three Sisters a conspicuous gully in the aureole marks the position of a quartz porphyry dyke about 15 ft wide which extends for over a mile to the NW. The hornfels is brecciated near this gully, and the dyke is greatly fractured and shows evidence of shearing.

The porphyry is fine grained and cream to pink in colour. Samples farthest from the microgranodiorite (Section 8514) contain rectangular to sub-rounded phenocrysts of quartz; phenocrysts of orthoclase now largely represented by pseudomorphs of sericite and kaolin?; and a microcrystalline groundmass of quartz, orthoclase, sericite, and occasional iron ore grains. However, at the contact (Section 8515) the felspar phenocrysts show little alteration to sericite and have a refractive index very close to that of the medium, suggesting they are of albite. Subhedral quartz phenocrysts and ragged plates of muscovite enclosing numerous rounded quartz grains are also present, while the groundmass of quartz and felspar is coarser grained than in Section 8514. These differences suggest that the dyke has been slightly metamorphosed by the microgranodiorite.

Another quartz porphyry dyke about 20 ft wide has been traced for nearly a mile to the S. from Flagpole Hill. Again the dyke is sheared, similar in appearance to that at the Three Sisters, except for occasional flakes of biotite 1-2 mm in diameter. Section 8516 taken from the S. end of the dyke contains phenocrysts of quartz, orthoclase, and biotite set in a fine-grained groundmass of orthoclase laths, sericite, biotite, and interstitial quartz. Section 8517 from near the microgranodiorite has similar quartz phenocrysts to Section 8516, but biotite phenocrysts are more numerous and tend to be ragged in outline. Small muscovite flakes in decussate arrangement are abundant, while muscovite and biotite, often in radial clusters, partly replace the orthoclase phenocrysts. The groundmass tends to be granulitic, with fewer felspar laths than in Section 8516. These changes suggest that this quartz porphyry dyke also has been slightly metamorphosed, but are not sufficient alone to indicate that the quartz porphyry dykes pre-date the microgranodiorite.

Several other quartz porphyry dykes are present within the area mapped, e.g. Section 8518 from a creek about 4 miles S. of Flowerdale.

Microgranodiorite:

The microgranodiorite is a fine-grained, mesocratic rock similar in appearance to a dacite, with individual crystals seldom exceeding 1·5 mm in diameter.

Section 8519 shows that the rock has the typical hypidiomorphic texture of a granodiorite, containing euhedral to subhedral andesine and oligoclase, both twinned and zoned, with the cores often altered to sericite and calcite; slightly cloudy orthoclase, with numerous inclusions of quartz and micas; ragged laths of dark-brown biotite containing many pleochroic haloes and often extensively altered to a pale-green chlorite; slender laths of muscovite, often arranged in radial pattern; interstitial quartz, and scattered grains of iron ore. Section 8520 from near the contact at the Three Sisters is rich in orthoclase, euhedral prisms of brown tourmaline indicating pneumatolytic action.

TABLE 4

Chemical Analyses of Granodiorites

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SiO_2	65·88	69·17	66·30		66·90	67·80	66·13	67·75
Al_2O_3	14·61	15·95	16·42		15·75	15·63	16·83	16·11
Fe_2O_3	0·85	0·88	0·52		0·75	0·48	1·11	0·50
FeO	4·15	3·64	3·00		3·95	3·56	4·17	4·00
MgO	2·74	1·12	1·05		0·38	0·23	1·83	0·79
CaO	1·45	3·04	1·85		3·30	2·14	3·26	2·68
Na_2O	3·23	2·64	2·65	1·99	3·88	3·80	2·25	2·60
K_2O	5·10	3·07	6·00	5·19	3·80	5·18	3·14	3·42
TiO_2	0·85	0·77	0·44		0·66	0·53	trace	0·85
H_2O+	1·11	0·36	0·42		0·43	0·54	1·91	1·16
H_2O-	0·23				0·06	0·09		
MnO		0·03	0·05				0·07	trace
P_2O_5		0·02	1·12				trace	0·09
Total	100·20	100·69	99·82		99·86	99·98	100·70	99·95

(1) Flowerdale Microgranodiorite. (Analyst: V. Biskupsky)
(2) Quarry Hill Granodiorite, South Morang. (Analyst: F. J. Watson)
(3) Porphyritic marginal phase, South Morang Granodiorite. (Analyst: A. B. Edwards)
(4) Metamorphosed Silurian shale adjacent to porphyritic granodiorite, South Morang.
(5) Non-porphyritic outer phase, Mt Disappointment Granodiorite. (Analyst: V. Biskupsky)
(6) Porphyritic inner phase, Mt Disappointment Granodiorite. (Analyst: V. Biskupsky)
(7) Bulla Granodiorite. (Analyst: F. J. Watson) (James 1920)
(8) Mt Gellibrand 'Adamellite', Broadmeadows. (Analyst: H. C. Richards) (Stillwell 1911)

A chemical analysis of the microgranodiorite (Table 4, No. 1) shows that although it is richer in potash and magnesia, and poorer in lime than other granodiorites from south-central Victoria, it has much in common with these rocks. The higher potash and magnesia contents are possibly due to the great amount of biotite in the microgranodiorite.

The fine grain and elongated shape of the microgranodiorite suggest that it is not the top of a typical stock, but tends more towards a large dyke, similar to the arcuate microgranodiorite dyke at Tooborac (Singleton 1949). The stronger aureole on the NE. side may be due to the microgranodiorite dipping to the NE., but there is no evidence available to support this.

MORANG GRANODIORITE

The Morang Hills, composed of a small granodiorite stock and associated metamorphosed Silurian sediments, form an inlier about 4 miles long and 3 miles wide in the Newer Basalt flows S. of Whittlesea.

The petrology of the igneous and metamorphic rocks has been described in detail by Edwards and Baker (1944). Portion of the E. margin of the granodiorite contains many anhedral perthite phenocrysts up to 3 in. long; a chemical analysis of this porphyritic phase (Table 4, No. 3) shows that it is distinctly richer in potash and phosphorus, and poorer in lime, than the normal granodiorite (Table 4, No. 2), but otherwise both phases are similar. Edwards and Baker considered that the enrichment of potash was due, in part at least, to assimilation of country-rock because of 'the abundance of xenocrystic matter in the marginal phase, and the established potassic character of the adjacent contact sediments' (Table 4, No. 4).

MT DISAPPOINTMENT GRANODIORITE

The Mt Disappointment Granodiorite is a small, oval-shaped massif about 8 miles long (NE.-SW.) and 5 miles wide, lying almost entirely within the Kinglake Basin and forming the most elevated country in the Kinglake district. The intrusion is surrounded by a prominent metamorphic aureole, although the exact contact with the country rock was difficult to map due to the thick soil and vegetation cover. Two distinct, roughly concentric phases are present in the granodiorite—the outer of medium grained granodiorite, and the inner of slightly coarser grain containing abundant large perthite phenocrysts.

Contact Metamorphism:

The aureole of thermally metamorphosed sediments is generally about ¾ mile wide, increasing to 1½ miles on the arcuate NE. boundary. Section 8521 taken about ¾ mile from the contact contains oval spots about 0·5 mm in length, composed mainly of a pale green, isotropic material of low refractive index. In the areas between the spots, the argillaceous matrix of the siltstone has recrystallized to a fine intergrowth of biotite and muscovite, although the detrital quartz grains appear unaffected. Nearer the contact, a dark-blue, tough cordierite hornfels has developed (Sections 8522 and 8523). The cordierite occurs as ragged porphyroblasts enclosing rounded quartz and iron ore grains, and flakes of muscovite and biotite, set in a fine-grained mosaic of quartz, biotite, and muscovite. Section 8523 shows the original sedimentary laminations, the sandy bands crystallizing into a coarser grained quartz-biotite-muscovite hornfels containing no cordierite.

The contact metamorphic rocks within the area mapped are all of a similar type, not rising above the grade of cordierite hornfels. Even though a small number of sections from the Mt Disappointment aureole were examined, it is likely that they are representative, as the argillaceous sediments change little either vertically or laterally. The low grade metamorphism of the sediments shows that the granodiorites were intruded under conditions of low temperature and pressure, and a high level of emplacement, similar to that of other Central Victorian massifs, is indicated.

Granodiorite:

Outer Phase. The granodiorite of the outer phase is a mesocratic, medium grained rock, containing no phenocrysts and only occasional xenoliths. Sections 8524 to 8528 consist of zoned and twinned oligoclase (Ab_{80}) partly altered to sericite and calcite; allotriomorphic and interstitial quartz; biotite, locally altered to a pale-green, fibrous chlorite; and orthoclase, often containing streaks of dusty inclusions and exhibiting perthitic intergrowth with albite. Accessory minerals include zircon, giving rise to pleochroic haloes in the biotite; irregular grains of ilmenite; and apatite. A chemical analysis (Table 4, No. 5) shows that the non-porphyritic phase is a typical granodiorite, similar in composition to the granodiorites at Morang, Bulla and Mt Gellibrand (Table 4, No. 2, 7, 8).

Inner Porphyritic Phase. The porphyritic phase is typified by the presence of numerous granitized xenoliths, and abundant rectangular orthoclase phenocrysts up to 4 in. long and 1½ in. wide containing numerous biotite flakes arranged in concetric layers (Pl. LI, fig. 1). The groundmass is a granodiorite, but slightly coarser grained than the outer phase. No actual contact between the two phases was observed, but where exposure was fair the change occurred over 50 yds to ¼ mile.

The groundmass of the porphyritic phase (Sections 8529 to 8533) is composed of quartz oligoclase (Ab_{80}), orthoclase, biotite, numerous large apatite prisms, and alteration products chlorite and sericite. Sections 8529, 8530 and 8531 show the phenocrysts to be of anhedral perthite, often showing Carlsbad twinning, and containing biotite, muscovite, and corroded oligoclase aligned parallel to the c-axis. These inclusions are probably due to the crowding aside of earlier formed tabular minerals during crystallization of the phenocrysts, indicating rapid crystallization in a fluid environment.

A chemical analysis (Table 4, No. 6) shows that the porphyritic phase is considerably richer in potash and poorer in lime than the normal granodiorite (Table 4, No. 5), but otherwise the two are very similar. Such variations were also noted by Edwards and Baker between the porphyritic and non-porphyritic phases of the Morang Granodiorite.

Xenoliths:

Xenoliths, ranging in size from a fraction of an inch to 18 in. in diameter, are common within the porphyritic phase, although rare in the non-porphyritic granodiorite.

In the normal phase the xenoliths tend to be small and round, contain abundant biotite and generally have the appearance of a microgranodiorite. Most commonly (Sections 8534, 8535, and 8536) they are composed of brown biotite, zoned oligoclase, quartz and othoclase, with minor amounts of sericite, chlorite, ilmenite, and apatite. Two sections (8537 and 8538) are composed almost entirely of oligoclase, biotite, and quartz, with little or no orthoclase, while Section 8539 is distinguished by abundant green hornblende, containing also biotite, oligoclase, quartz, and rare orthoclase.

Section 8540 shows the contact between the granodiorite and a dark, dense xenolith. The normal granodiorite changes near the contact to a fine-grained mosaic of andesine crystals containing subhedral to anhedral porphyroblasts of green hornblende. Further into the xenolith, labradorite is the dominant felspar, partly enclosed by large, embayed porphyroblasts of augite and hornblende. Thus, over about ¼ inch, the section shows a range in composition from granodiorite to gabbro.

The ovoid xenoliths of the porphyritic phase are generally larger, lighter coloured and contain less biotite than those of the normal granodiorite, their texture often being fibrous due to numerous fine felspar laths. The most common type (Sections 8541 to 8544) contains large twinned and zoned porphyroblasts of oligoclase and occasionally of quartz, set in a groundmass of slender oligoclase laths, biotite, interstitial quartz, and varying amounts of orthoclase, locally common. Section 8545 is similar except that it contains no large porphyroblasts and a little more orthoclase, while Section 8546 has a more granitic texture, being composed mainly of biotite, oligoclase, quartz, and a generous scattering of sphene and calcite grains.

Heavy mineral analyses were carried out for two xenoliths from the porphyritic phase, one dark brown with abundant biotite and the other light grey and containing little biotite. The presence of occasional rounded zircons in each suggests that most of the xenoliths represent granitized sediments.

The development of hornblende at the expense of biotite in several of the xenoliths from the non-porphyritic phase, and the apparent lack of orthoclase in several of these xenoliths suggest that the magma of the outer base was slightly undersaturated with respect to K_2O, as concluded for the Morang Granodiorite by Edwards and Baker. However, it is likely that the gabbroic xenolith (Section 8540) is a metamorphosed basic igneous rock, as the manner in which the augite porphyroblasts enclose labradorite is reminiscent of ophitic texture.

Dykes and Veins:

Thin aplites and pegmatites occur occasionally in both phases of the granodiorite, but together with quartz veins, are numerous in a small quarry at Nimmo Falls, Wallaby Ck Reserve. The micropegmatites and aplites show typical saccharoidal texture, being grey to cream in colour, with occasional dark flecks of tourmaline. Sections 8547 and 8548 consist chiefly of quartz and cloudy orthoclase often in granophyric intergrowth, with lesser amount of oligoclase and albite. Muscovite laths are generally arranged in radial clusters; biotite is rare. The tourmaline is interstitial, consisting mainly of brown schlorite, with a little blue elabite. Accessory minerals include pyrite grains and small zircons.

Thin quartz veins ¼ to ½ in. wide are common throughout the Kinglake district, comb structure and vuggy spaces suggesting injection under tension; occasional slickensided quartz along bedding planes and veins displaced by small faults indicate slight post-injection tectonic activity.

Structural Features:

Contacts.

The only places where the actual contact between granodiorite and country-rock is exposed are two cuttings on the NW. boundary, where it is roughly vertical. The relatively narrow metamorphic aureole suggests that this is so for most of the massif, although the greater width of the aureole along the arcuate NE. boundary may be due to the contact here dipping to the E.

The combination of arcuate and linear trends of the contact is a notable feature of the massif. The straight SE. boundary, about 6 miles long, almost certainly represents a large pre-intrusion fault, and the arcuate NE. contact is similar to the ring fracturing associated with numerous other Central Victorian granitic intrusions (Hills 1959). The linear portions of the NW. contact also suggest pre-intrusion faulting.

Flow Structure.

Generally the phenocrysts of the porphyritic phase are arranged at random like those of the Morang Granodiorite. However, occasionally the phenocrysts and ovoid xenoliths occur in sub-parallel arrangement; nearly always this flow structure is parallel to the neighbouring granodiorite contact, while S. of Mt Disappointment the phenocrysts are aligned vertically.

Joints.

The few accurate readings obtained suggest that the joints occur in three near vertical sets striking a few degrees W. of N., NW.-SE. and NE.-SW. These joints appear to have controlled the drainage pattern developed on the granodiorite.

Mechanism of Intrusion:

There seems little doubt that the Mt Disappointment Granodiorite is typical of Central Victorian massifs, having intruded high in the crust under conditions of low temperature and pressure. Its location within the Kinglake Basin has parallels elsewhere in Central Victoria. The Cobaw Massif was emplaced across the Riddell Trough developed in Ordovician sediments, while to the SE. the triangular outline of the Dandenongs Igneous Complex is closely parallel to the trend lines of the 'Lilydale Synclinal', which has a strong southerly plunge (Fig. 12). The fact that granitic emplacement has been influenced by fold structures is further supported by the arcuate Black Range Granodiorite, which follows the regional fold trend for over 20 miles.

Thus, it is possible that the granodiorite selectively intruded the Kinglake Basin following the subsidence of a large block of low-dipping sediments bounded by at least one arcuate and two linear fractures. There is no evidence of the intrusion having broken through to the surface, although some loose boulders of a typical quartz-hypersthene-biotite dacite (Section 8549) were found at Flowerdale. These boulders could have been derived from dykes intruded in similar fashion to the quartz-hypersthene-biotite dacites of the Black Spur region (Edwards 1932a).

The abundance of perthite phenocrysts and xenoliths in the inner phase of the Mt Disappointment Granodiorite has similarities with the marginal porphyritic phase of the Morang Granodiorite, while both these phases are considerably richer in potash than the adjacent normal granodiorites. However, the porphyritic phase of the Mt Disappointment Granodiorite cannot be considered a marginal development of the massif, nor can a differentiate in situ explain the abundance of xenoliths. Possibly, partial collapse of the country-rock ceiling above the intrusion caused the concentration of xenoliths in the centre of the granodiorite, with subsequent enrichment in potash and crystallization of the perthite phenocrysts. However, the possibility of further intrusive action, with the porphyritic phase being a separate, younger body, must not be entirely precluded.

BASALTIC ROCKS

BASALT FLOWS

The south-westerly corner of the area investigated is covered by flows of a dark, fine-grained olivine basalt, forming part of the E. margin of the extensive Newer Basalt plains of Western Victoria (Edwards 1938a). Here the boundaries of the basalt were taken from the Quarter Sheets No. 3 NE. and 3 SE., and needed little amendment.

The Bald Hills to the N. are composed of a dense, dark olivine basalt containing (Section 8550) euhedral to slightly embayed phenocrysts of olivine and smaller rectangular phenocrysts of augite, set in a medium-grained groundmass of slender labradorite laths, stumpy augite occasionally showing ophitic texture, and a brownish glass containing fine frondlike black inclusions. Except for a little alteration to talc and serpentine, the olivine and augite are fresh. Similar rock forms a small hill to the S. of Bald Hills, although here (Sections 8551, 8552, and 8553) some iddingsite has developed after olivine, and slender phenocrysts of labradorite are occasionally present.

LIMBURGITE: FLOWERDALE

The remnants of small limburgite flow outcrop in the valley of King Parrot Ck about 2½ miles S. of Flowerdale, right on the axis of the Reedy Ck Anticline. The rock, which resembles an olivine basalt in the hand specimen, occurs in three separate outcrops, the largest being about ⅓ square mile in area and rising sharply to over 50 ft above the valley floor.

Sections 8554 to 8557 contain abundant euhedral to embayed phenocrysts of olivine up to 2 mm long in sub-parallel arrangement, and occasional rectangular, twinned augite phenocrysts containing numerous iron ore grains, set in a groundmass of twinned augite laths; iron ore grains; olivine, often altered to iddingsite; occasional rounded patches of analcite; rare nepheline, and brown interstitial glass. Thus the rock is a typical limburgite, being very similar to the small limburgite flows of Central and Western Victoria (Edwards 1938a).

Vesicular rock with ropy flow surfaces occurs on a hilltop W. of King Parrot Ck at an elevation 100 ft above the highest outcrop of limburgite in the valley, and except for the vesicles and small laths of labradorite, this rock (Section 8558) is similar to the limburgite. The elevated position and evidence of flow of this limburgitic basalt suggest that it represents the point of eruption, the vesicles having been formed by gases streaming from the vent.

In all sections of the limburgite examined except 8555, the olivine phenocrysts are surrounded by a border of iddingsite nearly always in optical continuity with the olivine and having equal thickness on both crystal faces and embayments (Pl. LI, fig. 2). Some small, euhedral phenocrysts of olivine have been completely altered to iddingsite, indicating that they crystallized after the resorption of earlier formed olivine had ceased, but before the formation of the iddingsite.

The King Parrot Ck valley was probably formed almost as today when the limburgite was extruded from a hill on the W. bank. The limburgite flowed eastwards to the creek and then probably entirely to the S., as none is present in the valley N. of the point of eruption. The flow dammed back a small tributary on the W. side of King Parrot Ck, and although the main stream has cut through the limburgite to several feet below its base, the tributary has been filled with alluvium and preserved as a swampy hanging valley with a small waterfall at its mouth.

Edwards (1938b) considered the limburgite to be a small flow or plug belonging to the Older Volcanic Series. However, the fresh state of the rock, the preservation of flow surfaces and its short physiographic history suggest a Newer Volcanic age.

LIMBURGITE: CLONBINANE

A small, rounded volcanic hill occurs just E. of Sunday Ck, Clonbinane, rising about 200 ft above the surrounding alluvial flats. A small flow of basaltic rock extends to the W., the hill being the probable point of eruption.

The rock is dark and dense, with numerous small olivine phenocrysts up to

2 mm in length, while vesicles are common locally. Thin sections (8559 and 8560) reveal many subhedral olivine phenocrysts arranged in sub-parallel position and surrounded by a narrow iddingsite border, often not in optical continuity, and small, completely iddingsitized olivine phenocrysts. As with the Flowerdale limburgite, the iddingsite has equal width on both crystal faces and embayments. Euhedral to subhedral augite phenocrysts contain numerous iron ore inclusions, while the groundmass consists of abundant iron ore grains, iddingsite after olivine, augite laths, rare analcite and nepheline, and interstitial brown glass. Basic aggregations (Section 8561) are composed of a mosaic of augite grains; a green, isotropic interstitial material, probably serpentine; and cross-fibred crysotile. Thus, the rock is a true limburgite, very similar to that at Flowerdale.

The flow at Clonbinane must have been extruded when the Sunday Ck valley was well developed, as the base of the flow lies little above stream level. A Newer Volcanic age is likely.

LIMBURGITIC BASALT: REEDY CK

Two small volcanic cones about 50 yds apart occur on the top of a spur about 1 mile N. of Reedy Ck (Pl. LI, fig. 3). These cones mark the points of eruption of a small basaltic flow about ½ square mile in area.

The rock is fine-grained and dark grey in colour, with numerous dark brown flecks of iddingsite, and on weathering has a nodular appearance. Section 8562 from the flow contains numerous phenocrysts of olivine, partially altered to iddingsite; slender, twinned augite phenocrysts, often with a narrow rim of iron ore grains; and a groundmass of iron ore, rare nepheline and soda plagioclase, augite laths, abundant apatite needles, and interstitial glass.

The rock from the two cones (Sections 8563 and 8564) is coarser grained than that of the flow, containing completely iddingsitized olivine phenocrysts, and phenocrysts of titanaugite showing twinning, zoning and hour-glass structure. The groundmass is fairly coarse grained, being composed of abundant augite laths, iron ore grains, occasional analcite and nepheline, and numerous fine apatite needles, all enclosed by large, occasionally zoned crystals showing low birefringence and refractive index, probably soda plagioclase, although some of it could be nepheline. Thus, the rock has affinities with the limburgites, but the presence of soda plagioclase makes classification as a limburgitic basalt more accurate.

The flow has been reduced in area by erosion, although it was probably never extensive. A Newer Volcanic age seems likely, because of the apparent youth of the cones, and the proximity to proven Newer Basalts.

References

ANDERSON, E. M., 1951. *The Dynamics of Faulting*. Oliver and Boyd, Edinburgh.

BANKS, M. R., 1962. in The Geology of Tasmania. *Journ. Geol. Soc. Aust.* 9: 186.

BILLINGS, M. P., 1954. *Structural Geology*. Prentice Hall, New York.

BROWN, R. W., 1928a. Experiments relating to the results of horizontal shearing. *Bull. Am. Assoc. Petroleum Geologists* 12: 715.

CHAPMAN, F., 1904. Excursion to Yan Yean. *Vict. Nat.* 20: 165.

———, 1924. New or little-known fossils in the National Museum. Pt 28—Some Silurian rugose corals. *Proc. Roy. Soc. Vict.* 37: 104-118.

COULSON, A., 1929. On the relationship of the epidiorite and the granite at Barrabool Hills and Dog Rocks, near Geelong, Victoria. ibid. 42: 99-109.

———, 1932. Diabase rocks at the You Yangs, near Geelong. ibid. 45: 137-139.

CROOK, K. A. W., 1956. The stratigraphy and petrology of the Narrabeen Group in the Grose River district. *Journ. Proc. Roy. Soc. N.S.W.* 90: 61-79.

Dorf, E., and Rankin, D. W., 1962. Early Devonian plants from the Traveller Mountain area, Maine. *Journ. Palaeont.* 36: 999-1004.

Dunbar, C. O., and Rodgers, J., 1958. *Principles of Stratigraphy.* John Wiley and Sons, New York.

Edwards, A. B., 1932a. The geology and petrology of the Black Spur area (Healesville). *Proc. Roy. Soc. Vict.* 44: 49-76.

————, 1932b. On the dacite-granodiorite contact relations in the Warburton area. ibid. 44: 163-181.

————, 1937. Quartz diorite magma in Eastern Victoria. ibid. 50: 97-109.

————, 1938a. The Tertiary volcanic rocks of Central Victoria. *Quart. Journ. Geol. Soc. London* 94: 243-320.

————, 1938b. Petrology of the Tertiary Older Volcanic rocks of Central Victoria. *Proc. Roy. Soc. Vict.* 51: 73-98.

Edwards, A. B., and Baker, G., 1944. Contact phenomena in the Morang Hills, Victoria. ibid. 56: 19-34.

Elles, G. L., and Wood, E. M. R., 1918. A monograph of British graptolites. *Palaeont. Soc.*

Gill, E. D., 1942. The thickness and age of the type Yeringian strata, Lilydale, Victoria. *Proc. Roy. Soc. Vict.* 54: 21-52.

————, 1945b. Chonetidae from the Palaeozoic rocks of Victoria and their stratigraphical significance. ibid. 57: 125-150.

————, 1947. A new trilobite from the Yeringian (Lower Devonian) rocks of Kinglake, Victoria. ibid. 59: 8-18.

————, 1948b. Palaeozoology and taxonomy of some Australian homalonotid trilobites. ibid. 61: 61-72.

————, 1948d. A gens of dalmanitid trilobites. *Journ. Proc. Roy. Soc. N.S.W.* 82: 16-24.

Gill, E. D., and Caster, K. E., 1960. Carpoid echinoderms from the Silurian and Devonian of Australia. *Bull. Am. Palaeont.* 41: 1-72.

Hill, D., 1943. A re-interpretation of the Australian Palaeozoic record, based on a study of the rugose corals. *Proc. Roy. Soc. Queensl.* 54: 53-66.

Hills, E. S., 1940. *Outlines of Structural Geology.* Methuen and Co. Ltd, London.

————, 1941. The Silurian rocks of the Studley Park district. *Proc. Roy. Soc. Vict.* 53: 167-191.

————, 1945. Examples of the interpretation of folding. *Journ. Geol.* 53: 47-57.

————, 1952. The Wood's Point dyke swarm, Victoria. *A.I.M.M. Mawson Anniv. Vol.* 87-100.

————, 1959. Cauldron subsidences, granitic rocks, and crustal fracturing in SE. Australia. *Geol. Rundschau Band* 47: 543-561.

Hills, E. S., and Thomas, D. E., 1954. Turbidity currents and the graptolitic facies in Victoria. *Journ. Geol. Soc. Aust.* 1: 119-133.

Howitt, A. W., 1887. Notes on the area of intrusive rocks at Dargo. *Proc. Roy. Soc. Vict.* 23: 127-164.

Hubbert, M. K., 1951. Mechanical basis for several familiar geologic structures. *Geol. Soc. Am. Bull.* 62: 355-372.

Jaeger, H., 1959. Graptoliten und stratigraphie des juengsten Thueringer Silurs. *Abh. Deut. Akad. Wissen, Berlin* 1959, 2: 1-197.

James, A. V. G., 1920. The physiography and geology of the Bulla-Sydenham area. *Proc. Roy. Soc. Vict.* 32: 323.

Jenkins, H. C., 1902. An interesting occurrence of gold in Victoria. *A.A.A.S.* 1902: 308.

Jones, O. A., 1927. Silurian graptolites from Studley Park, Melbourne, Australia. *Geol. Mag.* 64: 101-105.

Junner, N. R., 1913. General and mining geology of the Diamond Creek area. *Proc. Roy. Soc. Vict.* 25: 323-353.

————, 1914. The petrology and mining geology of the country near Queenstown. ibid. 27: 119-147.

Jutson, J. T., 1908. The Silurian rocks of the Whittlesea district. ibid. 21: 211-215.

————, 1911. The structure and general geology of the Warrandyte goldfields. ibid. 23: 516-554.

Kelling, G., and Walton, E. K., 1957. Load cast structures: their relationship to upper surface structures and their mode of formation. *Geol. Mag.* 94: 481-490.

Kingma, J. T., 1958. The possible origin of piercement structures, local unconformities and secondary basins in the Eastern Geosyncline, New Zealand. *N.Z. Journ. Geol. and Geophys.* 1: 269-274.

———, 1960. The tectonic significance of graded bedding in geosynclinal sedimentary systems. *XXI Int. Geol. Congress* Pt XXI: 205-214.

Kopstein, P., 1954. Graded bedding of the Harlech Dome. *Geol. Inst. Groningen*. 81.

Krumbein, W. C., and Pettijohn, F. J., 1938. *Manual of Sedimentary Petrography*. D. Appleton-Century Co., New York and London.

Krynine, P. D., 1946. The tourmaline group in sediments. *Journ. Geol.* 54: 65-87.

Kuenen, P. H., 1953. Significant features of graded bedding. *Bull. Am. Assoc. Petroleum Geologists* 37: 1044-1066.

———, 1957. Sole markings of graded greywacke beds. *Journ. Geol.* 65: 231-258.

Kuenen, P. H., and Migliorini, C. I., 1950. Turbidity currents as a cause of graded bedding. *Journ. Geol.* 58: 91-127.

Lang, W. H., and Cookson, I. C., 1934. On a flora, including vascular land plants, associated with *Monograptus*, in rocks of Silurian age, from Victoria, Australia. *Phil. Trans. Roy. Soc. Lond.* Ser. B, 224: 421-449.

Langford, W. G., 1916. The petrology of the Silurian sediments near Melbourne. *Proc. Roy. Soc. Vict.* 29: 40-49.

Mead, W. T., 1920. Notes on the mechanics of geological structures. *Journ. Geol.* 28: 505.

Moody, J. D., and Hill, M. J., 1956. Wrench-fault tectonics. *Geol. Soc. Am. Bull.* 67: 1207-1246.

Murphy, M. A., and Schlanger, S. O., 1962. Sedimentary structures in the Ilhas and São Sebastião Formations (Cretaceous), Recôncavo Basin, Brazil. *Bull. Am. Assoc. Petroleum Geologists* 46: 457-477.

Murray, R. A. F., 1884. Reedy Creek goldfield. *Geol. Surv. Vict. Rep. Prog.* (7), 13.

Packham, G. H., 1960. Sedimentary history of part of the Tasman Geosyncline in SE. Australia. *XXI Int. Geol. Congress* Pt XII: 74-83.

Pettijohn, F. J., 1957. *Sedimentary Rocks.* 2nd edn. Harper and Bros, New York.

Philip, G. M., 1962. The palaeontology and stratigraphy of the Siluro-Devonian sediments of the Tyers area, Gippsland, Victoria. *Proc. Roy. Soc. Vict.* 75: 123-246.

Scotford, D. M., 1956. Metamorphism and axial-plane folding in the Poundridge area, New York. *Geol. Soc. Am. Bull.* 67: 1155-1198.

Singleton, O. P., 1949. The geology and petrology of the Tooborac district, Victoria. *Proc. Roy. Soc. Vict.* 61: 75-105.

Spencer, W. K., 1950. Asterozoa and the study of Palaeozoic faunas. *Geol. Mag.* 87: 393-408.

Stillwell, F. L., 1911. Notes on the geology of Broadmeadows. *Proc. Roy. Soc. Vict.* 24: 156-158.

Talent, J. A., 1959. *Contributions to the Stratigraphy and Palaeontology of the Silurian and Devonian of Gippsland*. PhD Thesis, Geol. Dept, Melb. Univ.

Thomas, D. E., 1937. Some notes on the Silurian rocks of the Heathcote area. *Min. and Geol. Journ.* 1: 64-67.

———, 1939. The structure of Victoria with respect to the Lower Palaeozoic rocks. ibid. 1 (4): 59-64.

———, 1958. The geological structure of Victoria. *Journ. Proc. Roy. Soc. N.S.W.* 92: 182-190.

Thomas, D. E., and Keble, R. A., 1933. The Ordovician and Silurian rocks of the Bulla-Sunbury area, and a discussion of the sequence of the Melbourne area. *Proc. Roy. Soc. Vict.* 45: 33-84.

Threadgold, I. M., 1958. Antimony-gold mineralization at Steel's Creek, near Yarra Glen, Victoria. *A.I.M.M. Stillwell Anniv. Vol.*: 241-248.

Whitelaw, H. S., 1899. Antimony ores in Victoria. *Geol. Surv. Vict. Prog. Rep.* (19): 51-59.

Williams, A., 1959. A structural history of the Girvan district, SW. Ayrshire. *Trans. Roy. Soc. Edin.* 63 (3), No. 27.

Withers, R. B., and Keble, R. A., 1933. The Palaeozoic starfish of Victoria. *Proc. Roy. Soc. Vict.* 46: 220-249.

———, ———, 1934. The Palaeozoic brittlestars of Victoria. ibid. 47: 196-212.

Explanation of Plates

Plate XLVII

Fig. 1—Well-bedded sandstones and mudstones of the Yan Yean Formation, exposed in a cutting near the Whittlesea Cemetery. The sandstones stand out in relief on weathering.

Fig. 2—Sandstones, with smooth joint faces, and thin rubbly mudstones of the Clonbinane Member. Cutting, Spur Rd, Clonbinane.

Fig. 3—Thick-bedded, gently dipping siltstones and fine sandstones of the Humevale Formation, exposed at Collins's Quarry, Kinglake West. Note the well-developed joints.

PLATE XLVIII

Fig. 1—Poorly sorted conglomerate of the Flowerdale Member occurring on a hillside 3 miles NW. of Flowerdale. The large quartz pebbles are well-rounded, while the smaller ones tend to be angular; the matrix is of mudstone.

Fig. 2—A well-preserved specimen of *Baragwanathia longifolia* in siltstones of the Humevale Formation, exposed in a cutting on the Kerridale Rd, Homewood (Locality A82).

Fig. 3—Laminated and current-bedded sandstones of the Yan Yean Formation, cutting, Cemetery Lane, 1 mile S. of Whittlesea. Lens cover is 2 in. in diameter.

PLATE XLIX

Fig. 1—Small flute and groove casts on the base of a sandstone bed of the Yan Yean Formation, cutting near Whittlesea Cemetery. The pen and small arrow indicate the probable current direction.

Fig. 2—Flute casts on the base of a sandstone block from the Clonbinane Member. Cross-bedding in the block gives a current direction shown by the arrow. × ½.

Fig. 3—Contorted bedding in mudstones and thin sandstones of the Yan Yean Formation; cutting, Doreen.

PLATE L

Fold patterns produced experimentally in soft grease covered by tissue-paper. Arrows indicate relative movements or directions of applied forces.

Fig. 1—Folds due to simple compression.

Fig. 2—Folds due to horizontal sinistral shear.

Fig. 3—Folds caused by stretching the tissue-paper.

Fig. 4—Folds shown in fig. 3 followed by horizontal sinistral shear.

Fig. 5—Folds due to simultaneous compression and one horizontal sinistral shear.

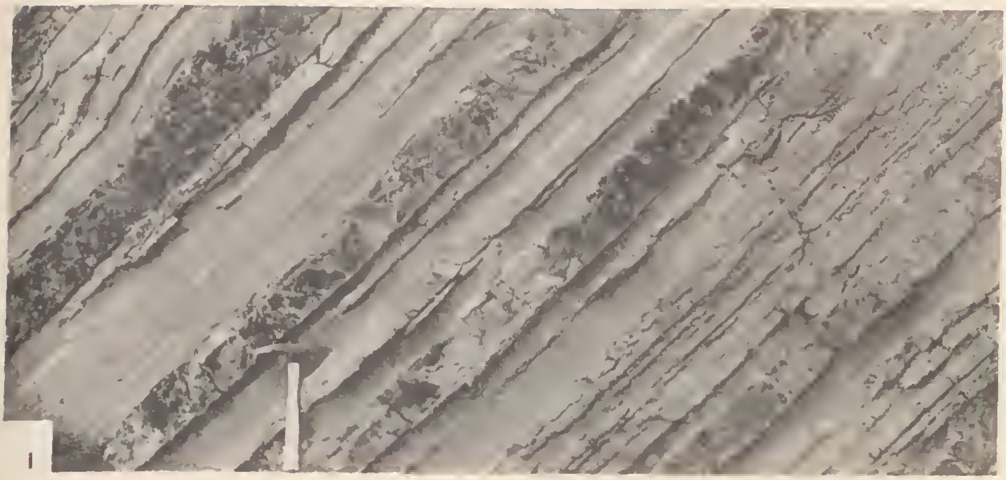
Fig. 6—Folds due to simultaneous compression and two non-parallel, horizontal sinistral shears.

PLATE LI

Fig. 1—Perthite phenocryst from the porphyritic phase of the Mt Disappointment Granodiorite, showing its slightly rounded outline and numerous biotite inclusions. Natural size.

Fig. 2—Photomicrograph of a large, embayed olivine phenocryst from the Flowerdale limburgite, with even border of iddingsite on both crystal faces and embayments. Section 8554, crossed nicols. × 70 approx.

Fig. 2—Two small cones of limburgitic basalt, Reedy Ck, with portion of the surrounding flow in the foreground. Looking S.



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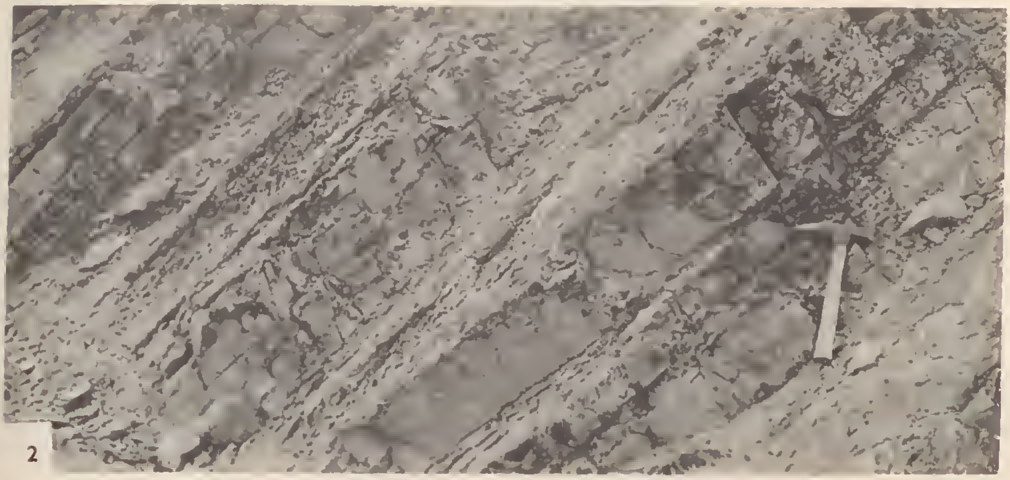

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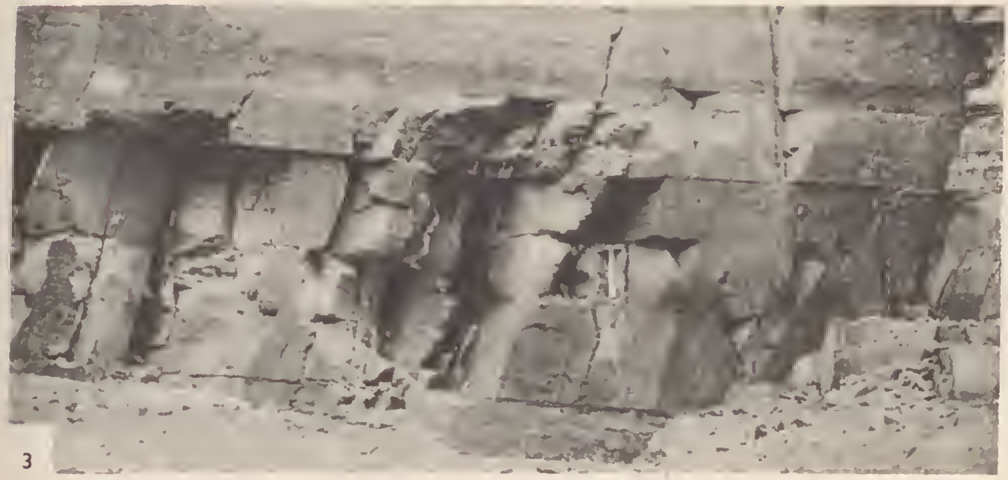

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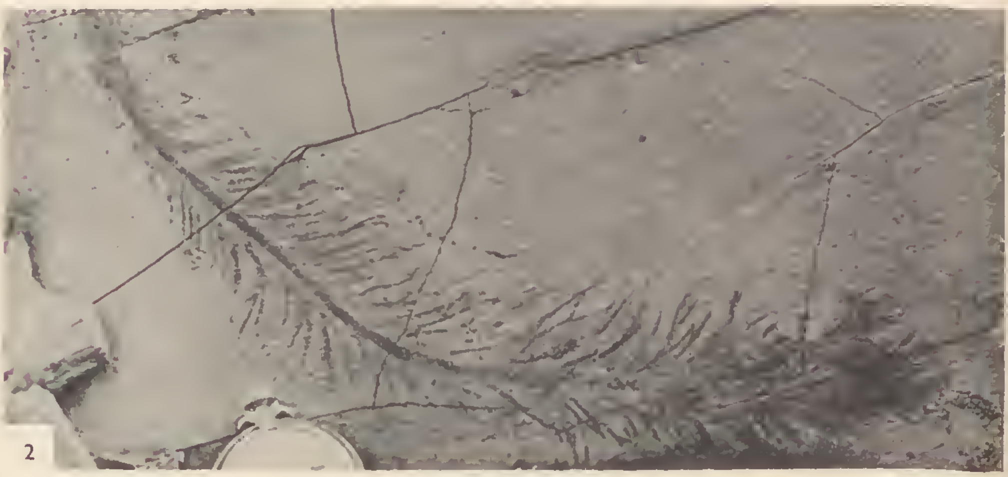

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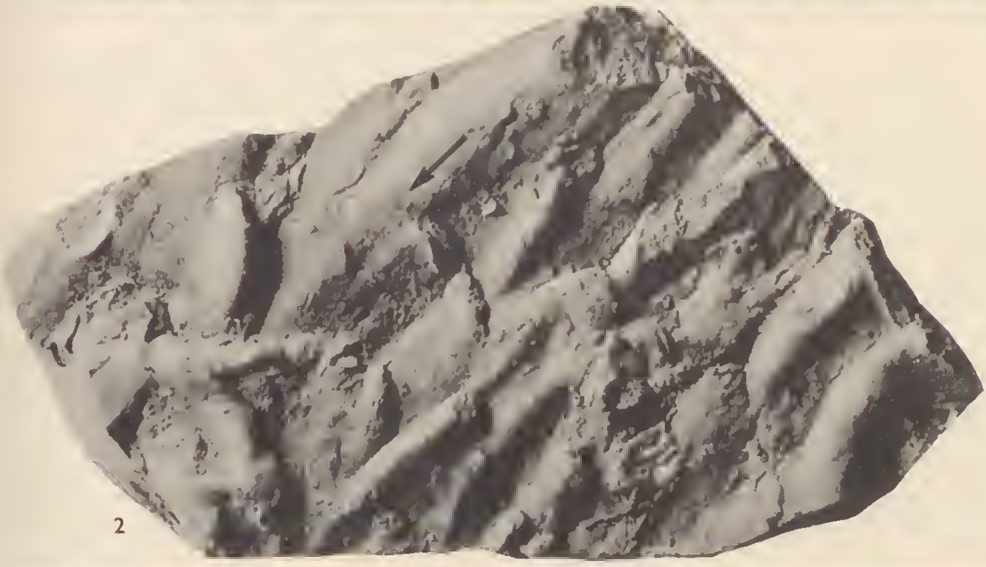

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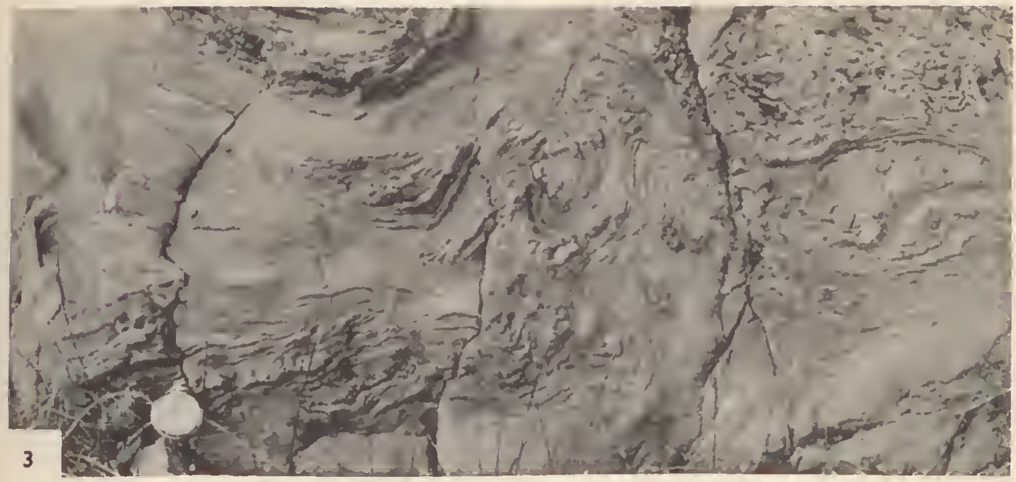

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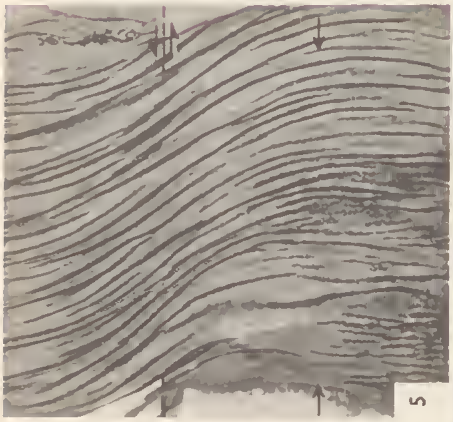

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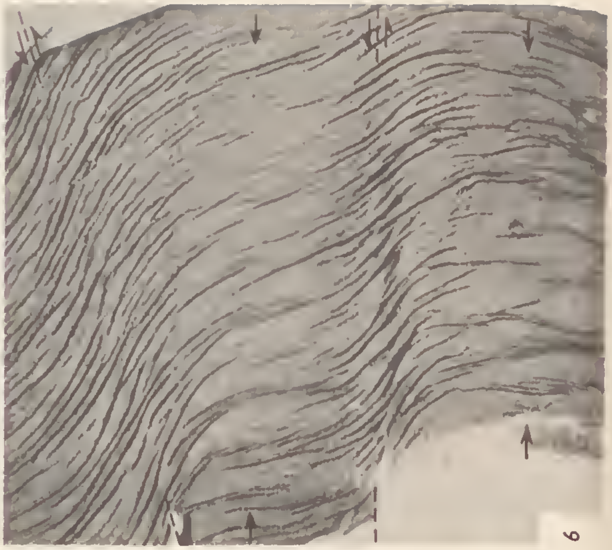

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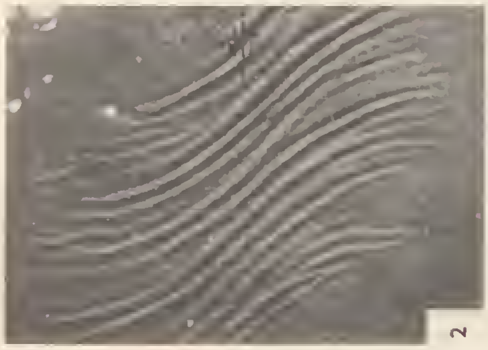

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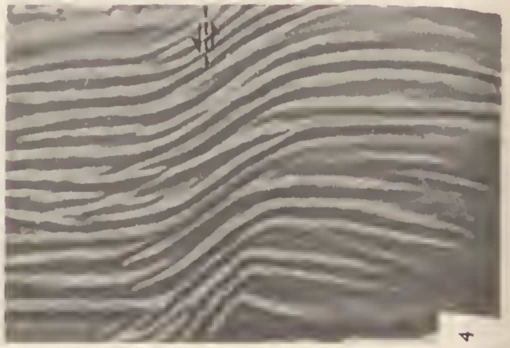

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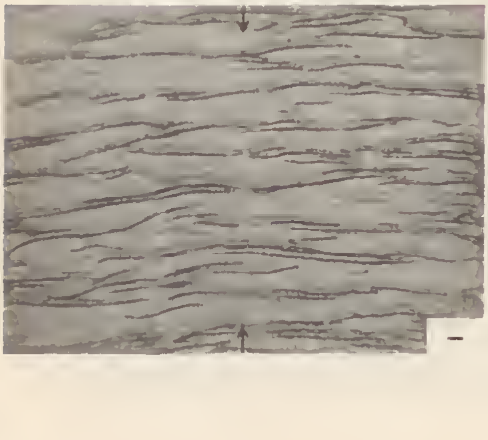

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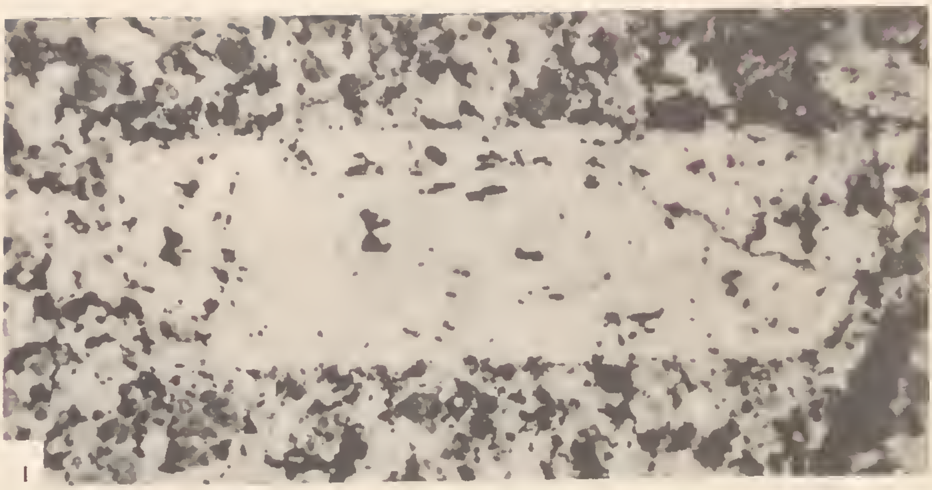

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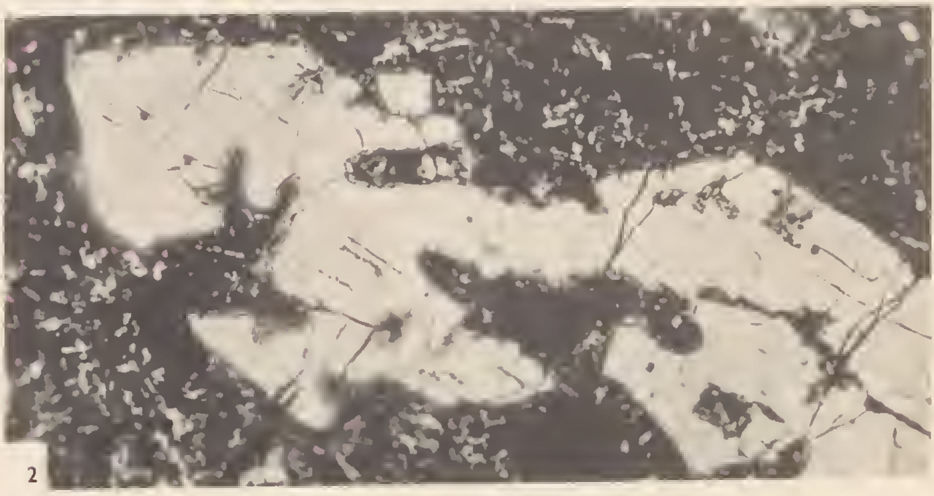

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11

THE BASALT PLAINS OF WESTERN VICTORIA

SYMPOSIUM

12 SEPTEMBER 1963

FOREWORD

A one-day symposium on the basalt plains of Western Victoria was held on 12 September 1963. The area of these plains comprises about 9,000 square miles and is reputed to be the third largest in the world. The object was to bring together the many kinds of scientific information available on this geographical unit, and to stimulate further research by bringing to notice through discussion the problems needing solution. This symposium followed the earlier successful symposium on the High Plains of Victoria, of which the contributions appeared in Vol. 75 of the *Proceedings*.

The 7 succeeding papers (No. 12-18) were given at the symposium. The accompanying map of average annual rainfall (Fig. 1) is extracted from a contribution from the Commonwealth Bureau of Meteorology, which is being published elsewhere.

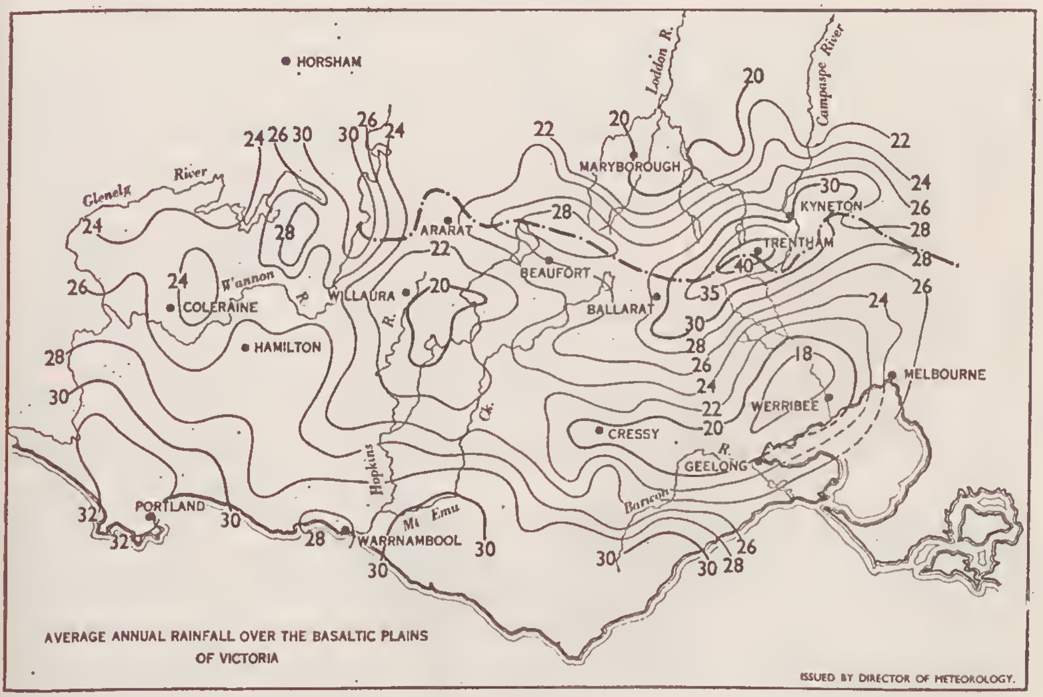

Fig. 1

12

ROCKS CONTIGUOUS WITH THE BASALTIC CUIRASS OF WESTERN VICTORIA

By Edmund D. Gill
National Museum of Victoria

Abstract

The 9000 sq. miles of volcanic rocks in W. Victoria were emplaced over some 15,000,000 years. Their numerous interfaces with sediments below and above are instructive both as to time and process (geologic and climatic). The tuffs and lavas seldom contacted the sea, so interfaces are commonly soils, which appear to be referable to 4 terrains:

1. Mid-Tertiary deeply kaolinized Nunawading Terrain.
2. Lower Pliocene lateritized Timboon Terrain.
3. ? Plio-Pleistocene krasnozems.
4. Mid-Pleistocene to present duplex and uniform soils.

In the Cainozoic there were two maxima of earth movements associated with the extrusion of the Older Basalts and the Newer Basalts respectively. The former period of movements is named the Bass Strait Epoch, and the latter has already been named the Kosciusko Epoch. The above 4 terrains appear to be useful for dating the movements of the Kosciusko Epoch where suitable fossils are not present. Some of the geological formations associated with the lava plain are briefly described, and some reasons given for the presence of quartz grains in soils on basaltic lavas and tuffs.

Introduction

Interfaces are important in many sciences and, in geology, the interfaces between formations are often most instructive. For the historical geologist they may yield information on process and may represent time expired. Thus the interfaces between the basaltic cuirass of W. Victoria and the contiguous rocks yield valuable information about the times of eruption, and the processes then going on. The study of these interfaces is complicated by the long period over which the volcanic rocks were emplaced, and by the vast area over which dissection has not yet exposed the pre-basaltic terrain.

The Upper Cainozoic basaltic rocks of W. Victoria constitute a shield or cuirass of some 9,000 sq. miles (Grayson and Mahony 1910) varying in thickness from a foot to over 200 ft. They consist entirely of basalts and basaltic tuffs. Just as the Lower Cainozoic basalts (called the Older Basalts) characterize E. Victoria, so the Upper Cainozoic Newer Basalts characterize C. and W. Victoria. But the two series are not mutually exclusive in distribution. Newer Basalts overlie Older Basalts, e.g. at Footscray, Essendon, Keilor and Maude, while at Waurn Ponds, W. of Geelong, pebbles of Older Basalt are included in Oligocene marine beds against which Newer Basalt has flowed.

The Older and Newer Basalts contrast in mode of eruption. Older Basalt dykes are very common, swarms of them being present in some areas, yet, although many streams have cut through the Newer Basalts to the underlying rocks, dykes of that age are unknown. On the other hand, eruption points for the Newer Basaltic volcanics are even more numerous than one would infer from the literature. On present evidence, therefore, the Older Basalts would appear to have been extruded mostly by dykes, but also by vents (Edwards 1934), while the Newer Basalt eruptions were by vent only.

The Newer Basaltic vulcanism of W. Victoria has been chiefly effusive, but in the final stage dominantly explosive yielding hundreds of tuff and scoria cones (some 250 have been counted so far) that characterize the present geomorphology of the lava plains. This period of vulcanism began in the Upper Miocene something like 15,000,000 years ago. Unless the evidence has been destroyed (and tuff is one of the most easily eroded rocks), most of the explosive phase has been limited to the past 15,000 years.

Period of Eruption

No Newer Basaltic vulcanism is known older than the very end of the Miocene; it continued until a few thousand years ago. The earliest activity so far discovered is that at Minhamite, 25 miles SE. of Hamilton. On Goodwood Station, where Spring Ck intersects the base of the basalt, tuff and richly fossiliferous marly marine sands outcrop immediately under the basalt (Fig. 1). The beds contain *Aturia australis*, a pelagic cephalopod, which genus is not known to exist later than the Miocene. Species of *Eucrassatella, Neotrigonia, Placamen* and *Zenatiopsis* (Gill and Darragh 1963) found there are at evolutionary stages comparable with the Cheltenhamian rather than the Kalimnan Stage (Lower Pliocene). The Minhamite fauna probably represents the upper part of the Cheltenhamian Stage, in other words, the end of the Miocene.*

[* Their age has been discussed with Mr T. A. Darragh.]

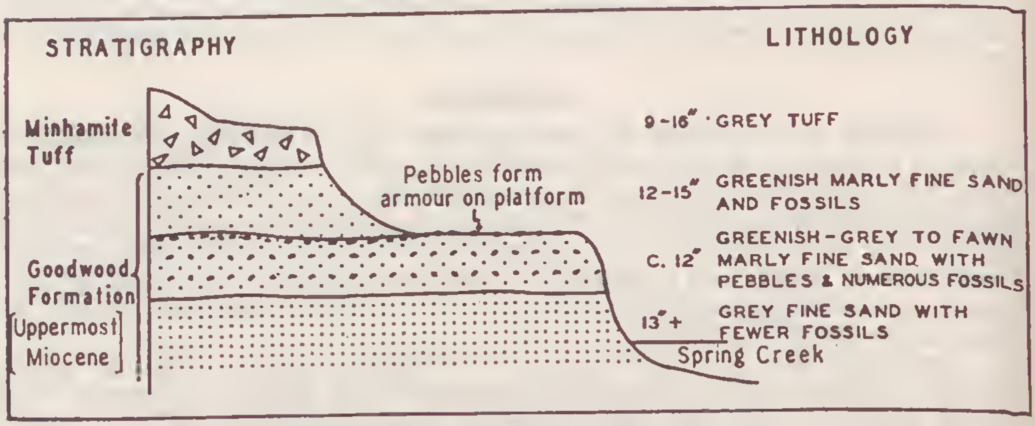

FIG. 1—Late Miocene marine strata beneath basalt at Minhamite, 25 miles SE. of Hamilton, Vict. Stratigraphic names here proposed.

That Lower Pliocene eruption took place can be proved at Muddy Ck 4 miles W. of Hamilton, where basaltic tuff occurs in marine beds of Kalimnan age (Gill 1957a, p. 162). Fig. 2 shows sections at Hamilton on Muddy Ck and the next creek to the N., Grange Burn. No tuff bed occurs on Grange Burn as it does on Muddy Ck, but tuff minerals occur in the fossil soil.*

[* On both creeks there is a duplex soil with abundant carbonate nodules in the B horizon (Gill 1955, p. 16). The fossil soil is overlain with basalt which at the surface is semi-lateritized, then later modified by krasnozem formation, followed by leaching of the top 12 in.—a polygenetic soil (Gibbons and Gill 1964). Under the basalt at Grange Burn are the stumps of a stand of Celery Top Pine (*Phyllocladus*), now extinct on the Australian mainland, but still growing in W. Tasmania and in New Zealand in temperate rainforest. *Phyllocladus* has been found under the basalt in a mine at Daylesford. The determinations are by Mr H. D. Ingle of CSIRO Division of Forest Products.]

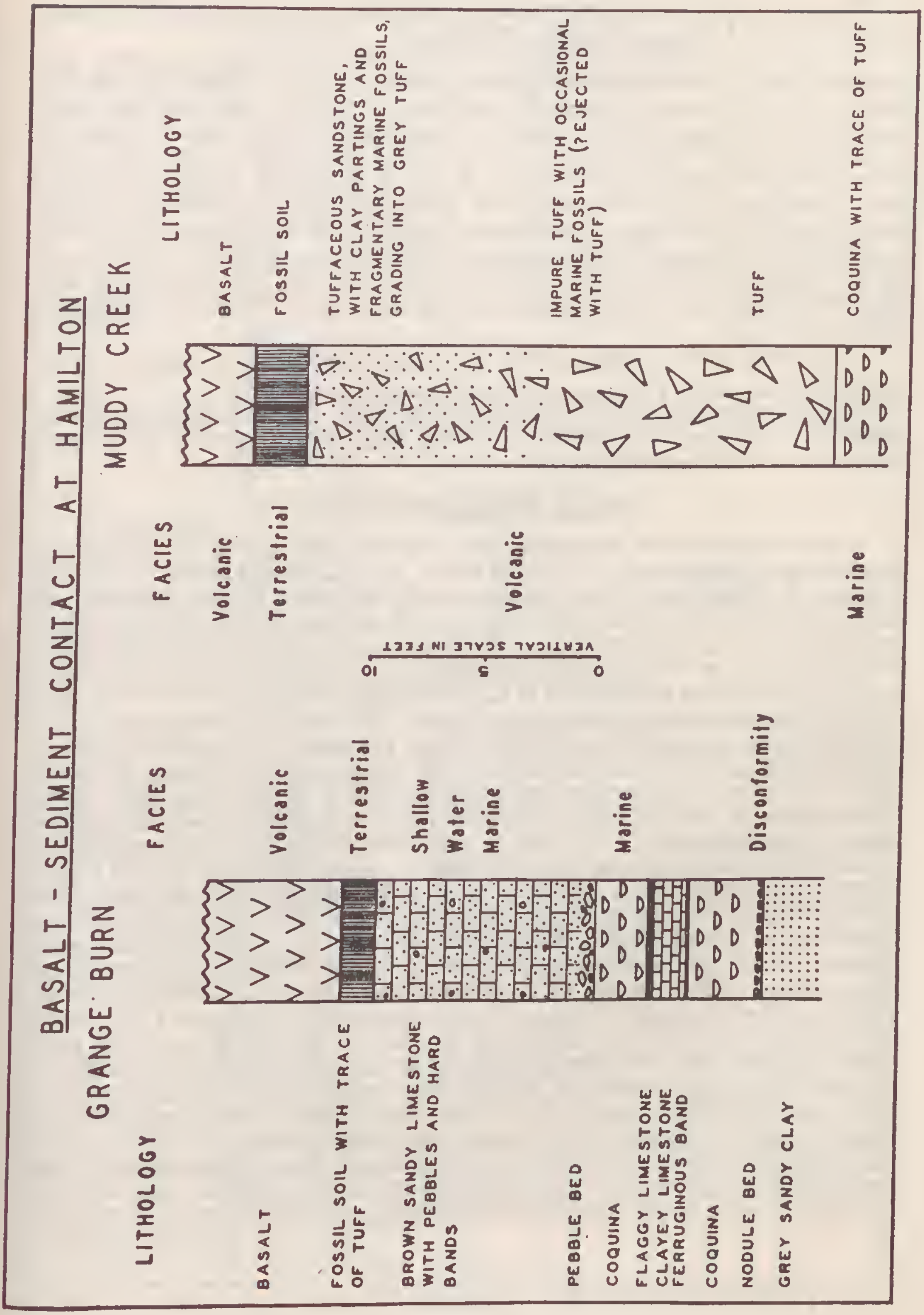
BASALT - SEDIMENT CONTACT AT HAMILTON
GRANGE BURN
LITHOLOGY
FACIES
BASALT
Volcanic
FOSSIL SOIL WITH TRACE OF TUFF
Terrestrial
BROWN SANDY LIMESTONE WITH PEBBLES AND HARD BANDS
Shallow Water Marine
PEBBLE BED
COQUINA
Marine
FLAGGY LIMESTONE
CLAYEY LIMESTONE
FERRUGINOUS BAND
COQUINA
NODULE BED
Disconformity
GREY SANDY CLAY
VERTICAL SCALE IN FEET
0
5
10
MUDDY CREEK
FACIES
LITHOLOGY
Volcanic
BASALT
Terrestrial
FOSSIL SOIL
TUFFACEOUS SANDSTONE, WITH CLAY PARTINGS AND FRAGMENTARY MARINE FOSSILS, GRADING INTO GREY TUFF
Volcanic
IMPURE TUFF WITH OCCASIONAL MARINE FOSSILS (?EJECTED WITH TUFF)
TUFF
Marine
COQUINA WITH TRACE OF TUFF

FIG. 2

Thus, the oldest evidences of vulcanism belonging to the Newer Basalt series in Victoria are late Miocene and Lower Pliocene.

No evidences of volcanic activity can be found at the present time. There are no active vents, no fumaroles, and no heat gradients in bores suggesting continued activity. There is, however, a group of volcanoes such as Tower Hill near Warrnambool, Mt Shadwell near Mortlake, Red Rock near Alvie, and the volcano containing L. Elingamite near Cobden that can be shown by their physiography and soils* to be among the youngest of the vents. At Tower Hill beach, a soil with marine shells (collected by the aborigines) and aboriginal implements lies just a little above the tuff; the shells gave a radiocarbon date of 4,315 ± 195 years B.P., which provides a minimum age for the cessation of the main ash vulcanism (Gill 1953a). At Mt Gambier, South Australia, nests of charcoal in the A horizon of the soil under the tuff gave a radiocarbon date of 4,830 ± 70 years (Fergusson and Rafter 1957).

[* On similar slopes of basaltic tuff in this area, the accumulation of maghemite in the soil has been found to be a function of time and so useful for dating.]

Present evidence indicates that the period of eruption was late Miocene to mid-Holocene. Thus, there are interfaces of many different ages between the complex of volcanics and the contiguous rocks.

Marine Rocks under Basalts

S. of the Dividing Ra., the basalt plain is usually underlain by marine strata of Cretaceous to Pleistocene age, while in the N. the underlying rocks are usually all non-marine. During the Upper Cretaceous and Paleocene the sea gradually encroached on W. Victoria. By the Oligocene the sea had covered extensive areas, including part at least of what is now the Otway horst, as is indicated by the marine rocks of that age at Waurn Ponds on the fringe of the Barrabool Hills, at Birregurra on the N. flank of the Otways, and at Kawarren, high in the Otways. However, some of the Otway area was land during the Tertiary as is shown by the presence of the mid-Tertiary deep kaolinization, and the Lower Pliocene lateritization (see below). Miocene beds are by far the commonest of the marine rocks underlying the basalts. Miocene marine rocks can be seen under the Newer Basalt in the valley of the Maribyrnong R. and its tributaries downstream from Keilor, where the Tertiary shoreline appears to have occurred on Older Basalt. Similarly, they underlie the basalts of the Werribee Plain, e.g. at Mt Mary or Green Hill (Murray 1884) where they can be collected from the ejectamenta; at Spring Hill brown coal mine (Parr 1942) which is 3½ miles WNW. of Mt Mary (Fig. 3); and at the old brown coal mines of the Altona district. Although the brown coal extends as far inland as Bacchus Marsh, the overlying marine beds do not extend that far (Thomas and Baragwanath 1950). In the valley of the Barwon R. and its tributaries in the Geelong district, extensive Miocene marine strata occur (Coulson 1932, Bowler 1963). Similarly Curdie R. farther W. has incised the basaltic terrain to reveal Tertiary strata. This river cuts in deeply in its headwaters, then flows marginal to the lava field before crossing the coastal plain, free of basalt flows, to enter the sea at Peterborough. One mile S. of Oil Well Corner (on the Warnambool-Cobden road ½ mile E. of South Ecklin), on the right bank of Curdie R., there is a small volcano not previously recorded. A bulldozer trench cut in the ejectamenta of this small hill recently revealed Miocene marine limestone, sandstone, and white clay brought up by the eruption (the occurrence was reported by Mr J. Halford of Laang).

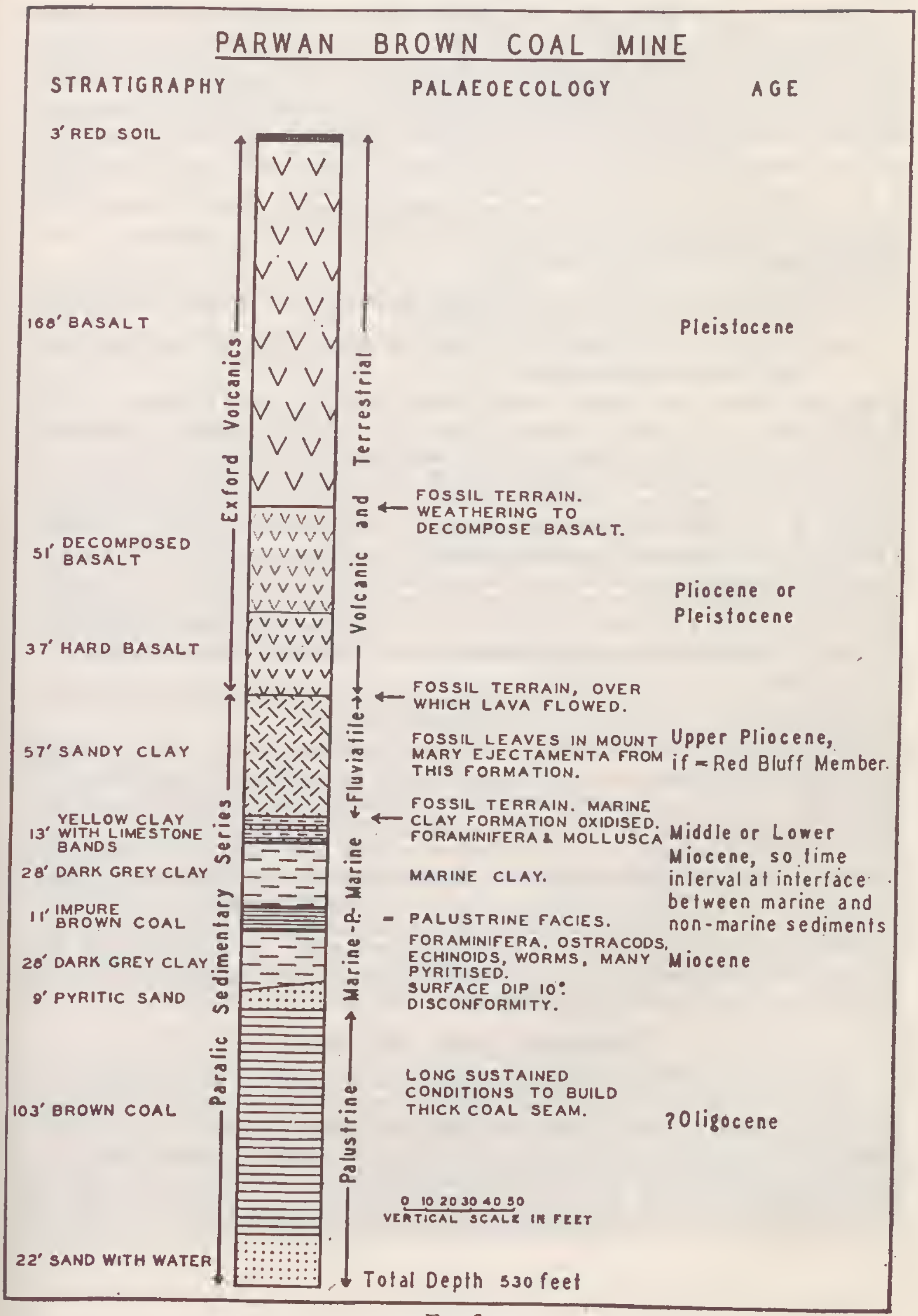
PARWAN BROWN COAL MINE
STRATIGRAPHY
PALAEOECOLOGY
AGE
3' RED SOIL
168' BASALT
51' DECOMPOSED BASALT
37' HARD BASALT
57' SANDY CLAY
13' YELLOW CLAY WITH LIMESTONE BANDS
28' DARK GREY CLAY
11' IMPURE BROWN COAL
28' DARK GREY CLAY
9' PYRITIC SAND
103' BROWN COAL
22' SAND WITH WATER
Exford Volcanics
Paralic Sedimentary Series
Volcanic and Terrestrial
Fluviatile
Marine - P. Marine
Palustrine
FOSSIL TERRAIN. WEATHERING TO DECOMPOSE BASALT.
FOSSIL TERRAIN, OVER WHICH LAVA FLOWED.
FOSSIL LEAVES IN MOUNT MARY EJECTAMENTA FROM THIS FORMATION.
FOSSIL TERRAIN. MARINE CLAY FORMATION OXIDISED. FORAMINIFERA & MOLLUSCA
MARINE CLAY.
PALUSTRINE FACIES.
FORAMINIFERA, OSTRACODS, ECHINOIDS, WORMS, MANY PYRITISED.
SURFACE DIP 10°.
DISCONFORMITY.
LONG SUSTAINED CONDITIONS TO BUILD THICK COAL SEAM.
Pleistocene
Pliocene or Pleistocene
Upper Pliocene, if = Red Bluff Member.
Middle or Lower Miocene, so time interval at interface between marine and non-marine sediments
Miocene
?Oligocene
0 10 20 30 40 50
VERTICAL SCALE IN FEET
Total Depth 530 feet

FIG. 3

Miocene marine fossils have been found in the ejectamenta of Mt Porndon (Skeats and James 1937), Red Rock NW. of Colac, Mt Noorat, Wangoom Hill (found by Mr L. K. M. Elmore), Bradshaw's Hill at Terang, Mt Shadwell near Mortlake, and Tower Hill near Warrnambool. From Mt Shadwell, Mr Brian Campion collected gasteropods including *Bathytoma rhomboidalis*, a turrid, the scaphopod *Dentalium* (*Fissidentalium*) *mantelli*, a coral *Trochocyathus*?, foraminifera and ostracoda. Mr D. Burns found marine Tertiary fossils occurring as casts in a tuff underlying basaltic ejectamenta at the S. end of L. Colac (mentioned further in discussion of lacustrine and palustrine sediments). Miocene marine beds have been recorded from Rokewood, 10 miles NNE. of Cressy (Dennant 1899). In this paper two localities are recorded:

(a) 'From the bores about a mile south of Rokewood, in the parish of Kuruc-a-ruc'. . . 'collected by Mr A. M. Howitt.'
(b) 'The junction of Ferrer's Creek with the Woady Yallock, and thus about four miles north of Cressy.'

It may be that the two separate small samples in the Dennant Collection in the National Museum of Victoria marked 'Rokewood' come from these two localities.

Dr A. N. Carter kindly examined the samples, and also reported that the old bores near Rokewood went through clay with angular quartz, basalt, carbonaceous clay, sandy mottled clay, fossiliferous marine sediment, and Lower Palaeozoic bedrock, in that order. Dennant's first specimen (Reg. No. P16413 NMV) provided a fragment of *Nodosaria* cf. *annulata*, small button-shaped colonies of bryozoa, a fragment of a calcareous worm tube, the operculum of a small gasteropod like that of *Astraea, Turritella*, a pyrenid, *Limopsis* and *Nuculana*. The second sample (P16414) contained *Cibicides mediocris, Limopsis*, and some fragments of bryozoa. Dr Carter concluded that, on the evidence of the *Cibicides*, the age is Middle or Lower Miocene.

Miocene marine rocks also outcrop under the volcanic ejectamenta of L. Bullenmerri, L. Gnotuk, L. Keilambete and at Tower Hill.

In the Portland district, basalt flows are associated with marine strata belonging to the Maretimo Member and the Werrikoo Member of the Whaler's Bluff Formation (Boutakoff 1963); the Pliocene-Pleistocene boundary is placed at the base of the latter (Gill 1957b, 1961a). These basalts have deep krasnozems developed on them over a considerable area, but in the writer's opinion such soils are not related to present conditions or they would occur much more widely on Pleistocene basalts. Evidence of their relict nature is provided by the leaching of the top 12 to 15 in. with the development of minute nodules of magnetic iron oxide (maghemite).

Marine rocks under basalt flows provide a maximum age for them, but also indicate changes in conditions, for the basalts seldom rest directly on the marine rocks but have interposed a non-marine formation and/or a fossil soil.

Non-Marine Rocks under Basalt

The Kosciusko Epoch of earth movements (Andrews 1910) raised the Dividing Ra. and the Otway horst to their present elevations, so that the sea retreated from the area of plains S. of the Divide. This uplift began slowly in the Upper Miocene, but the pronounced movements were in the Upper Pliocene and Lower Pleistocene; movement continues, but on a minor scale. The uplift caused piedmont deposits to be washed out over the plain, while the rejuvenated rivers spread their sediments over a wide area. The non-marine sediments thus produced consist of clayey sands to sandy clays, i.e. poorly sorted and poorly washed sediments. Over most of SW. Victoria these deposits were buried by basalt flows and ash spreads. They were lateritized in places. Towards the W., as the Murray Gulf is approached, the movements were less severe and Lower Pliocene (Kalimnan) marine beds there cover Miocene strata. Due to the Kosciusko uplift, no post-Kalimnan Pliocene marine beds are known in Victoria (except for the very late Pliocene Maretimo Member), but they have been found on Flinders Is. in Bass Strait (Gill 1962a).

Fossil Soils Beneath and on the Basalts

Fossil soils are common at the lower interface of basalts and tuffs, but they have seldom been recorded. Four successive phases of pedological activity can be distinguished on the terrains buried by the basaltic and associated deposits. These fossil soils are products of different climates at different times and so can be used for dating; they make possible a determination of approximate age in non-marine deposits where at present there is no other method of dating.

MID-TERTIARY DEEP WEATHERING

Attention has been drawn already to the very deep weathering of the Nillumbik Peneplain (Gill 1961b, Fig. 3). The rocks are kaolinized from 30 to 150 ft deep. The brick and tile works of Melbourne are based on this terrain, and the maximum depth of their quarries is usually the maximum depth of kaolinization at the site. In the railway cuttings on each side of Camberwell railway station, Melbourne, strongly kaolinized Silurian rocks occur. Over the eroded surface of this formation are lateritized late Miocene(?) clayey sands, demonstrating the relative ages of the kaolinized and lateritized terrains.

The relationships of both the Newer Basalt and the Older Basalt to this zone of weathering is shown in Fig. 4, which is a semi-diagrammatic section across the Moonee Ponds Ck just N. of Reynard's Rd and E. of Strathmore railway station (see Hanks 1934, p. 145). The Older Basalt is marked on Quarter Sheet 1 NW. as a dyke, but it is part of a flow. The Newer Basalt forms the plain into which the stream has cut. Beneath are the non-marine clayey sands that form a considerable delta at Melbourne (the Red Bluff Member of the Sandringham Sands, Gill 1957a). Beneath the Red Bluff sediments is the kaolinized terrain and, at this point, Older Basalt has been reduced to kaolinite (kindly determined by Mr A. J. Gaskin), sub-basaltic sands leached so that plant fossils are reduced to impressions, and the Upper Silurian bedrock kaolinized. At Minifie's wheat silos, Lennon St, S. Kensington, the foundations consist of kaolinized Older Basalt resting on a white claystone consisting of kaolinite (determined by Mr A. J. Gaskin), with a moderate amount of quartz, and a trace of mica. This is the same terrain where it is inclined into the Port Philip Sunkland on the Melbourne Warp (Gill 1961b). Where Dry Ck enters the Maribyrnong R. at Arundel, a mile N. of Keilor, sections in quarries and in the river bank show the kaolinized surface well. Both the Older Basalt and the underlying Silurian marine strata are affected. The kaolinization of the granodiorite at Bulla (Gaskin 1944) is due to this same event.

This same kaolinized terrain can be recognized at various places W. of Melbourne, e.g. Bacchus Marsh, Brisbane Ra., and at Colac where the brick pit is situated in kaolinized Lower Cretaceous rocks. Similarly, E. of Melbourne, areas of kaolinization and bauxitization have been recorded, e.g. at Mirboo North where Older Basalt and Lower Cretaceous freshwater sediments are involved (Raggatt

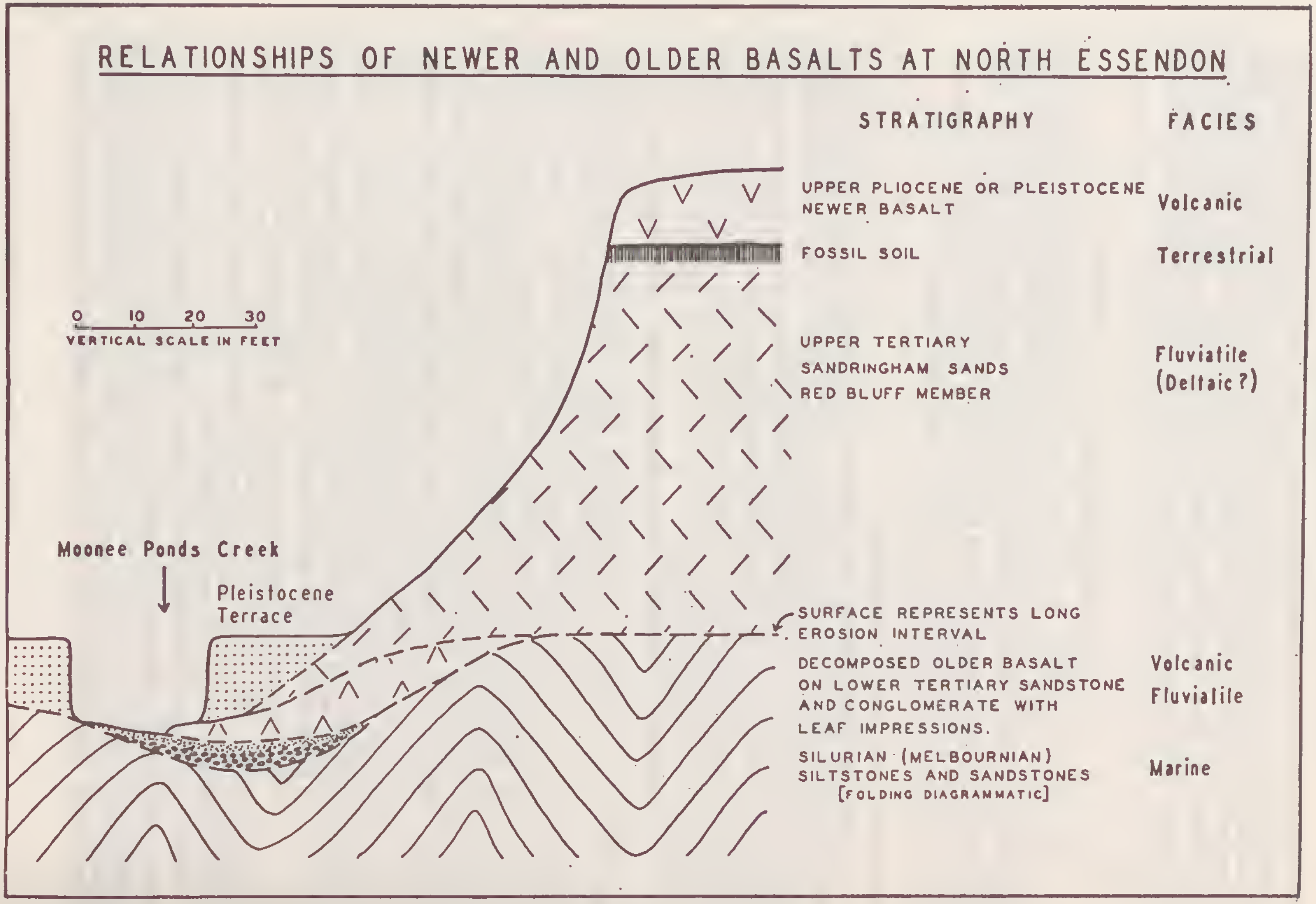
RELATIONSHIPS OF NEWER AND OLDER BASALTS AT NORTH ESSENDON
STRATIGRAPHY
FACIES
UPPER PLIOCENE OR PLEISTOCENE NEWER BASALT
Volcanic
FOSSIL SOIL
Terrestrial
UPPER TERTIARY SANDRINGHAM SANDS RED BLUFF MEMBER
Fluviatile (Deltaic ?)
SURFACE REPRESENTS LONG EROSION INTERVAL
DECOMPOSED OLDER BASALT
Volcanic
ON LOWER TERTIARY SANDSTONE AND CONGLOMERATE WITH LEAF IMPRESSIONS.
Fluvialile
SILURIAN (MELBOURNIAN) SILTSTONES AND SANDSTONES [FOLDING DIAGRAMMATIC]
Marine
0 10 20 30
VERTICAL SCALE IN FEET
Moonee Ponds Creek
Pleistocene Terrace

FIG. 4

et al. 1945, Owen 1954, Bell 1960). The kaolinization is believed to result from severe leaching under a tropical or subtropical rainforest (Gill 1961c, d).

As so many quarries show this ancient soil to advantage in the City of Nunawading on the E. side of Melbourne (e.g. Robertson's tile works), this terrain is here named the **Nunawading Terrain or Surface.** A distinction is made between the exhumed fossil plain known as the Nillumbik Peneplain, which precedes the Older Basalt, and the Nunawading Terrain which is a land surface younger than the Older Basalt on that peneplain. The original surface of the Nunawading Terrain over the Nillumbik Peneplain was probably to a large extent sands and gravels which have since been stripped away.

The Nunawading Terrain can be traced into New South Wales, South Australia and Tasmania. At Launceston in N. Tasmania, e.g., this terrain does not extend beneath the Paleocene-Eocene deposits in the Tamar Graben, as formerly thought, but is later than them, kaolinizing the sediments for a hundred feet or so, as is shown in the brick pits at Prospect and King's Meadows, and in the core of a bore at the Talbot Rd reservoir. When the dolerite and overlying sediments are horizontal, as at Prospect, they are kaolinized, but where they are well drained by dip, as at St Leonard's, or by faults, as at First Basin, they are bauxitized. Thus, where the silicic acid is drained away bauxite is formed and, where not, kaolinite is formed. This environmental consideration could guide future prospecting for bauxite in high latitudes.

The mid-Tertiary Nunawading Terrain has been found useful for dating, though it needs to be discriminated from the pallid zone of the laterite about to be discussed. Along the aqueduct that runs into the reservoir on Stony Ck on the top of the Brisbane Ra., the Ordovician slates are thoroughly kaolinized; such impervious rocks are not easily altered in this way. Over the top of this Nunawading Terrain at this locality are Kosciusko clayey sands which have been lateritized. The Rowsley fault and associated faults bound the Brisbane Ra. to the E., causing the above beds to be well drained; the fossil soils could not be formed in the beds as at present uplifted, and so must pre-date the faulting.

Lower Pliocene Lateritization

Equally widespread as the Nunawading Terrain, but of later age (proved by superposition and by the age of the marine beds affected), is a zone of laterization. This type of fossil soil may be seen in the Timboon railway cutting W. of L. Bullenmerri. Similar lateritic profiles have been located in many places in W. Victoria (often beneath the basalt plain), New South Wales, South Australia and Tasmania. In Victoria, marine rocks of many ages have been lateritized, but none younger than Cheltenhamian (uppermost Miocene) as at Beaumaris, Red Bluff (Gill 1963a), Royal Park, and the Maribyrnong R. valley. Lateritized areas and the Lower Pliocene marine beds are mutually exclusive in distribution and therefore thought to be contemporaneous. The Upper Pliocene basalt at Hamilton (which overlies a Lower Pliocene marine bed) is semi-lateritized (Gibbons and Gill 1964); this is apparently due to fading out of lateritizing conditions. 'Laterite' is used in many senses, even to include buckshot gravel. The term is used here for a profile of deep weathering 10 to 50 ft) with development of a thick ironstone layer (2 to 10 ft). This widespread and well-defined fossil terrain is here named the **Timboon Terrain or Surface** from its typical development in the Timboon railway cutting W. of L. Bullenmerri and S. of the Princes Highway (see Gill 1953b). At this, the type locality, it is underlain by non-marine clayey sands below which are Miocene marine beds (Fig. 5).

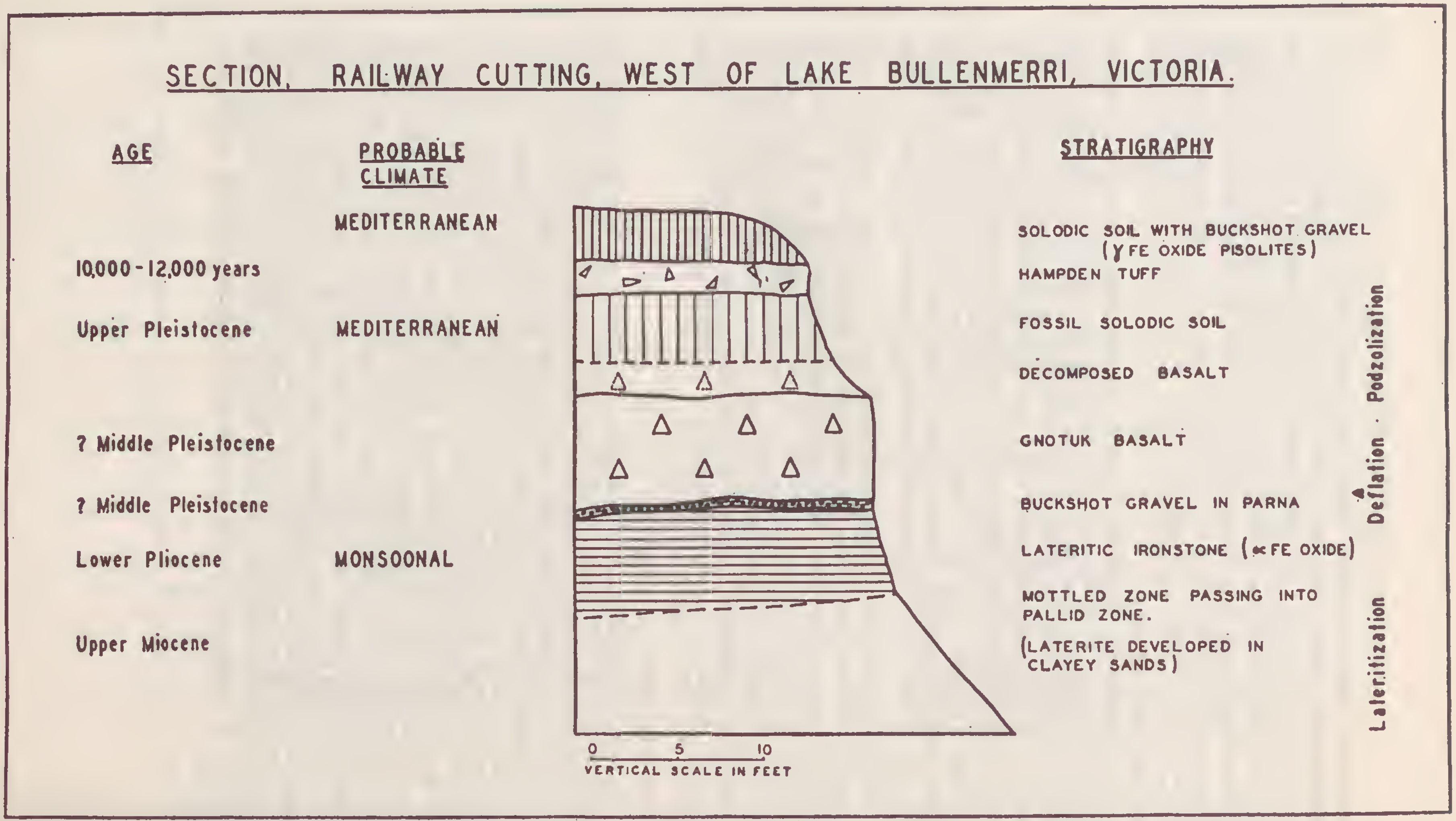
SECTION, RAILWAY CUTTING, WEST OF LAKE BULLENMERRI, VICTORIA.
AGE
PROBABLE CLIMATE
STRATIGRAPHY
MEDITERRANEAN
SOLODIC SOIL WITH BUCKSHOT GRAVEL (γ FE OXIDE PISOLITES)
10,000 - 12,000 years
HAMPDEN TUFF
Upper Pleistocene
MEDITERRANEAN
FOSSIL SOLODIC SOIL
DECOMPOSED BASALT
? Middle Pleistocene
GNOTUK BASALT
? Middle Pleistocene
BUCKSHOT GRAVEL IN PARNA
Lower Pliocene
MONSOONAL
LATERITIC IRONSTONE (α FE OXIDE)
MOTTLED ZONE PASSING INTO PALLID ZONE.
Upper Miocene
(LATERITE DEVELOPED IN CLAYEY SANDS)
Podzolization
Deflation
Lateritization
0
5
10
VERTICAL SCALE IN FEET

FIG. 5

Immediately above the laterite shown in Fig. 5 is a layer consisting essentially of fawn silt and magnetic buckshot gravel. Fig. 6 shows that, in grain size, these two materials are strongly contrasted; it is essentially a bimodal sediment consisting of—

(a) A loess- or parna-like oxidized silt interpreted as the product of soil deflation. Grain size analysis shows it is mostly wind-borne. The small amount of coarser material was probably saltatory.

(b) The maghemite-bearing pisolites (buckshot) are produced only in a duplex soil like that existing on the present surface of the Hampden Tuff at that site; a soil must have been broken down to provide this material.

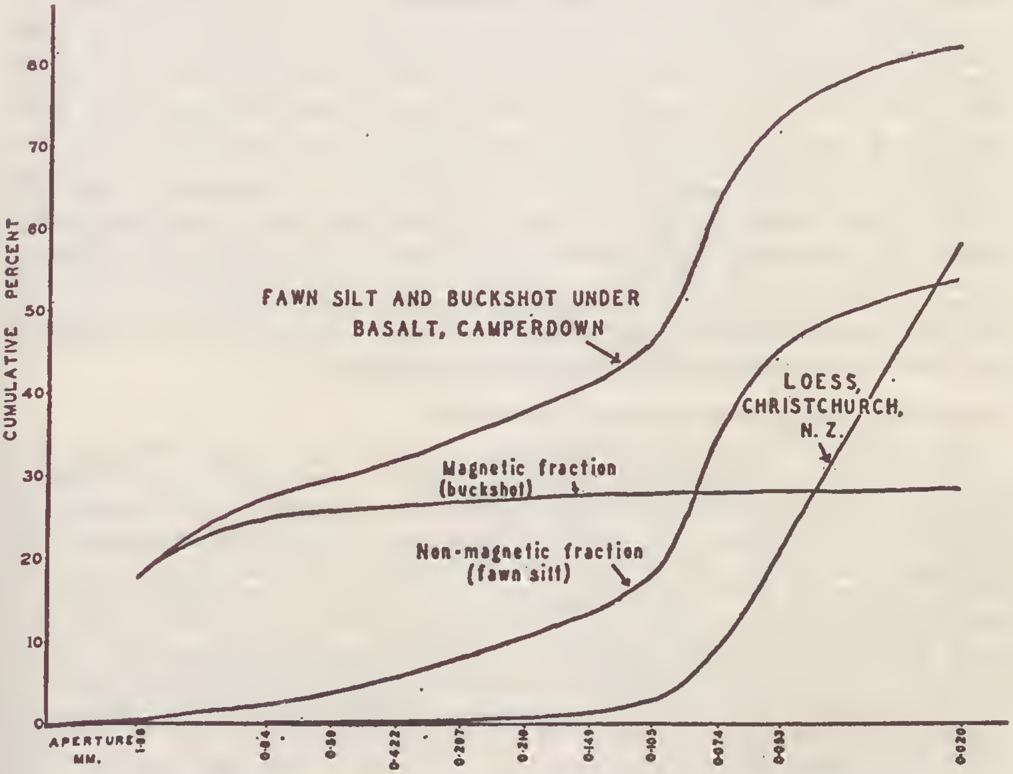

FIG. 6—Grain-size analysis of layer between laterite and basalt in the Timboon railway cutting. Analysis by the same laboratory of a loess from Christchurch, N.Z., is provided for comparison with the silt. Analyses carried out by Mr H. A. Stephens of the Foundry Sands Group of the CSIRO Division of Applied Mineralogy.

This deposit has been traced along the railway cutting for a few hundred yards. While maintaining its essential character, the bed shows variation due to inclusion of other material, including pieces of lateritic ironstone. It is most unlikely, if not impossible, that both the buckshot and the 'parna' were produced where they were found. It is envisaged that a solodic soil produced the buckshot at this general locality; this involves a fair rainfall to carry out the leaching. This soil may have developed in detritus from the breakdown of the laterite. The wind-borne silt fraction implies the breakdown of a soil or the desiccation of a lake floor from which the silt fraction was transported by the wind to the locality where it is found now. So, following on a period of climate like the present when buckshot was developed, there was a dry period when the terrain was desiccated. It is thought that the buckshot was derived from the local desiccation while the silt was brought in from a source farther away. If a dry climate occurred now, and the soil on the Hampden Tuff were desiccated, a layer of buckshot would be left.

A third character of this deposit needs to be explained, namely, the complete mixing of silt and buckshot. The deflation that left the buckshot would remove any silt and clay size material, but could leave some sand. Buckshot left behind by water erosion is not so clean and is characterized by its unsorted condition. On the other hand, when buckshot is left as a deflation product, it is clean and lying in a layer more or less one pisolite thick. The deposit under consideration consists of clean buckshot, not one pisolite thick but thoroughly mixed through the silt so that, generally, the pisolites are not touching one another. To lift the buckshot from occurring as a layer to being mixed so thoroughly can occur probably by only one process—water action. Dr E. C. T. Chao suggested that rain caused the silt and pisolites to form a slurry which flowed slowly down the low declivities of the terrain, mixing them thoroughly together. A search was made for similar materials on the extant terrain; they were found on the Port Campbell coastal plain (but not in the valleys cut therein) on the N. side of the Ocean Rd about ¾ mile W. of the township, and also on the E. side near the Waarre pine plantation.

? PLIO-PLEISTOCENE KRASNOZEM FORMATION

Krasnozems occur on the basalts associated with the marine Maretimo and Werrikoo Members of the Whaler's Bluff Formation at Portland (Boutakoff 1963). Gill (1957b, 1961a) places the Pleistocene lower boundary at the base of the Werrikoo. In the Portland area, these krasnozems (the 'laterite' of Boutakoff) can be demonstrated to be older than Pleistocene aeolianite, and they also show modification in that the top 12 to 15 in. have been leached so that they are lighter in colour, the clay content is reduced, and they have minute maghemite pisolites in them. This surficial leaching is interpreted as a Quaternary podsolization of the surface of the krasnozem. As krasnozems consist of little more than kaolinite and iron oxide (very stable materials), it is not surprising that they are difficult to modify. At Tarrington (allotment 4 of 12, Par. of S. Hamilton) in W. Victoria, Mr F. R. Gibbons showed me a krasnozem overlying a deep weathering of basalt described as a semi-lateritization. It was noted that here also the top foot or so has been further leached. A later flow of basalt occupies a valley cut in this terrain.

This same leaching of the top 12 to 15 in. of krasnozems has been noted in C. Victoria and E. Victoria. Krasnozems may also show signs of erosion over a considerable period (observations at Lilydale by A. M. Gill and writer). Although the age or ages of krasnozems in Victoria have not been worked out in detail as yet, it seems likely that they are a product of conditions following the period of laterization but before the present types of soils began to develop under a Mediterranean (in the broad sense) type of climate.

Further evidence for this interpretation is provided by a large section forming the N. end of the Standard Quarries pit in Wearing St, Footscray, a suburb of Melbourne. This is shown in Fig. 7, where a krasnozem has been formed on deeply weathered Older Basalt (a function of the Nunawading Terrain) of probable Oligocene age.*

[* A palynological analysis by Dr Isabel Cookson of carbonaceous sediments from between flows of Older Basalt in the Yarra Delta nearby gave a Yallournian age. The sample was obtained by the writer from a bore on Coode Is. put down by the Melbourne Harbour Trust Commissioners in 1950. Dr A. B. Edwards identified the basalt as an olivine type of uncertain affinities, but possibly Mooroodue Type Older Basalt.]

The soil developed on the Older Basalt is red and uniform (not duplex). It is overlain by a grey clayey sand which thickens towards the valley floor and ultimately replaces the krasnozem. The basalt-soil interface can be followed for a considerable distance in the quarry; the S. wall transects the former valley wall again. In between, the contact is along a flat plane, apparently the floor of the valley. A few remains of woody plants normal to the soil surface suggest it is a terrace and not the thalweg. Thus, a krasnozem was formed on the strongly decomposed Older Basalt, and this was followed by a different type of soil formation before the three or more flows of lava filled the ancient valley. As the valley is cut in the Timboon Terrain (i.e. through the laterite at Royal Park, Essendon and Keilor), the krasnozem is post-laterite. On the other hand, the Newer Basalt that buried the krasnozem has areas of deep montmorillonitic clay on it, showing that it is older than Holocene in age. The krasnozem could be Lower Pleistocene, similar in age to that at Portland.

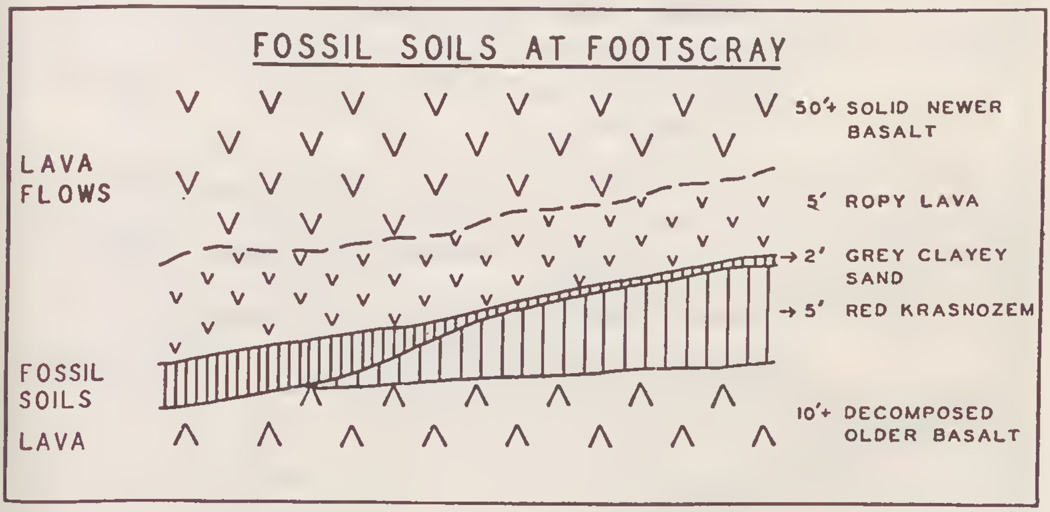

FIG. 7

QUATERNARY DUPLEX SOILS AND LOAMS

Holocene soils on basaltic ash spreads and lava flows in W. Victoria consist of juvenile soils or minimal duplex types if on tuff under good soil-forming conditions. Tuffs are the most easily weathered volcanic materials; duplex soils with pea-sized buckshot gravel* are found on spreads of late Pleistocene tuff. Soils on basalt flows

[* By buckshot gravel is meant magnetic pisolites rich in gamma iron oxide (maghemite). In the W. District the ironstone gravel from the breakdown of laterite is often called buckshot gravel by the farmers, but the iron therein is the non-magnetic alpha iron oxide.]

similar to those on tuffs are much older than those on the latter. The flows with massed buckshot and deep clay subsoil are Middle (and sometimes perhaps Lower) Pleistocene in age.

Hypothesis of Fossil Soil Succession

The following series of soils, characterizing successive terrains, were formed:

(a) Nunawading Terrain. Deep kaolinization and/or bauxitization. Middle Tertiary, mostly Miocene.
(b) Timboon Terrain. Lateritization. Lower Pliocene.
(c) Kraznozem formation. Probably Plio-Pleistocene, i.e. late Pliocene and Lower Pleistocene.
(d) Quaternary duplex soils (including montmorillonite-bearing soils on basalts and tuffs) and loams on younger substrates.

The foregoing changes in type of soil formation are not due simply to differences in the time factor. The marine faunas throughout this period of time, the land faunas

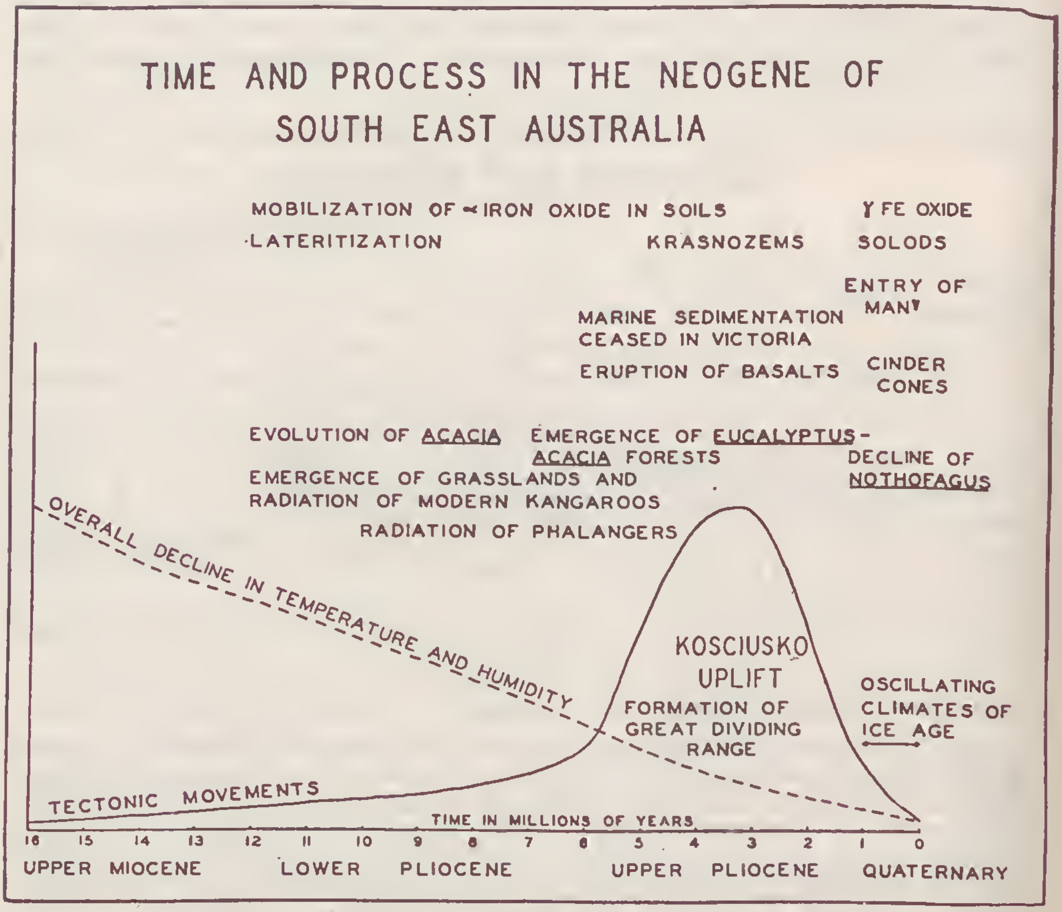

Fig. 8

(Gill 1961c,d) and the results of oxygen isotope palaeotemperature analyses (Dorman and Gill 1958) provide independent evidence of climatic changes. These are summarized in Fig. 8.

If the foregoing hypothesis can be proved, these fossil terrains will enable dating in areas where correlation is difficult or seemingly impossible. Two examples will illustrate the method. The type of Professor McCoy's fossil wombat *Vombatus pliocenus* came from 'hard gold cement' at Dunolly, Victoria. The fossil came from a depth of 50 ft in a mass of secondary carbonate at the bottom of a channel filled with auriferous sands and gravels. It can be shown that this stream system was incised in the Timboon Terrain, and the thick gravels themselves are evidence of the Kosciusko uplift. As the fossil is later than the Timboon Terrain it is later than Lower Pliocene. In that it was found in thick Kosciusko sediments, it probably belongs to the Upper Pliocene or Lower Pleistocene when the main movements took place. Since it is at the very bottom of these sediments, it is probably Upper Pliocene in age.

Another example is the dating of the Rowsley Fault at Bacchus Marsh (Fenner 1918, 1925; Hills 1934; Thomas and Baragwanath 1950). The Timboon Terrain of Lower Pliocene age caps the Rowsley Scarp and is covered in some areas by basalt. The laterite characterizing this terrain could not have been formed with the Rowsley Scarp present, because its genesis depends on alternate water-logging and aeration of the ground that could not take place at such a well-drained site. The fault is accordingly later than Lower Pliocene and probably Upper Pliocene. The basalt is on the uplifted plateau and also infills a youthful valley in the scarp seen at Dogtrap Gully, so the basalt was extruded shortly after the faulting and should also be referred to the Upper Pliocene.

Silica in Soils on Basalts

As there is no free quartz in basalt, it is necessary to explain the presence of quartz in soils on basaltic flows and tuff spreads in W. Victoria. The quartz is of the high temperature variety and is derived apparently from granitic sources. The grains vary in size from the finest silt to waterworn boulders, with much variation in shape and angularity. There are three main mechanisms by which such silica has been emplaced; each mechanism has produced a distinctive type of deposit.

Emplacement by Wind Action

This type of deposit may be recognized by the grain size analysis, which gives a cumulative curve similar to that of loess. Where a soil has an appreciable quantity of rounded quartz grains of silt size, it can be inferred that the deposit has been transported by the wind, as this is the only way in which such material can be sorted to this degree. There exist many loess-like deposits round lakes (Hills 1939, 1940a; Stephens and Crocker 1946; Gill 1953a) and, in addition, there are deposits of this type infilling hollows in the landscape with greater frequency than has been recorded. Some river terraces also consist of loess-like materials interpreted as redeposited loess or materials resembling loess, e.g. the Doutta Galla Silt of the Maribyrnong R. Valley (Gill 1962b).

No grain size analysis has yet placed any of these deposits strictly in the category of loess as now so closely defined; usually the deposits are more clayey (the 'parna' of Butler 1956) or more sandy. On the other hand, many of the deposits are so like loess that visitors from overseas familiar with that material have regarded our deposits as such.

Some of the quartz comes from the wind-sifting of coastal dunes, but the majority comes from the deflation of dry lake floors. At the present time many shallow lakes on the basalt plain dry up in summers of low precipitation and high temperatures, e.g. 12 summers in the past 40 L. Colongulac at Camperdown has gone dry. In drier times, such as the postglacial thermal maximum, such a lake would dry up every summer, and deflation of the lake floor would take place. The considerable volume of dunes on the E. and SE. sides of the lakes is witness to the measure of this movement. During such periods, the playas have been lowered, so extending the life of the lakes, and the material has been supplied for the dust storms that carried the silt-sized silica across the countryside and built up the lunettes and similar structures. The prevailing winds were then NW. in SW. Victoria and not SW. as at present. The more clayey deposits are due to the fretting of mud polygons and the blowing up of the clay as aggregates; the more sandy deposits are due to the addition of saltatory material. For example, at the NE. end of L. Weering there is a good deal of sand in the soil on basalt and this appears to have its origin in saltatory material from the floor of L. Weering.

EMPLACEMENT BY VOLCANIC ACTION

Leeper et al. (1936) have described the distribution at Mt Gellibrand (a volcano) of silica sand in the soil with lines of equal percentage concentric on the crater, the greatest percentages being nearer the vent. We can conclude from this that the volcano is responsible for the emplacement of this silica, or at least for the major part of it. Hanks (1955, p. 13) has recorded silica gravel in a lava flow at Bunker's Hill and four other sites N. of Melbourne; he lists references to earlier records of quartz in basalt in Victoria.

The area covered by the basalt plain of W. Victoria has had great quantities of sand and clay deposited on it. It is, therefore, not surprising that volcanoes breaking through these formations have brought the material to the surface and distributed it with other ejectamenta or in the lava flows. As far as the author's observations have gone, silica is brought up by every volcano, but the amount varies. The volcano Ecklin Hill (Gill 1947) has the greatest quantity observed so far, so much so that in certain layers of the ejectamenta it enhances the value of the material for roadmaking. Owing to the mechanical activity involved, more silica has been distributed by the explosive than by the effusive volcanoes. Pyroclastic products decompose more readily and so more quartz is present in soils developed on ejectamenta; such silica is characterized by its lack of sorting, and sometimes by its relations to vents.

EMPLACEMENT BY WATER ACTION

Lakes are common on the basalt plain of W. Victoria, but they were far more extensive and more numerous during the wetter and cooler glacial periods of the Pleistocene when there was greater precipitation and less evaporation. Lakes are particularly abundant in the area between the Dividing Ra. and the Otways, because the raising of the Otways caused a general damming of the southerly drainage (Gill 1964). Between the Barwon R. in the E. and Mt Emu Ck in the W. there are few streams but dozens of lakes, often orientated in N.-S. direction. Water washing across the land to these lakes and from lake to lake in wet periods has helped to distribute water-sorted silica across the basalt plain. Where there are high level basalts and low level basalts, e.g. in the Moorabool R. valley near Geelong (Coulson 1938) and in the Hopkins R. valley at Allansford near Warrnambool, silica sand may wash from the sub-basaltic deposits of the higher flows on to the surfaces of the lower flows. Where a valley has been infilled with basalt, sand will wash from the surrounding terrain on to the basalt flow because it occupies the area of lowest relief. Lying on a grassy slope in the rain, one can watch the Lilliputian streams between the grass roots gradually conveying grains of sand downslope. Although the declivity be low, great quantities of quartz grains and other particles can be shifted in this fashion, given geological time and the wetter periods of the past since the basalt was extruded. The range of grain sizes carried and the degree of sorting will depend on the amount of water, its energy, and the distance carried.

Basalt-sediment Interface and Tectonics

In E. Australia, tectonic movements continued through the Cainozoic Era, but there were two maxima associated with the extrusion of the Older Basalts and Newer Basalts respectively (Gill and Sharp 1957). The span of time during which the second period of movements took place was called by Andrews (1910) the **Kosciusko Epoch.** The effects of these movements are widely recognized throughout E. Australia. A similar term is needed for the earlier series of movements; it is proposed that this time interval be called the **Bass Strait Epoch** because Bass Strait was formed (shown by marine encroachments), the Port Philip Sunkland initiated, and the Tamar Graben formed in N. Tasmania (Gill 1962a) at that time.

These two series of movements can be illustrated well at Bacchus Marsh, 35 miles WNW. of Melbourne. Fenner (1918, 1925) worked out the structure, and later Thomas and Baragwanath (1950) extended knowledge of the area. The essential structures consist of—

(1) Two roughly E.-W. faults (Greendale and Spring Ck) that in Lower Cainozoic time formed the Ballan Sunkland.
(2) The roughly N.-S. Rowsley Fault connected with the uplift of the highlands in the upper Cainozoic.

The laterite of the Timboon Terrain can be seen under the basalt on the S. side of the Werribee Gorge. It also caps Table Hill and the hill N. of the Western Highway and W. of Korkuperrimal Ck. Such laterite could not form on the edge of a plateau because the situation would be too well drained. The Rowsley Scarp must have developed, therefore, after the Timboon Terrain laterite formed in the Lower Pliocene. On the Rowsley Scarp at Dogtrap Gully, between Parwan Ck and the Werribee R., basalt infills a youthful steep-sided valley. Therefore, uplift had taken place and this valley had been eroded before the basalt that infilled it was extruded. The Rowsley Fault scarp must have been formed, therefore, prior to the Upper Pliocene and/or Pleistocene basalts, and prior to the ?Upper Pliocene lacustrine deposits at Coimadai (see below) but, being at the same time post Lower Pliocene in age, it was most likely an Upper Pliocene event.

Two remarkable characteristics have been noted about the sediments under the basalt in the Maryborough, Avoca, Huntly and Ballarat districts (Baragwanath 1923, Mines Dept 1937):

(1) The bottoms of the leads have for some miles downstream a rising instead of a falling gradient.
(2) There are widespread lacustrine as opposed to fluviatile sediments.

These two characteristics are no doubt related. The uplift of the Dividing Ra. took place in such a way that the direction of flow of many streams reversed; this led to the ponding of streams and lacustrine sedimentation.

Basalt in Glacial Period Channels

The geological map of Melbourne (published by the Department of Mines 1959) shows basalt flows coming down from more northern eruption centres and occupying the valley of the Yarra R. (see also Hanks 1955). The drainage is southerly and then turns westerly under the influence of the Melbourne Warp (Gill 1961b). Bores and excavations show that the bed of the Yarra occupied by the basalt is graded to a much lower sea level. The basalt extends as far as Spencer St, Melbourne, where excavations for the bridge showed the thalweg to be about 83 ft below present sea level (Gill 1949, p. 39); this is probably part of the channel that reached a depth of 113 ft below sea level at Port Melbourne.

Reid's basalt quarry on Steele Ck at Niddrie, a suburb of Melbourne, shows Newer Basalt occupying a valley crossing the Maribyrnong R. at Braybrook, thus causing a large loop in the river. The thalweg of the stream is a considerable distance below sea level, and even allowing for the earth movements in the time involved, this is probably due to gradation to a lower sea level of a Pleistocene glacial period. The walls of the Maribyrnong R. valley intersect the walls of the fossil valley on the E. and W. limbs of the river loop respectively. On the E. side, near the old tea gardens, fossil vascular plants in position of growth were found in the fossil soil of the former valley wall; the normal river level therefore was below this. At Allansford near Warrnambool, at Port Fairy, and at Portland in W. Victoria there are lava flows in old valleys graded to a lower relative level of the sea.

Aeolianite and Basalts

While the E. coast of Australia is characterized by siliceous sand dunes, the S. coast is characterized by calcareous sand dunes. The Pleistocene limey dunes are lithified into aeolianite. The Riss/Würm dunes in Victoria have only a hard travertine crust, while the older ones are lithified throughout, but the degree of lithification may vary with age, as can be seen in the three superposed dune systems with intercalated fossil soils in the large quarry at the E. end of Albert Park, Warrnambool. The faces of road and rail cuttings through Riss/Würm dunes have to be specially treated to prevent sand flow; on the other hand, the aeolianite of Middle and Lower Pleistocene age is used for building houses and stone walls.

Differing opinions have been expressed whether aeolianite dunes are a product of glacial periods with low sea level (when the continental shelves were bare), or represent times of higher sea level in the interglacial periods. This is surely a false antithesis. As the dunes are a product of coastal processes, the extant dunes on the coast must have been produced when the sea was at or near its present level. Some must have been built during the interglacial periods, e.g. those resting on the Riss/Würm interglacial marine beds that pass up into dunes. On the other hand, there is evidence from bores below sea level and from submarine contours that there are dunes built in the colder times of lower sea level. Such dunes were built successively as the sea advanced and retreated from low glacial to high interglacial positions, and so probably range from interglacial to glacial in age.

At Warrnambool, three snail faunas are preserved in dunes:

(1) Dry facies snails in the aeolianite itself.
(2) Wet facies snails in the intercalated terra rossa soils.
(3) Introduced snails in the mobile dune sands deposited since the system was disturbed by European occupation.

The aeolianite continues far out under the sea and it would be interesting to know if the dunes further out on the continental shelf have a different snail fauna suited to the colder and wetter times.

The basalts of the W. plain vary in their relationships to these dunes, providing evidence of the age of the flows and of past climatic conditions. At Warrnambool, the farthest inland aeolianite rests on the weathered surface of the basalt (Gill 1943), the weathered surface showing the basalt to be somewhat older than the aeolianite. The basalt is at least as old as Lower Pleistocene, because at least two other and older cycles of aeolianite formation can be demonstrated prior to the Riss/Würm interglacial. Similar conditions are found at Portland (Boutakoff 1963). In all places examined, the Holocene mobile dunes overlie both basalts and tuffs.

Marine Deposits on Basalt Plain

Along the coast, aeolianite dunes fringe the basalt plain in many places. Intercalated with these dunes, overlying them, and also in places where dunes do not occur, are marine beds of Quaternary age. The most widespread are beds that are obviously very recent by reason of their lack of consolidation, their unoxidized condition, the extremely good preservation of the shells, the lack of secondary carbonate features such as pipes, and their grading in relation to present coastal structures. Many of these have now been dated by radiocarbon and have been shown to be mid-Holocene in age. Some writers have called such beds storm beaches, but when they occur in enclosed lagoons they cannot be so explained. Such ideas are obviously inappropriate when the ecology of these sediments is studied. The beds are stratified and so must have been laid down below low tide mark, there are fine sediments that storm waves would carry away, there is no flotsam and jetsam, and often bivalves are present in great numbers with both valves still together. Moreover, these beds carry faunal evidence of slightly warmer seas. Conversely, since the postglacial thermal maximum was a time of greater warmth, higher seas would be expected on the glacial control theory. This theory can be accepted as at least the major factor in sea level change in the Quaternary, as radiocarbon has made it possible to prove that the sea level was low during the times of glaciation on land during the last glacial period.

The alternatives are that these strata have been uplifted by tectonic movement, or have emerged by reason of eustatic changes of sea level. The latter view is favoured because, when allowance is made for difference in tidal range, these beds have emerged to very closely the same amount whether on stable blocks or along sinking coasts of basins where the tectonic vector is downwards. To ask that, whatever the tectonic environment, all these beds in this short space of time should all be elevated to the same amount correct within a foot or two appears to the writer to be a *reductio ad absurdum.**

[* This is part of a world problem which is being studied by a Commission of INQUA with which the ANZAAS Committee for the Investigation of Quaternary Shoreline changes is co-operating.]

Next oldest are beds reaching about 25 ft above present LWM. They are consolidated, oxidized, have been incised below present sea level, have secondary carbonate structures such as pipes, possess faunal evidence of warmer seas, pass below the youngest aeolianite dunes (those with a travertine crust), and are beyond the range of radiocarbon dating. They are believed to be Riss/Würm Interglacial in age, and are useful for providing a minimum date for lava flows that they cover, such as at Port Fairy.

There are evidences of yet older sea levels of Quaternary age overlying the fringe of the basaltic plain, but these evidences are mostly erosional and lack biological dating. The early Pleistocene marine deposits (the Werrikoo Member in the Glenelg R. to Portland area, and the Moorabool Viaduct Sands of the Geelong area) underlie the local basalts.

Lacustrine and Palustrine Deposits

Hollows in the basaltic plain were filled with water and became lakes. Water occupying such areas of negative relief increased their extent by erosion of the banks; because the level of the water was constantly changing, wide areas could be eroded in this fashion. Such water also enlarged the hollows to some extent by solution.* The hollows occupied by lakes have been formed in many different ways. Some are sags in the lava plain. Some are low areas between lava flows. Some are due, like L. Colac, to the blocking of drainage by faults. At Colac, a fault at the S. end of the lake brings up the Cretaceous rocks, and has also uplifted an ancient river bed covered with basalt; a volcano is sited there as well, but this is younger than the underlying lake sediments, so the fault is considered to be the primary cause of lake formation. The hill at the S. end of L. Colac on which the Colac Motel stands is a much eroded and weathered volcano of possibly Lower Pleistocene age. The lake shore section W. of the unnamed creek shows, from below up, a laucustrine bed without tuff, then a lacustrine bed with tuff containing leaves, eucalypt fruits and a few marine shells, and finally a thick bed of volcanic agglomerate. The lacustrine beds prove that L. Colac formerly extended farther S. than at present.

[* Along the coast where basalt outcrops but receives only spray action and not direct wave action, the rock may be honeycombed, demonstrating solution by sea water.]

At Camperdown, S. of L. Colongulac there is a complex of volcanoes connected with the formation of that lake. As far as it has been elucidated, the succession of events is as follows:

(1) An effusive volcano S. of Camperdown (Gill 1953a, p, 28) extruded lava flows that blocked the drainage. The surfaces of the basalt flows on the S. side of the lake dip N. and pass under the lake floor.

(2) The explosive volcanoes Gnotuk, Bullenmerri, and Leura deposited ash over the terrain (Hampden Tuff), partly infilling the lake. The scoriaceous ejectamenta forming Mt Leura represent a later event.

(3) In the mid-Holocene tuffaceous sediment from the lake floor was blown up into dunes (Colongulac Parna), thus deepening the lake a little. Basalt flows on the E., N. and W. banks formed the original limits of the lake in those directions.

Other lakes occupy volcanic craters (e.g. Bullenmerri, Burrumbete, Gnotuk, Terang, Keilambete, Wangoom), while others again occupy hollows between aeolianite dune systems and the former coast (e.g. Gillear and Bridgewater).

Lake basins gradually become infilled and form swamps; indeed a given catchment may oscillate between swamp and lake according to climatic conditions or even seasonal conditions. Pejark Marsh at Terang is probably a lake that has become a swamp. Some old lakes associated with the lava plain accumulated sediments but were then drained and dissected. An example of such a lake is represented by the lacustrine deposits at Coimadai (Officer and Hogg 1897-8, O'Donoghue 1916, Summers 1923, Coulson 1924, Keble 1925). Two formations are represented; for which names are here proposed:

Upper **Alkemade Siltstone** (after the type locality of Alkemade's Quarry).
Lower **Coimadai Dolomite** (the quarried rock).

In 1958, the following section was measured on the E. wall of Alkemade's Quarry:

13′ 0″	Claystone and siltstone, laminated in lower part.
9″	Limestone.
4″	Ferruginous sandstone.
1′ 3″	Laminated claystone with plant fragments and ostracods.
1′ +	Dolomite. The beds above this layer constitute the Alkemade Siltstone which forms a face at an angle of 35° to the horizontal, while the underlying limestone maintains a vertical face. Material slipping from the siltstone formation obscured the limestone below and so the section was continued a little farther N. whence the plant bed could be easily followed.
18′ 0″	Banded dolomite.
3″	Speckled fawn sand.
8″	Thin bands of calcareous siltstone to silty limestone.
1′ 4″+	Limestone breccia. The above four beds constitute Coimadai Dolomite.

The limestone has yielded the bones of marsupials, some of which are different from the usual Pleistocene faunas and are thought to be older.* Fenner's explanation (1918) of the formation of the lake by the Bullengarook lava flow blocking the drainage is untenable because the base of the lava flow is higher than the deposits in the valley.**

[* Dr Isabel Cookson and Mrs Kathleen McWhae examined separate samples of the carbonaceaus siltstone, but neither was able to discover pollens or spores with which to date the bed. A *Casuarina* cone has been found in the limestone, but this does not help dating.]

[** The Coimadai Fault of Fenner (1918) probably does not exist since the platform cut on the Ordovician bedrock is at similar elevations on the N. and S. sides of the Coimadai valley.]

The following reconstruction is suggested:

1. Uplift of the highlands resulted in streams cutting valleys in higher areas; the Coimadai valley was probably cut at this time.
2. Alluvial fans from the uplifted country to the W. and N. of this valley spread out, blocked the drainage and formed the lake. This hypothesis accounts for the great thickness of clayey sands under the Bullengarook basalt, and the apparent absence of stream gravels, in this area. A stream probably drained overflow from this lake and ran S. to the Werribee R.
3. The Bullengarook basalt flowed down from the N. and infilled this stream bed, but did not infill the Coimadai valley because it was already infilled with sediments.
4. Twin streams marginal to the basalt cut down to form the valleys of Goodman's Ck and Pyrete Ck.

A feature of the Coimadai Limestone is the presence of large collapse structures with dips commonly as much as 20-25°, but as high as 55°, that occurred before the Alkemade Siltstone was emplaced. The simplest explanation seems to be that at times the streams draining the area cut down faster than the piedmont deposits filled the valley mouth, so that the lake was temporarily lowered. The low level of the water would then cause solution and erosion low in the formation and so initiate collapse. Later, with further uplift, the sediments from the highlands completely sealed the valley, and the clayey upper formation was deposited. Then the Bullengarook basalt formed a shield over the outwashed clayey sands, and streams cut back along its margins without being overloaded. In time the stream on the NE. side cut back far enough to drain the Coimadai lake and then incise the deposits. Remnants of the lacustrine beds remain round the valley at Alkemade's, Hjorth's and Davies's quarries, indicating that they once existed right across the valley, as one would infer. The amount of erosion performed by so small a stream is indicative of a long history. Until recently there were active springs at Alkemade's, so solution by spring waters may have been an alternative or additional factor causing collapse.

Fluorine tests have been made on a series of bones from beneath the basalt from Ballarat to Coimadai, and while evidence of high fluorine content on its own proves little, it strengthens the case for giving these beds some antiquity. On the above reconstruction, the formations at Coimadai are pre-basaltic and not post-basaltic. As the Rowsley Fault is epi-Timboon Terrain (Lower Pliocene) in age, and the Coimadai deposits followed close on the faulting, an Upper Pliocene age for the Coimadai Limestone and Alkemade Siltstone seems likely. The upper Pliocene has a time span of 6 or 7 million years and the Quaternary only one million so, considering the succession of events to be fitted in, it is more likely that the deposition of the lacustrine deposits at Coimadai took place in the Upper Pliocene than in the Pleistocene.

Another notable feature of the limestone at Coimadai is that it is recrystallized. A similar recrystallized limestone, the Lara Limestone, occurs to the SW. near Geelong, and it is also related to the basalts and to the group of faults of which the Rowsley Fault is the main one. However, the Lara Limestone overlies the basalt, but as it has a similar relationship to the movements dated as Upper Pliocene, it is also considered to be of this age. If one distinguishes between the fossils found in the limestone and those found in cavities in the limestone, this also has a fauna that is older than the accepted Pleistocene one. The *Diprotodon* found in the Lara Limestone is not the Pleistocene *D. optatum* but the related *D. longiceps* (Keble 1945). A *'Unio'* collected from this limestone by Dr G. B. Pritchard is stated by Dr D. McMichael to be a new genus. A limestone similar to the Lara Limestone occurs on the S. side of Corio Bay, forming Limeburners' Point. It would appear that this limestone is part of the same formation or series of formations infilling a valley, the drainage of which was blocked by Upper Pliocene earth movements. The formation of Corio Bay is a later, aparently Pleistocene event; it is earlier than Holocene because incision of the valleys occurred during the last low sea level.

Lacustrine Deposits and the Latest Eruptions

From a great deal of available information, the relationship as seen at Pirron Yallock will be described. This village is W. of Colac at the S. end of L. Corangamite. Even at the height of the 'creeping lakes' advance of lake level in the past 10 years, the water did not come within 6 to 10 ft. of this platform. The village is on the Pirron Yallock Ck which is marginal to the Stony Rises newer basalt flows (cf. Skeats and James 1937, Hills 1939). Some years ago when a new bridge was being built across the creek at the Princes Highway, bedded tuffs were exposed showing well-formed ripple marks at a number of levels (Fig. 9). A section showing the tuff can still be seen just downstream from the bridge. Skeats and James (1937) recorded the brackish water snail shell *Coxiella* in tuffs in this area, pointing out that they indicated a lake level 5 ft or so higher than the present. Since the tuffs are spread round the Vaughan Is. volcano at the S. end of the lake, that must be their source.

Stony rises are overlain by parna dunes on the E. side of L. Corangamite in the Dreeite area. The stony rises (in the Corangamite area at least) are thus older than the Vaughan Is. eruption and older than the parna dunes. The former was a time of higher lake level and the latter a time of dryness. Evidences for recent changes of

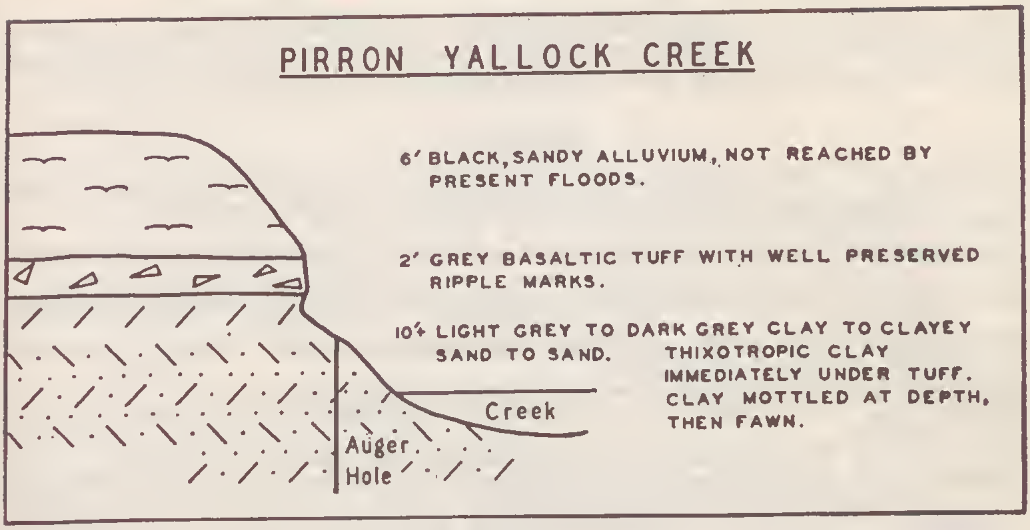

FIG. 9

this kind are common on the basalt plain, and so are a function of climatic change rather than local conditions.

The Lava Plain and Parna Dunes

During the mid-Holocene drier period (postglacial thermal maximum—Gill 1955) most if not all the surficial lakes (as against the deeper crater lakes) dried up, at least in the summer, so that the floors were desiccated and the dunes on the E. and SE. shores built up (Hills 1939, Stephens and Crocker 1946, Gill 1953a). Hills (1940) proposed the geographical name **lunette** for the new-moon shaped dunes so characteristic of the round lakes. There is a tendency to call all parna dunes lunettes, but to do this will rob the term of its distinctive meaning. Of recent years, the term **loess** has been stripped of its genetic implications and specifically defined as grains falling within a given grain size analysis. As far as is known, only air transport can bring about sediment of such sorting. This is therefore a good term, being solely descriptive by definition, yet having useful genetic implications. Butler (1956) has pointed out that the dune materials round many lakes is too clayey to be called loess in its modern definition and so he introduced the term **parna** for 'aeolian clay'. Such sediments could not have been blown through the air as separate entities or they could not have formed these dunes. It is implied that they blew up as aggregates, as can be seen happening now in dry years in small measure. This term also is in danger of losing its distinctiveness by being used for any materials found in such dunes, i.e. given a genetic significance. By definition, parna is a material of much finer grain size than loess. As parna always has much carbonate in it, this chemical constituent may also help to keep it in aggregates. A fabric analysis of material found blowing at the present time might yield helpful information.

Conclusion

As the volcanic rocks of the W. District lava plain have been emplaced at many times from the Upper Miocene to the Upper Holocene, there are numerous interfaces both below these rocks and above them that yield helpful information regarding time and process. Further radiocarbon datings for the end of this period of time, and potassium/argon datings for the earlier basalts and tuffs are needed.

References

ANDREWS, E. C., 1910. Geographical unity of eastern Australia in late and post-Tertiary times, with applications to biological problems. *J. Roy. Soc. N.S.W.* 44: 420-480.

BARAGWANATH, W., 1923. The Ballarat gold-field. *Mem. Geol. Surv. Vict.* 14.

BELL, G., 1960. Notes on the bauxite deposits of the Mirboo North district, South Gippsland. *Min. & Geol. J.* 6 (4): 51-62.

BOUTAKOFF, N., 1963. The geology and geomorphology of the Portland area. *Mem. Geol. Surv. Vict.* 22.

BOWLER, J. M., 1963. Tertiary stratigraphy and sedimentation in the Geelong-Maude area. *Proc. Roy. Soc. Vict.* 76: 69-137.

BUTLER, B. E., 1956. Parna, an aeolian clay. *Austr. J. Sci.* 18: 145-151.

COULSON, A., 1932. Phosphatic nodules in the Geelong district. *Proc. Roy. Soc. Vict.* 44: 118-126.

———, 1938. The basalts of the Geelong district. ibid. 50: 251-257.

COULSON, A. L., 1924. The geology of the Coimadai area, Victoria, with special reference to the limestone series. ibid. 36: 163-174.

DENNANT, J., 1899. Notes on Tertiary fossils. *Progr. Rept. Geol. Surv. Vict.* 11: 28-29.

DORMAN, F. H., and GILL, E. D., 1958. Oxygen isotope palaeotemperature measurements on Australian fossils. *Proc. Roy. Soc. Vict.* 71: 73-98.

EDWARDS, A. B., 1934. Tertiary dykes and volcanic necks of South Gippsland. ibid. 47: 112-132.

FENNER, C., 1918. The physiography of the Werribee River area. ibid. 31: 176-313.

———, 1925. The Bacchus Marsh Basin, Victoria. ibid. 37: 144-169.

FERGUSSON, G. J., and RAFTER, T. A., 1957. New Zealand ^{14}C age measurements—3. *N.Z. J. Sci. & Technol.* B 38: 732-749.

GASKIN, A. J., 1944. Kaolinized granodiorite in the Bulla-Broadmeadows area. *Proc. Roy. Soc. Vict.* 56: 1-18.

GIBBONS, F. R., and GILL, E. D., 1964. Soils and terrains of the basaltic plains of far Western Victoria. ibid. 77 (2).

GILL, E. D., 1943. The geology of Warrnambool. ibid. 55: 133-156.

———, 1947. Ecklin Hill—a volcano in the Western District of Victoria. *Vict. Nat.* 64: 130-134.

———, 1949. The physiography and palaeogeography of the River Yarra, Victoria. *Mem. Nat. Mus. Melb.* 16: 21-49.

———, 1953a. Geological evidence in Western Victoria relative to the antiquity of the Australian aborigines. ibid. 18: 25-92.

———, 1953a. Buckshot gravel as a time and climate indicator. *Vict. Nat.* 70: 72-74.

———, 1955. The Australian 'Arid Period'. *Austr. J. Sci.* 17: 204-206.

———, 1957a. The stratigraphical occurrence and palaeoecology of some Australian Tertiary marsupials. *Mem. Nat. Mus. Vict.* 21: 135-203.

———, 1957b. The Pliocene-Pleistocene boundary in Australia. *Austr. J. Sci.* 20: 86-87.

———, 1961a. The Pliocene-Pleistocene boundary in Australia. Internat. Geol. Congr., 20th Sess., Mexico 1956, Sect. 7, p. 389-395.

———, 1961b. Eustasy and the Yarra Delta, Victoria, Australia. *Proc. Roy. Soc. Vict.* 74: 125-133.

———, 1961c. The climates of Gondwanaland in Cainozoic times. *Descriptive Palaeoclimatology* chap. 14. London and New York.

———, 1961d. Cainozoic climates of Australia. *Annals New York Acad. Sci.* 95: 461-464.

———, 1962a. The geology of Tasmania—Cainozoic. *J. Geol. Soc. Austr.* 9 (2): 233-253.

———, 1962b. ANZAAS Committee for the Investigation of Quaternary Strandline Changes: Report—Victoria. *Austr. J. Sci.* 25: 203-204.

———, 1963a. The age and ecology of fossil Mollusca from Red Bluff, Sandringham, Victoria. *J. Malac. Soc. Austr.* 7: 7-11.

———, 1963b. The geology of the Shire of Hampden, Western Victoria. Centenary Publication of Shire, Camperdown.

GILL, E. D., and DARRAGH, T. A., 1963. The evolution of the Zenatiinae (Mactridae: Lamellibranchiata). *Proc. Roy. Soc. Vict.* 77: 177-190.

GILL, E. D., and SHARP, K. R., 1957. The Tertiary rocks of the Snowy Mountains, Eastern Australia. *J. Geol. Soc. Austr.* 4 (1): 21-40.

GRAYSON, H. J., and MAHONY, D. J., 1910. The geology of the Camperdown and Mount Elephant districts. *Mem. Geol. Surv. Vict.* 9.

GREGORY, J. W., 1903. *The Geography of Victoria: Historical, Physical, and Political.* Melbourne.

HANKS, W., 1934. The Tertiary sands and Older Basalt of Coburg, Pascoe Vale and Campbellfield, V. *Proc. Roy. Soc. Vict.* 46: 144-150.

————, 1955. New volcanic vents and lava fields between Wallan and Yuroke, V. ibid. 67: 1-16.

HILLS, E. S., 1934. Some fundamental concepts in Victorian physiography. ibid. 47: 158-174.

————, 1939. The physiography of north-western Victoria. ibid. 51: 297-323.

————, 1940a. The Lunette, a new land form of aeolian origin. *Austr. Geogr.* 3 (7).

————, 1940b. *The Physiography of Victoria.* Melbourne.

KEBLE, R. A., 1925. Tertiary magnesian limestone at Coimadai. *Rec. Geol. Surv. Vict.* 4: 441-443.

————, 1945. The stratigraphical range and habitat of the Diprotodontidae in southern Australia. *Proc. Roy. Soc. Vict.* 57: 23-48.

LEEPER, G. W., NICHOLLS, A., and WADHAM, S. M., 1936. Soil and pasture studies in the Mount Gellibrand area, Western District of Victoria. ibid. 49: 77-134.

MINES DEPARTMENT OF VICTORIA, 1937. Deep leads of Victoria. Melbourne.

MURRAY, R. A. F., 1884. Bacchus Marsh district. *Progr. Rept. Geol. Surv. Vict.* 7: 51-56.

NORTHCOTT, K. H., 1960. Effectual key for the recognition of Australian soils. *CSIRO Div. Soils, Div. Rept.* 4/60, Adelaide.

O'DONOGHUE, J. G., 1916. Excursion to Parwan and Coimadai. *Vict. Nat.* 33: 5-7.

OFFICER, G., and HOGG, E. G., 1897-8. The geology of Coimadai. *Proc. Roy. Soc. Vict.* 10: 60-74, 180-197.

OWEN, H. B., 1954. Bauxite in Australia. *Bur. Min. Res., Geol. & Geophys., Austr., Bull.* 24.

PARR, W. J., 1942. The age of the lignite deposits at Parwan. *Min. & Geol. J.* (Vict.) 6: 363-364.

RAGGATT, H. G., OWEN, H. B., and HILLS, E. S., 1945. The bauxite deposits of the Boolarra-Mirboo district. *Min. Res. Surv. Austr., Bull.* 14.

SKEATS, E. W., and JAMES, A. V. G., 1937. Basaltic barriers and other surface features of the newer basalts of Western Victoria. *Proc. Roy. Soc. Vict.* 49: 245-292.

STEPHENS, C. G., and CROCKER, R. L., 1946. Composition and genesis of lunettes. *Trans. Roy. Soc. Sth. Austr.* 70: 302-312.

SUMMERS, H. S., 1923. The geology of the Bacchus Marsh and Coimadai district. *H'book Pan-Pacific Congr.* 1923: 97-112.

THOMAS, D. E., and BARAGWANATH, W., 1950. Geology of the brown coals of Victoria, Pt 3. *Min. & Geol. J.* (Vict.) 4 (2): 41-62.

13

VOLCANIC PHYSIOGRAPHY OF THE WESTERN PLAINS OF VICTORIA

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Abstract

94 named points of volcanic eruption occur on the W. plains of Victoria, associated with extensive flows of olivine basalt. The volcanoes take the form of basalt cones, scoria cones, maars and complex types. Vulcanicity probably extended from earliest Pleistocene times to the Recent, with changes in location and type of vulcanicity. There are few lineaments in the pattern of eruption, and since many flows can be related to particular vents it is believed that central eruption was prevalent. Most of the hills are small and although, in many cases, there were successive eruptions from one point, these were probably close together in time and genetically related so that the volcanoes are essentially monogenetic. The explosion index is low, and this combination of features suggests that the Newer Volcanics of Victoria constitute a distinct geomorphic/petrographic province. Physiographic features of the flows, such as tumuli, stony rises, and lava blisters, are frequently well preserved, but in older flows extensive weathering and soil formation has occurred. Dating methods applied to the vulcanicity are reviewed; although comparatively little progress has been made so far, there is ample material available for working out a detailed geomorphic history.

Introduction

The Newer Volcanics of Victoria, which are of perhaps Pliocene to Recent age, occupy much of the SW. of the State both in the W. plains and the W. highlands. In this paper we shall restrict ourselves to the plains, as shown in Hills (1940). Areas to the N. have been described by Coulson (1954) and Yates (1954) among others, and, since these papers mention over 150 points of eruption, there is no room for repetition here. The volcanics of Central Victoria have been described by Edwards (1938), Hanks (1955), and others, and there are many papers dealing with particular areas or topics which we shall refer to later.

In this paper we shall describe in some detail the volcanic physiography of the W. plains, including the volcanic hills which dot the plains, and also discuss some generalities which concern the Newer Volcanics as a whole.

The W. plains were in existence before volcanic activity started, and igneous rocks only veneer a pre-existing surface. Recent work is showing that considerable areas of the plain, in fact, are not underlain by basalt, and the total extent of the lava sheets may be much less than was formerly supposed. Early writers on the area often followed Gregory (1904) in believing that much of the volcanic activity took place in a large lake, a view based on the bedding of pyroclastics (supposedly sub-aqueous) and the general flatness of the area. Hall (1907) disposed of this idea and showed that the tuffs were subaerial deposits, and we now believe that most volcanics were erupted on a recently uplifted plain, although lakes existed in parts for considerable periods, and there would have been a high water table. Currey (1964) has given a description of the former extent of L. Corangamite, and a good deal of volcanic activity post-dates this lake.

The Newer Volcanic Province is remarkable in having a large number of points of eruption, none of which grew to any great size. Almost all the volcanoes are less than 500 ft above their base and the majority are less than 300 ft. In the Daylesford area, Coulson recorded 123 points of eruption in an area of 600 square miles. In the W. plains we have attempted to record all named volcanoes which number over 90. Some of these are multiple eruptions and there are many other small points of eruption which are not named, but some arbitrary limit had to be set in the compilation.

These many small hills mark points of eruption which poured out large quantities of lava, forming a carapace over much of the plains and giving rise to distinctive landforms; the hills, although very eye-catching, only represent a small portion of the lava erupted.

The relative youth of most of the volcanoes is indicated by the small amount of erosion that they have suffered. Many of them are remarkably well preserved and have just the shapes they had when newly formed. The lack of erosion means that there is a lack of exposure of the interior parts of volcanoes, and opinions must be based on surface exposures and occasionally on exposures in quarries and road cuttings, or on bore records. However, from the shape of the hill and such exposures as there are, it is usually possible to classify the volcanoes.

Types of Volcanoes

BASALT CONES

These are usually low-angle hills, made up of a number of lava flows with no apparent scoria. Mt Atkinson and Mt Cotteril are examples near Melbourne, and on the latter Condon (1951) has mapped individual flows. Other examples are Mt Widderin, Mt Vite Vite, and Mt Rebecca. All of these are weathered and have little or no sign of a crater. Mt Hamilton is a perfect lava cone, with a large crater ¼ mile wide and 100 ft deep. The crater has steep inner walls which are unbreached, but the outer slopes are only about 4°, merging into the plain around.

Basalt without scoria seems to have been erupted at Lawaluk, but this is not a simple cone but a steep-edged, flat-topped disc of lava. Mondilibi is probably of the same type, and the lava sheet within the ring barrier at Mt Porndon (Skeats and James 1937) is possibly a similar, though larger, feature. Warrion Hill is a basalt complex forming an elevated plateau with a diameter of over a mile, and having steep sides with many lava outcrops.

Basalt hills are not as common as scoria hills and, in general, appear to be older.

SCORIA CONES

The ideal scoria cone is a single cone with steep sides and a crater at the top. Mt Elephant and Mt Noorat are two very good examples. The even height of the crater rim often causes the hills to look flat-topped from a distance, like a truncated cone. Many mountains are multiple cones, where several eruptions have taken place from a number of vents in close proximity, so that the scoria cones overlap to form irregular hills, and in some cases it is not easy to find the actual points of eruption. Robertson's Hill, Mt Shadwell, Meningorot, and Mt Wiridgil are of this type. The ejectamenta shows a wide range of variation from coarse bombs and blocks to fine ash. The coarser the fragments the steeper is the hill that results. Sometimes the scoria is welded together, especially close to crater rims. Mt Noorat and Mt Napier show very steep crater edges made of welded scoria. Bombs are common on some volcanoes, such as Mt Porndon, Mt Noorat, and the Anakies. These may contain cores of basalt, olivine (peridotite), or the local country rock. Country rock fragments may also be thrown out along with the general scoria, but without the wrapping of lava to make a typical bomb. At the Anakies, granite is thrown up (one block of several tons is reported), at Mt Rouse quartz fragments, at Elingamite and Wangoom limestone fragments, and at Cape Bridgewater fragments of shale and hornfels. Bombs have been described in more detail by Baker (1964).

Around the rims of scoria cones may be found walls or heaps of lava which congealed on reaching the surface, probably being more viscous than normal. Sometimes they have the appearance of dykes but it is hard to see them as true dykes connected to a magma chamber as they have failed to produce flows. They may be due to the squeezing out of residual liquid from the scoria of the cone along lines of weakness during compaction or settling, possibly accompanied by faulting. The rim of the crater is one line of weakness where such squeeze-ups are found, as at Mt Myrtoon, Mt Warrnambool, and Mt Rouse.

Contrasting with these rim squeeze-ups are the linear squeeze-ups found at Mt Anakie, Mt Rebecca, and Mt Warrnambool. These are long ridges on the flanks of the volcano, and are probably of similar origin to the first type. Others may be radial, while at Mt Misery an unusual curved squeeze-up runs through the centres of three circular outcrops of basalt, which appear to mark the positions of former craters. Similar curved outcrops are found at The Cap.

The highest scoria cone on the W. plains is Mt Elephant which rises some 780 ft above its base. Other cones are about 500 ft high, but most are 300 ft or less (see Table 2).

Maars or Tuff Rings

These are low rings or ramparts of pyroclastic material surrounding wide but comparatively shallow craters. There is some confusion about the terminology. Some authorities say real maars are formed of only country rock, thrown out by a volcanic explosion which did not erupt any volcanic rock, and that if the ejectamenta contains much pyroclastic material then a 'tuff ring' is formed. Rittmann (1962), however, restricts 'tuff ring' to those landforms of indurated pyroclastics, and 'maar' to the crater lakes within them. We will use the term 'maar' for both the outer ring (consisting of pyroclastics or country rock) and the lake. Most of the landforms, in fact, do have lakes in them, and the geographical place names often refer to the lake rather than to the ring which encloses it.

There is a considerable variation in the amount of country rock contained in the ejectamenta. Wangoom Hill consists almost entirely of limestone fragments in the S. quarry at least, but there are also pieces of dense black basalt. Elingamite is mainly pyroclastic but has a few fragments of limestone, as does Mt Ewan, while Purrumbete is almost entirely volcanic ash.

The typical form is a circular ring of pyroclastics, steep on the inside and very gentle on the outside (3-4°), merging into the surrounding plain. The craters are ½ to 1 mile in diameter, and the walls go up to about 50 ft typically, although in exceptional cases, such as Bullenmerri, they may be higher. There is often an asymmetrical distribution of ash, with high walls on the E. side, and low walls, or no walls at all, on the W. This distribution is not always present, and Munderong is lowest to the N.

Many maars contain lakes, such as Purrumbete, Gnotuk, Elingamite, and Bullenmerri. Some, such as Munderong and Cobrico, are swampy and others, such as Terang and Wangoom, are dry. Those with lakes may suffer 'coastal erosion', as can be seen on the E. downwind side of L. Elingamite where the rampart is cliffed and a small beach has formed. The water levels in the maars have not remained constant, and old beach levels may be found, as at Keilambete, Gnotuk, and Bullenmerri.

The pyroclastic material shows distinct bedding, which dips outward from the crater at the same low angle as the ground surface. The ash beds originate with periodic ejections during a single eruption, the material becoming sorted during its descent. Purrumbete also shows cross bedding in the outward dipping ash, indicating that wind action has a part in the sorting and deposition too.

Purrumbete is also unusual in having inward dipping bedding in the ash on the inside of the crater rim. This is steeper than the bedding on the outside, and shows much scour and fill (possibly achieved in the dry state), and landsliding. Inward dipping tuffs have been found also at Mt Leura. It is much more common for the outward dipping ash beds to be truncated at the inner edge, as at Tower Hill. This is most probably due to the crater walls collapsing into the empty vent after the eruption, but whether this is on a scale sufficient to regard the maars as calderas is open to question.

The flat floors of the drained and swampy maars, such as Terang, Wangoom, and Cobrico, indicate considerable infilling of the original crater, though what the filling consists of, and when it happened, is not yet known. Other maars, however, have deep lakes, such as Gnotuk (103 ft), Bullenmerri (263 ft) and Purrumbete (150 ft) (see Fig. 1).

The separation of maars from scoria cones at times can be difficult, and a continuous series can be postulated as from Elingamite (perfectly circular and shallow) to Purrumbete (rough circle) to Gnotuk and Bullenmerri (more irregular in outline), the latter, according to Hills, being three coalesced craters. It is then only a short step to The Basins (a multiple scoria cone with two wide craters containing round or oval lakes) and then to Red Rock (which has 7 craters and 5 broad lakes, and rises to 300 ft above lake level). If Red Rock were a little higher above the water table it might resemble a multiple scoria cone such as Mt Shadwell, and there would be a complete transition from maar to scoria cone. Despite the presence of transitional types, the separation of maars from scoria cones seems worth while, and our main criterion has been the presence of thin-bedded ash layers in the low angle outer ring.

With the exception of a few doubtful cases, the maars are concentrated in the Camperdown area, on bedrock of Tertiary limestone, and on a flat plain where groundwater is near the surface, perhaps causing the explosive eruption.

CALDERAS

According to Howell Williams (1941), calderas are large depressions, usually over a mile wide, and formed by volcanic subsidence. It is generally agreed that Tower Hill is a caldera, but it should be realized that it is the minimum size for a caldera, and its outer edge is similar to that of the maars. Its shape is roughly circular and the 'caldera' lake at Tower Hill is similar to the lakes of the maars. Within it is a multiple scoria cone, so it has been described as a nested caldera or nested crater. The outer wall is highest on the E., as in most of the maars, and the ash is asymmetrically distributed over the surrounding countryside, being mainly to the NE. Gill ascribes this to a south-westerly wind at the time of eruption.

Gill has also suggested that other calderas exist in the W. District, e.g. Ecklin, Mt Warrnambool, Mt Leura, and Wangoom. We regard these as tuff rings. Mt Warrnambool is a complicated hill, consisting of an outer, low tuff ring and an

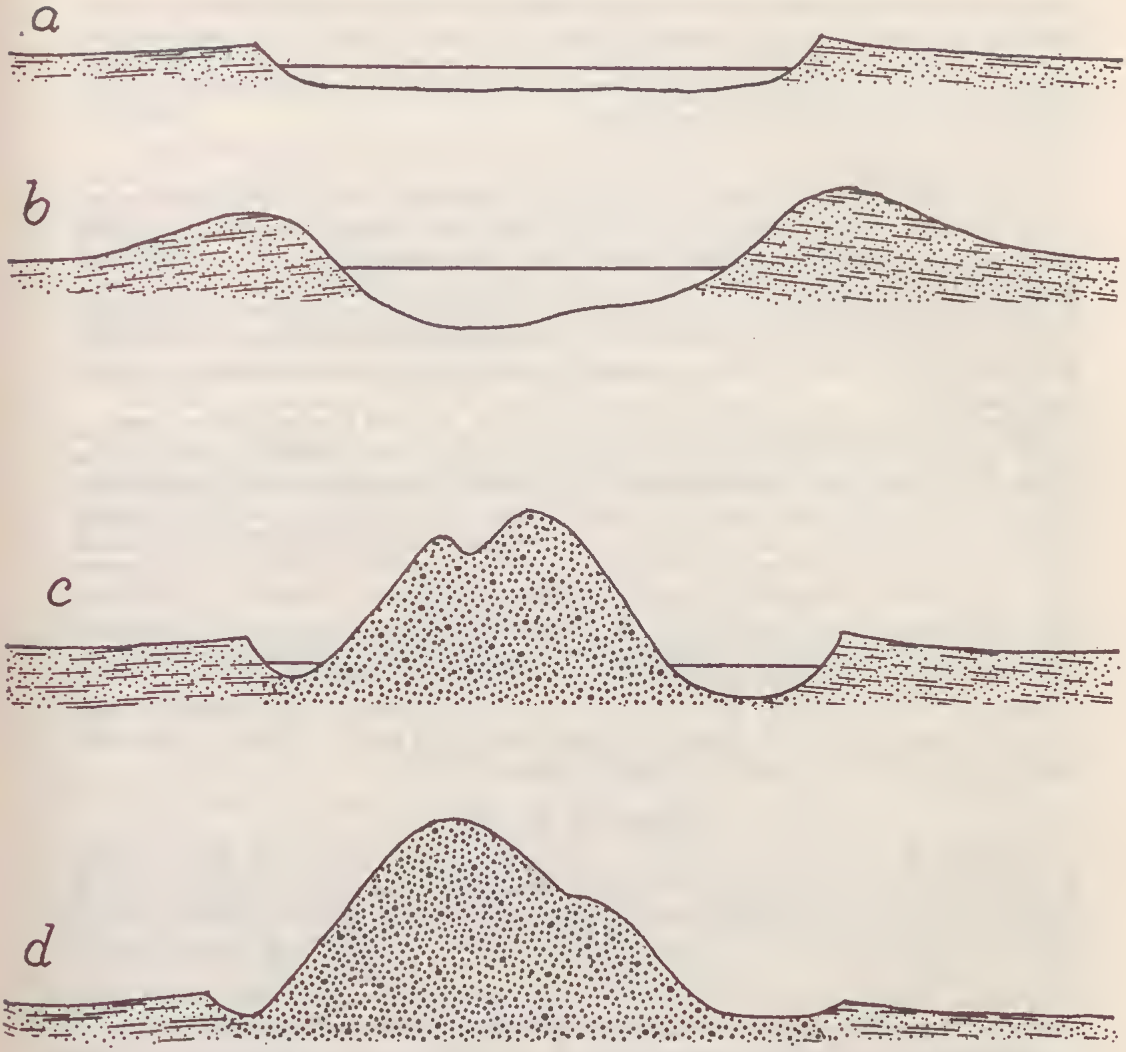


FIG. 1—Diagrammatic representation of the transition from a simple maar to a complex type. a is a simple maar, such as Keilambete, Elingamite or Purrumbete. b is a maar such as Bullenmerri or Gnotuk with higher hills around the edge and a deeper lake. c is a maar with a scoria cone growing in the centre of the lake, such as Tower Hill. d is similar to Tower Hill, but there is no lake and the scoria cone is the dominant feature, as at Mt Warrnambool, Ewans Hill, and Bostock.

inner high hill. The outer ring, which is highest on the E. and almost non-existent on the W. is similar to the outer rim of Tower Hill and to the maars, and has a diameter of about 2 miles. This could be a 'nested tuff ring' as definite evidence of collapse is missing, especially on the W. side.

Boutakoff (1963) has described Bridgewater Bay, Nelson Bay, and Grant Bay (all to the W. of Portland) as collapse calderas, each 2 miles or more in diameter, and has shown the existence of a fault along the W. edge of Bridgewater Bay. Infilling with sediment and breaching by the sea has occurred, giving the present bays, the submarine topography of which reveals probable eruption points inside and around the submerged rim of the caldera. These calderas are Lower Pleistocene and older than the maars or Tower Hill.

COMPEX VOLCANOES

Some hills do not fit directly into the classification given above because of complications during eruption. Several eruptions may occur in close proximity giving rise to a multiple volcano. In Victoria, the several hills of a multiple hill tend to be all of about the same size, as for instance at Mt Monmot, and it is not possible to distinguish main and parasitic cones. Generally the parts of a multiple volcano are similar in composition, as at the Wiridgil Hills which are all of scoria. When material of different sorts is present we have called the hills composite rather than multiple.

Mt Rouse is a composite hill of scoria and lava, with an elongate crater running E.-W. in the scoria part, and on the S. a smaller and more distinct crater with a basalt rim, which may be the remains of a fire-pit. The composite Mt Porndon has a large shield with a diameter of about 2 miles, in the centre of which are a number of scoria hills, partly arranged in concentric arcs. Staughtons Hill consists of a maar (Keayang swamp), a scoria hill (Mt Cunnies Hill), and a basalt-rimmed separate crater (L. Mumblin). Most composite hills appear to consist of individual hills which are genetically related, but it is possible that some, such as Staughtons Hill, are due to accidental superimposition of eruption points from different times, and not related genetically. Petrological work could be instructive here.

Mt Clay, Mt Eckersley, Mt Vandyke, and Mt Deception, of the Portland area, do not fit into any of the types of volcano described so far. They are smoothly rounded hills of bedded tuff, with basalt plugs and flows.

Features of the Vent

Craters are not always present, or they may be obscure, as at Mt Vandyke, Deception, Lawaluk, and Rebecca. Other volcanoes have perfect craters, such as Mt Leura, Noorat, and Elephant amongst the scoria cones, and Mt Hamilton among the lava cones. Mt Rouse, a complex volcano, has a large crater in the scoria part, with a perfect crater at a lower level in basalt. Craters can be several hundred feet deep as at Mt Noorat (500 ft) and Mt Leura (300 ft). The maars have craters often a mile or more across, but other craters are smaller, usually less than 400 yards.

Breached craters are common in scoria volcanoes, the breach taking the form of a gap in the crater rim, as at Mt Elephant. Many do not have a lava flow going through the breach and the breach, therefore, is not formed by lava break-through and outflow. At Mt Elephant, an accumulation of scoria debris lies below the breach, but in most cases there is no accumulation whatever. Some authors have indicated a preferred direction of breaching, usually maintaining that most breaches are on the W. side, correlating this with supposed wind direction at the time of eruption. Our observations (for the entire Newer Volcanic Province, not only the plains) indicate a random direction of breach, with, if anything, a maximum to the N. and NW.

Some breaches may occur by slumping of the wall into the crater, or down to the outside, due to explosive shock, settling, loss of liquid from the cone material in the form of squeeze-ups or the movement of lava through the cone walls from the crater to the outside. The latter explanation may apply to Mt Elephant, where two flows appear to have emerged from the base of the cone. One flow may have caused part of the inside wall to slump down into the crater, while the other caused a section of the rim to slump down to the outside, thus lowering the rim and giving a breach.

Some hills appear to be breached at both ends, giving a dumb-bell shaped crater remnant as at Mt Eckersley. Mt Monmot consists of two adjacent craters, the W. crater breached to the W., and the E. one to the E. Mt Eccles has an elongate crater, with the lowest point to the N. end, but from this a very marked flow emerges.

Many craters are flat bottomed, due to a fill of debris and alluvium, e.g. Mt Hamilton, Wangoom, and L. Terang. Others, such as Noorat, have simple concave crater bottoms with very little fill and some, such as Mt Napier, have a convex boss in the middle of the crater. The E. Monmot crater has a small, steep-sided hump of congealed, scoriaceous lava, rather like a hornito.

A small spatter cone S. of Mt Eccles has an open vent. A small crater leads into a constriction about 15 ft wide, below which the shaft opens out like an inverted wine glass. The shaft goes to a depth of almost 100 ft, with a floor of large loose scoriaceous blocks, and walls festooned with lava stalactites. Withdrawal of magma after eruption is indicated, which is probably a common phenomenon but it has usually been destroyed by collapse.

Features of the Lava Flows

The lava flows that poured over the W. plains were not entirely uniform, and several types of flow occurred, associated with certain landforms.

SHEET FLOWS

These gave rise to the flattest of the lava plains and were formed by very liquid lava. Large areas were covered, but an examination of boring records shows that an average flow was only about 25 ft thick. Hanks (1955), in the region N. of Melbourne, and Condon (1951), in the Mt Cotteril area, were able to map distinct flows, and showed that even apparently flat sheets of lava were made up of many individual lobes. On the W. plains the original topography probably helped the rapid lateral spread of the lavas. Some bore records indicate several flows separated by layers of ejectamenta.

CONSTICTED FLOWS

Some lava flows followed valleys and now still have the form of valleys, being thicker in depth but narrower laterally than the sheet flows. The youngest flows of this type, such as the Harman valley flow at Byaduk, still occupy their valleys and are not affected by subsequent erosion. Others have lateral streams, such as the Tyrendarra flow from Mt Eccles. In the Geelong area, Bowler (1961) has found several generations of constricted flows, the younger ones following the lateral streams that were formed alongside earlier flows.

The lava that flowed down the old valleys must have been very liquid for it flowed for many miles (at least 15 miles in the case of Byaduk, over 30 miles for the Mt Eccles flow), but some flows were more liquid than others. The very fluid ones reached their position of rest as liquids; in other cases the lava seems to have been congealing during flow and gives rise to 'layered lava' as exemplified at Byaduk. Here the lava is divided into many layers, separated by partings and lines of vesicles, and there is no vertical segregation on cooling. Skeats and James (1937) regarded the layers as individual flows, but we believe they are formed by laminar flow within the basaltic lava.

STONY RISES

Much of the ground in certain volcanic regions is very irregular although tending to a plain on a broad scale. Hummocks and depressions, channels and ridges, make a completely confused topography with relief of usually only 20 ft or less called 'stony rises'. There appear to have been several varieties of this. Some were individual narrow flows of lava emerging from the base of a broad lava sheet. These are found especially on the S. shores of L. Corangamite. Differential draining of lava from beneath the skin of a partly congealed lava plateau caused elongated depressions if the surface sagged, and this type of stony rise is the most common. The drained channels can coalesce, so that the ridges break up into a number of isolated hillocks with accordant, often flat summits.

OTHER FEATURES OF THE FLOWS

Where lava flows into water it solidifies into the peculiar form of pillow-lava, consisting of rounded masses of lava, each mass having a tachylitic chilled edge, and radial cracks in the more crystalline interior. There is a very fine example of pillow lava at Toolern Ck, Exford. This pillow-lava is unusual only in that it appears to have formed in fresh water rather than in the sea, and is associated with thin bands of alluvium.

Columnar jointing develops in stationary flows which cool fairly slowly. Crude jointing is present in most flows, but there are very good examples at Sydenham, and at Hopkins Falls on the Hopkins R.

Tumuli are small humps on a lava sheet, where localized pressure from underlying liquid forces up the early cooled lava skin into a bulge above the general level, without actually breaching it. Good examples are found near Mt Gellibrand. Tumuli associated with stony rises add to their complexity, and there is no clear dividing line between the two.

So-called lava blisters of Victoria have the form of very exaggerated tumuli, rising very steeply from their base, and cracked across their tops due to the great bending they suffer. The best examples are at Wallacedale, and have been described by Skeats and James (1937), who believed they were formed by gas pressure due to steam generated when a lava flow crossed a swamp. We have not been able to find any hollow blisters, and do not believe that this special explanation is necessary. The lava blisters are tumuli of exaggerated type, but still due to local lava pressure, and not to steam generated beneath the flow. The term 'lava blister' should be reserved for hollow features, such as exist in other parts of the world.

Boutakoff (1963) has found depressions 30-40 ft in diameter which he calls 'steam bubble' structures. These depressions are hemispherical or egg-shaped, surrounded by concentric joints, and occur in the Lower Pleistocene basalt along the coast to the W. of Portland. Boutakoff believes they are cavities left by steam and gas bubbles escaping from a viscous lava.

Where lava is drained from beneath an early formed skin, stony rises are not the inevitable result. If withdrawal takes place on a large scale, large broad depressions which are completely enclosed may be formed. Two such depressions are present near Exford (Meredith Sheet Grid Ref. 5243).

On the other hand, the lava skin may not collapse at all and, when lava is withdrawn, it merely leaves a space beneath, which is a lava cave, lava tunnel or lava tube. Lava caves are known from Byaduk, Mt Eccles, Mt Hamilton, Mt Widderin, Mt Warrnambool, Parwan, Mt Porndon, and Mt Gisborne. Ollier and Brown (1963) have described these caves and discussed the mechanism of cave formation. The idea of Skeats and James (1937) that the caves consisted largely of great lava blisters which were buried under later flows is no longer acceptable. Descriptions of individual caves, together with surveyed plans and sections have been published in the *Victorian Naturalist* (Gill 1944, 1959; Ollier 1963) and others will be published in the same journal (Ollier in lit.).

Barriers and pressure ridges have been described by Skeats and James (1937). These are elongate ridges of basalt pushed up by movement of the underlying lava. Some are lateral to flows and late withdrawal of lava is partly responsible for their construction; others are transverse and formed in one operation. The Great Barrier of the Harman Valley flow is the best example; it is curved downstream, indicating differential flow between the centre and the sides of the lava stream.

Lineaments

In some volcanic areas, especially those with fissure eruptions, it is common to find volcanoes falling along a number of straight lines. It is hard to find such lines in Victoria. Mt Eccles is in line with at least 8 small hills or spatter cones, and a total of 20 or so vents, including that of L. Surprise which lies in an elongated crater. This is probably the most distinct evidence for lineaments in Victoria. Boutakoff thinks the lineament is related to the edge of an underlying laccolith structure, which has been indicated by gravity surveys.

From our own map no clear lineaments emerge. The Anakies are 3 scoria hills which appear to lie, *en echelon*, along a straight line, possibly related to jointing in the underlying granite. E. of Quarry Hill there are at least 5 small vents, not indicated on our map, which run in an E.-W. line parallel to the escarpment to the S. A number of N.-S. lines may be recognized in the maars of the Camperdown district —Gnotuk, Bullenmerri and Bostock; Ewans Hill, Cobrico, Elingamite; Terang, Staughtons Hill, Ecklin—but all these 'lines' contain very few points, and may be only imaginary.

Coulson (1954) attempted to construct a map of lineaments for the 123 points of eruption of the Daylesford district, although he was well aware of the difficulties of this. We have performed the experiment of giving a map of the points of eruption to 10 people; 10 sets of lineaments were produced, having little agreement with either Coulson's map or each other.

There is a noticeable concentration of volcanoes along the line Geelong-Camperdown-Heywood, which coincides with the axis of the Tertiary Basin (see Fig. 2).

Nature of the Volcanic Eruptions

It is commonly supposed that lava plains are erupted from fissures. This could be so in the W. District, but erosion has not yet revealed any such dykes. Certainly the Older Volcanics in E. Victoria were fed by many dykes, but most of the Newer Volcanic eruptions appear to be of central eruption type. The lava plains, when mapped by Hanks (1955) and by Condon (1951), have been shown to consist of individual lobes which can be traced to distinct points of eruption. Mt Rouse, Mt Porndon, Mt Napier, and Warrion Hill, are all surrounded by expanses of flows and stony rises which almost certainly are derived from these points of eruption, and there are many other examples. The form of the cones suggests central type eruption, and the lack of lineaments is regarded as evidence against fissure eruptions.

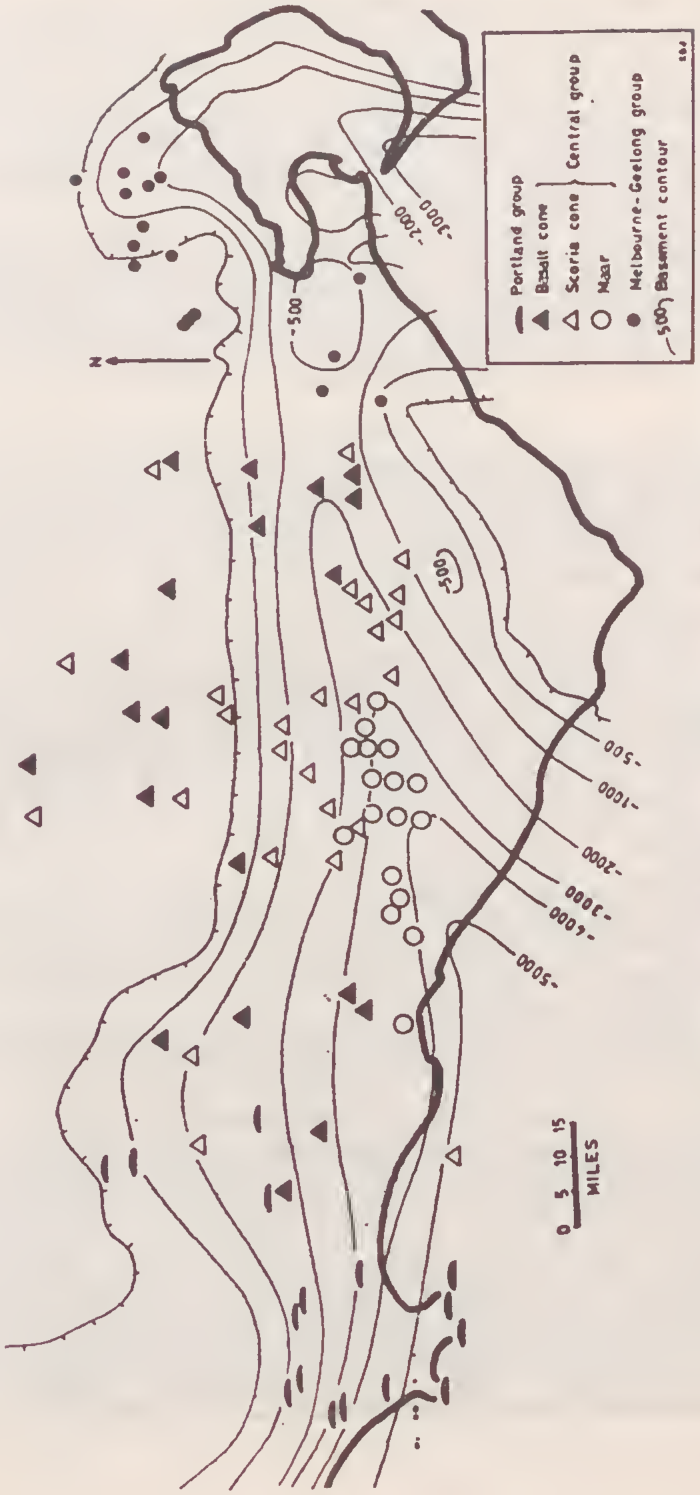


FIG. 2—The distribution of volcanoes on the W. plains in relation to the Tertiary basin. The classification shown is only approximate.

It must be borne in mind that the cones represent only the last period of activity, and the earliest type of eruption may have been different, but the balance of evidence indicates that we have a region of central eruption activity.

The scoria cones are probably monogenetic—i.e. the result of one continuous series of eruptions rather than the numerous eruptions, widely separated in time, from the one site which are typical of pyroclastic volcanoes. Rittmann (1962) suggests that, while pyroclastic volcanoes are usually formed by eruption of viscous magmas (which probably does not apply to Victorian volcanoes), small pyroclastic volcanoes can be formed from fluid magmas, provided the pressure behind the magma is too weak for a lava stream to follow the first explosive outbreak. Such structures are often formed during the last phase of a mixed eruption and overlie previous lava streams. This would appear to be common in the W. plains of Victoria.

As a very broad generalization, the sequence of eruption on the plains appears to have been an outpouring of lava to give a lava plain, stony rises and flows, followed by formation of scoria cones. Some lava flows may be erupted along with the ash and scoria, as at Mt Rouse. At Mt Porndon, a distinct disc of lava was erupted on top of earlier lavas before the formation of several scoria cones. Lawaluk may have formed as a small scale disc of the Mt Porndon type, not followed by any pyroclastics. There are also many simple basalt hills with no scoria, such as Mt Hamilton and Mt Cotteril.

According to Rittmann, pumice cones are encountered more frequently than scoria cones, but presumably he is thinking of acid igneous activity. In Victorian Newer Volcanics, the fluid, basic lavas have given rise to many scoria cones, and only a few volcanoes of the maar type with fine pyroclastics. The maars may seem fairly common on the plains, but for the province as a whole they are rare.

Some of the maars, such as Wangoom, Elingamite, and Cobrico, may represent single explosive eruptions neither preceded nor followed by extrusion of lavas. Mt Warrnambool, Mt Leura, and Bostock Hill are maars with later multiple scoria cones built on the same centre of eruption.

It is generally supposed that maars are formed by violent explosions, perhaps where hot lava meets ground water. The maars of the W. plains all occur in positions where this is feasible, as they are usually underlain by limestone. Thin bedding in the pyroclastics of the maars indicates that the eruption was not cataclysmic, and this is a feature of maars in other regions, such as the Eiffel maars.

Rittmann has invented an explosion index (E) which is the percentage of fragmentary material in the total volcanic material produced. We have attempted to calculate the explosion index for the Newer Volcanics of Victoria; this can only be done roughly, but working within reasonable though wide limits we found E to be about 1%. This seems surprisingly low, but shows that the lava flows, though thin, are extensive, while the more noticeable scoria cones are really much smaller in total volume.

This may be compared with the following figures from Rittmann (1962):

Area	E (%)
Island arcs	95
Southern Italy	41
African Rift Valleys	40
Iceland	39
Atlantic and Indian Oceans	16
Pacific	3

Even allowing for a large error in our calculations it is clear that the explosion index for the Newer Volcanics is very low. According to its E, the volcanic activity should correspond with the Hawaiian or Icelandic type of eruption. However, the Victorian eruptions are not of Hawaiian type (lava shield) and if we are correct in believing fissure-eruptions are not dominant, then the eruptions cannot be of Icelandic type (distinguished by its fissure eruptions). The individual scoria cones in Victoria are probably formed by explosive eruption of Vulcanian or Strombolian type, but of a more basic lava than usual.

Thus, the Newer Basalts may represent a distinct type of geomorphic/petrographic province, characterized by extensive plains of basaltic lava, and many small, monogenetic, central eruption hills, formed in the last stages of vulcanicity.

Weathering, Soils, and Erosion

In the youngest volcanoes even small-scale features are preserved intact. Near Mt Eccles, the small spatter cones have perfectly preserved ropy lava and lava stalactites, even in exposed positions. A rough assessment of ages can be based on the preservation of cones or flows—the Harman valley flow from Mt Napier, for instance, shows an aa surface, still almost complete, whereas old flows, such as from nearby Mt Pierrepoint, are scarcely distinguishable.

The youngest flows are remarkably fresh, with virtually no soil cover, as in the N. flow from Mt Eccles. Stony rises, wherever they occur, are little altered or eroded, so are believed to be fairly young features, and the volcanoes from which they were erupted are therefore fairly young also as, for instance, Mt Rouse, Mt Porndon, Mt Eccles, and Warrion Hill.

The older flows of the Hamilton and Cressy districts show much spheroidal weathering, with the development of deep soils including laterites. Except where covered by sediments, basalts of the Portland area are deeply lateritized (Boutakoff 1963), as is also Mt Clay.

Weathering and soil formation can often only be used as a rough guide in dating since many factors are in action besides the time factor. Krasnozems, Red-brown Earths and Black Earths may all be found on the basalt from one volcano. Often complicated soil profiles are present, and the significance of many observed soil relationships is not known. Gibbons and Gill (1964), however, have attempted the recognition and classification of 'soil landscapes' which, to a large extent, indicate the relative ages of different flows.

The scoria cones have little run-off due to their porosity and they naturally show little erosion although, in fact, even the lava cones show surprisingly little erosion. In some of the older volcanoes, erosion has given rise to a general rounding rather than gulleying and the original forms are obscure. Mt Pierrepoint and Mt Bainbridge, e.g. are low and rounded with ill-defined breached craters. Volcanoes of the Portland area (Mt Clay, Richmond, Vandyke, etc.), including both lava volcanoes and tuff cones, are rounded hills with little indication of original shape. The sequence of erosion described by Kear (1957)—(1) volcano stage, (2) planeze stage, (3) residual mountain stage, (4) skeleton stage—cannot be applied in Victoria.

Volcanoes of the Ballarat area show some gulleying, but within the area of the plains, gulleys are rare. Mt Eckersley has a gulley running from the crater on its E. flank. Mt Vandyke has ravines on the E. slopes which have exposed the underlying tuff (Boutakoff 1963).

Mt Noorat is distinguished by a number of radial gullies which divide its flanks into planeze-like sectors. However, there is some evidence that these gullies are not normal erosion gullies; they do not breach the crater at their head, and they end in blind, enclosed depressions at the base. Possibly the gullies are grooves formed by lahars or landslides soon after eruption ceased.

The blocking of drainage by lava flows naturally causes modifications to the river systems, and a number of the drainage diversion systems have been studied. The most common modification is to have a lateral stream at the edge of a lava flow, or sometimes twin laterals, one on each side. Some of the very young flows, such as the Harman valley flow, have not developed any lateral streams at all. Others, such as the Tyrendarra flow from Mt Eccles, have well developed lateral streams, even though young. The actual incision of lateral streams will depend on the size of the catchment, amount of run-off, and other factors besides age. Some of the lateral streams near the edge of the highlands have incised valleys several hundred feet deep. In the Geelong area, lateral streams of one period gave rise to valleys that were then filled by later flows (Bowler 1961). Similar complexity has been discovered in the Bacchus Marsh area (Fenner 1925).

Dating of Volcanoes

A complete discussion of the attempts which have been made to date the vulcanicity of Victoria is beyond the scope of this basically physiographic paper but, since an understanding of the physiography does depend on the age and chronology of the volcanics, a brief review of the methods of dating which have been applied in Victoria is necessary here.

Weathering, soil formation, and erosion are clearly good indicators of relative age, but they have to be used with some caution because, as explained in the section above, there are more factors in operation than age. For the grosser deductions, however, such features as preservation of detail or lack of it, depth of soil, and drainage modifications provide useful clues in establishing a relative chronology. Flows may be dated relatively by their superposition, as in Hanks (1955), and the flows can then be traced back to their volcanoes to give an age sequence for the volcanoes themselves. Relative dating of flows by studying drainage diversion is also possible, as mentioned above.

In the SW. area and around Geelong, a number of volcanoes can be dated relative to extensive sheets of aeolianite which make a convenient reference age. Mt Duneed, in the Geelong district (Coulson 1938), and Cape Nelson and Bald Hill (Macarthur) are all pre-aeolianite, while Mt Eccles and Mt Napier are post-aeolianite.

Cape Grant and Cape Nelson have been dated by reference to a 100 ft marine platform, which truncates tuffs and plugs, and is believed to be of Middle Pleistocene age. Mt Eccles has been dated relative to a 15 to 20 ft beach which rests on part of the flow.

If we can date the material underneath a volcano we can get its maximum age. Too often in the past there has been a tendency to assume the underlying deposits give an actual age for the volcanics, and flows have been dated as Lower Pliocene or earlier on insufficient evidence, when there is possibly an unconformity between the underlying material and the volcanics. This distinction is of less importance when the underlying material is of recent age, for other dating methods become available. In a number of places artefacts have been found beneath volcanic material (Gill 1953). At Mt Gambier in South Australia, implements and hearths have been found beneath the volcanics and artefact dating and radio-carbon dating are possible. The younger volcanoes are certainly within the range of carbon 14 dating and results are awaited eagerly.

A few fossils have been recovered from within volcanic deposits, but not in sufficient numbers to be of much use in dating. Fossils found in lava caves give a minimum age of their flow, for the volcano and caves may have been in existence a long time before they were occupied. Wakefield (1964) has described this line of enquiry in detail.

Many craters and maars have swampy deposits in their bottoms, and there are many swamp deposits around the margins of flows due to drainage modifications. This suggests that pollen analysis might eventually be used for relative dating of the volcanics. Preliminary tests have been made and it has been found that, although only a little pollen is present in crater samples, the method appears to be feasible. It will, however, take a considerable time to build up a pollen sequence.

Palaeoclimatology is a rather indirect way of dating but has been used a little. Buckshot gravel, laterite formation, and soil types have been taken as indicators of former climates and tentatively correlated with certain times in a Pleistocene chronology. The asymmetric distribution of ash around Wangoom and Mt Warrnambool indicates a W. wind, from which Gill (1950) deduces that the eruption took place during the last period of glaciation when W. winds would be more prevalent over Victoria.

The Sequence of Vulcanicity in Victoria

From the previous section it is apparent that, although there are many possible means of dating Victorian volcanoes and volcanic activity, actual progress so far has been small, and we are just moving into a period when rapid advances in the establishment of chronology can be expected. However, a few generalizations can be made at present.

It has been suggested that there is a tendency for the vulcanicity in Victoria to move to the W. with time, so that the older volcanoes are in the E., the youngest in the W. This neat generalization does not seem to have much basis in fact.

The Portland group, in the far W. of Victoria, consisting of Eckersley, Sugarloaf, Cape Bridgewater, Cape Nelson, Cape Grant, Vandyke, Deception, Richmond, Kincaid, Bald Hill, and Clay are old volcanoes—pre-aeolianite, Lower Pleistocene (according to Boutakoff), well rounded and weathered. Farther N. are Mt Pierrepoint and Mt Bainbridge, old weathered remnants, possibly comparable in age with the Portland group.

In the N. central part of the plains, weathered basalt cones of the type of Mt Widderin occur. In the E. limits of the plains, the Melbourne-Geelong group also consists of weathered basalt cones. These two groups may be similar in age, and we consider both are younger than the Portland group.

The central part of the plains contains many fresh scoria cones, such as Mt Elephant and Mt Noorat. The S. central area contains the maars. These two groups are younger again than the basalt cones mentioned above, and the maars are probably younger than the scoria cones.

Scattered among the volcanoes mentioned are the very young volcanoes which erupted at the close of the volcanic period. Mt Hamilton is younger than the volcanoes surrounding it, while the scoria cones of Mt Rouse and Mt Napier are both youthful. Mt Eccles in Victoria, and Mt Gambier and Mt Schank in South Australia, are the youngest in the plains.

Comparison with the volcanoes of the uplands is difficult, but most of the vulcanicity in the Ballarat and Daylesford regions is perhaps of the middle period—younger than the Eckersley group, but certainly older than the Gambier-Eccles period.

Far from moving to the W., the eruptions in the plains have moved progressively S., to finally concentrate over the axis of the Tertiary basin (see Fig. 2). Detailed mapping of physiography and surficial geology should make this picture much clearer, and it should not be very long before a fairly detailed chronology can be applied to the W. plains.

References

BAKER, A. A., 1964. Ejectamenta of the late Cainozoic volcanoes of Western Victoria. 1. Volcanic bombs. *Proc. Roy. Soc. Vict.* (in press).

BOUTAKOFF, N., 1963. The geology and geomorphology of the Portland area. *Geol. Surv. Vict.* Mem. 22.

BOWLER, J. M., 1961. Stratigraphy, sedimentation and geomorphology of the Geelong-Maude area. Unpublished thesis, University of Melbourne.

CONDON, M. A., 1951. The geology of the Lower Werribee River, Victoria. *Proc. Roy. Soc. Vict.* 63: 1-24.

COULSON, A., 1938. The basalts of the Geelong district. ibid. 50: 251-257.

————, 1941. The volcanoes of the Portland district. ibid. 53: 394-402.

————, 1954. The volcanic rocks of the Daylesford district. ibid. 65: 113-124.

CURREY, D. T., 1964. The former extent of Lake Corangamite. ibid. (in press).

EDWARDS, A. B., 1938. Tertiary volcanic rocks of central Victoria. *Quart. Journ. Geol. Soc. London* 14: 243-320.

FENNER, C., 1925. The Bacchus Marsh basin. *Proc. Roy. Soc. Vict.* 37: 144-169.

GIBBONS, F. R., and GILL, E. D., 1964. Basaltic plains of Western Victoria, terrains and soils. ibid. (in press).

GILL, E. D., 1944. Basalt cave at Panmure, Western Victoria. *Vict. Nat.* 60: 167; 61: 42.

————, 1947. Ecklin Hill, a volcano in the Western District of Victoria. ibid. 64: 130-134.

————, 1950. An hypothesis relative to the age of some Western District volcanoes. *Proc. Roy. Soc. Vict.* 60: 189-194.

————, 1953. Geological evidence in Western Victoria relative to the antiquity of the Australian aborigines. *Mem. Nat. Mus. Melbourne* 18: 25-92.

————, 1959. The Parwan caves, Bacchus Marsh district, Victoria. *Vict. Nat.* 75: 159.

GRAYSON, H. J., and MAHONEY, D. J., 1910. The geology of the Camperdown and Mount Elephant districts. *Geol. Surv. Vict. Mem.* 9.

GREGORY, J. W., 1904. *The Geography of Victoria.* Whitcombe and Tombs, Melbourne.

HALL, T. S., 1907. Note on the deposition of bedded tuffs. *Proc. Roy. Soc. Vict.* 20: 21-26.

HANKS, W., 1955. Newer Volcanic vents and lava fields between Wallan & Yuroke, Victoria. ibid. 67: 1-16.

HILLS, E. S., 1939. The age and physiographic relationship of the Cainozoic volcanic rocks of Victoria. ibid. 51: 112-139.

————, 1940. *The Physiography of Victoria.* Whitcombe and Tombs, Melbourne.

KEAR, D., 1957. Erosional stages of volcanic cones as indicators of age. *N.Z. Jour. Sci. & Tech. B.* 38: 671-682.

OLLIER, C. D., 1963. The Mount Hamilton lava caves. *Vict. Nat.* 79: 331-336.

OLLIER, C. D., and BROWN, M. C., 1964a. The Lava Tunnels of Victoria. *Bull. Vulcanologique* (in press).

————, ————, 1964b. The Byaduk lava caves. *Vict. Nat.* 80: 279-290.

RITTMANN, A., 1962. *Volcanoes and their Activity*, translated by E. A. Vincent, New York, Interscience.

SKEATS, E. W., and JAMES, A. V. G., 1937. Basaltic barriers and other surface features of the Newer Basalts of Western Victoria. *Proc. Roy. Soc. Vict.* 49: 245-278.

WAKEFIELD, N. A., 1964. Mammals past and present. *Proc. Roy. Soc. Vict.* (in press).

WILLIAMS, H., 1941. Calderas and their origin. *Bull. Dep. Geol. Univ. Calif.* 25: 239-346.

YATES, H., 1954. The basalts and granitic rocks of the Ballarat district. *Proc. Roy. Soc. Vict.* 66: 63-101.

FIG. 3—Key to the volcanoes of the W. plains.

TABLE 1

1	Vandyke
2	Mt Deception
3	Little Kincaid
4	Mt Kincaid
5	Mt Richmond
6	Cape Bridgewater
7	Sugarloaf
8	Mt Eckersley
9	Mt Clay
10	Cape Nelson
11	Cape Grant
12	Lawrence Rocks
13	Bald Hill (Macarthur)
14	Mt Eccles
15	Lady Julia Percy
16	Mt Bainbridge
17	Mt Pierrepoint
18	Mt Napier
19	Ripponhurst
20	Vine Bank
21	Blackwood
22	Mt Rouse
23	Green Hills (Penshurst)
24	Green Hills (Winslow)
25	Mt Taurus
26	Tower Hill
27	Wangoom
28	L. Munderong
29	Tank Hill
30	Mt Warrnambool
31	Mondilibi
32	Mt Shadwell
33	The Sisters
34	L. Keilambete
35	Terang
36	L. Terang
37	Staughtons Hill
38	Ecklin
39	Noorat
40	The Bald Hill (Tatyoon)
41	Weejort
42	Mt Hamilton
43	The Peak
44	Meningorot
45	Ewans Hill
46	Cobrico
47	Elingamite
48	Mt Koang
49	Gnotuk
50	Bullenmerri
51	Bostock
52	Banangil
53	Vite Vite
54	Mt Elephant
55	Mt Kurweeton
56	Mt Leura
57	Monmot
58	Mt Widderin
59	Little Elephant
60	Mt Myrtoon
61	Wiridgil
62	Purrumbete
63	Mt Porndon
64	Wallinduc
65	Vaughans Is.
66	The Basins
67	Warrion Hill
68	Alvie
69	Red Rock
70	Robertsons Hill
71	Quarry Hill
72	Mt Rebecca
73	Mt Hesse
74	Mt Gellibrand
75	Mt Mercer
76	Lawaluk
77	Gow's Hill
78	Mt Pleasant
79	The Cap
80	Mt Pollock
81	Wurdi Buloc
82	Mt Moriac
83	Mt Duneed
84	Anakie
85	Bald Hill (Bacchus Marsh)
86	One Tree Hill
87	Spring Hill
88	Green Hill
89	Mt Cotteril
90	Greek Hill
91	Black Hill
92	Kororoit
93	Atkinson
94	Diarmuids Hill

Explanation of Plates

(Aerial photographs reproduced by permission of Lands and Survey Department.)

PLATE LII

Lava cone. An aerial view of Mt Hamilton with stereo cover, and a ground view of the crater, looking N.

PLATE LIII

Scoria cone. An aerial view of Mt Elephant with partial stereo cover, and a ground view from the NE.

PLATE LIV

Maar. An aerial view of L. Elingamite, and a ground view of Keilambete, looking E.

PLATE LV

Complex volcano. An aerial view of Mt Rouse with partial stereo cover, and a ground view of the lava crater with the scoria mound in the background.

TABLE 2

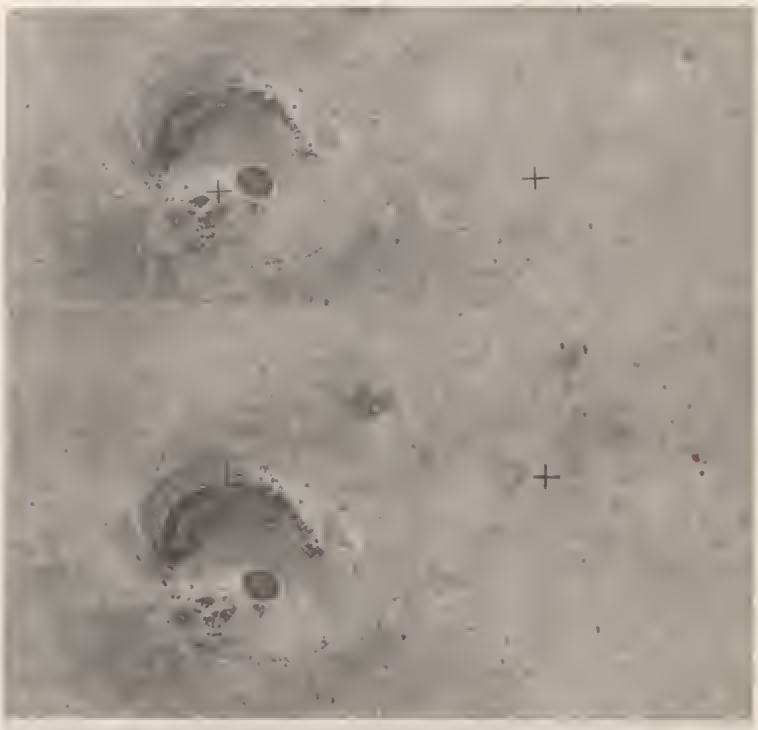
Name	No.	Altitude (Ft)	Height (Ft)	Synonym	Remarks
Alvie	68	750	250		Multiple scoria cone. Several closed depressions.
Anakie	84	1310	500	The Anakies, Anaki, Anaki Youwan	3 elongate scoria mounds, and a small tuff ring or crater to N.
Atkinson	93	459	50		Low basalt cone.
Mt Bainbridge	16	800	100		Basalt dome, very weathered. Craterform.
Bald Hill (Macarthur)	13	600	200		Rounded hill of tuff and ejectamenta.
Bald Hill (S. of Bacchus Marsh)	85	731	200		Basalt and scoria hill.
The Bald Hill (Tatyoon)	40	1117	150		Scoria hill, highest to W., with perfect crater 400 yds across and 50′ deep.
Banangil	52		100		Low basalt dome.
The Basins	66	500	50		Double scoria cone with crater lakes.
Black Hill	91	190	100	Cowie's Hill	Scoria cone.
Blackwood	21		50		Basalt hill, steep to E. and gentle slope to W., with squeeze-ups.
Bostock	51	800	200	Waller's Hill	An outer maar with a multiple scoria cone inside.
Cape Bridgewater	6	450	450	Stony Hill	Eroded remnant of volcanic complex or caldera. Tuff and basalt.
Bullenmerri	50	900	300		Lake 263′ deep. Possibly 3 coalescing maars.
The Cap	79	425	50		Scoria cone.
Mt Clay	9	622	500		Broad flat-topped hill, consisting largely of tuff, with some lava flows.
Cobrico	46	450	50		Maar. Flat bottom largely swampy. Open to SW.
Mt Cotteril	89	669	100	Cottril	Simple lava cone.
Mt Deception	2	524	200		Well rounded hill consisting largely of tuff.
Diarmuids Hill	94	196	50		Lava cone.
Mt Duneed	83	340	100		Low basalt hill.
Mt Eccles	14	584	200	Eels	A complex of several aligned scoria and spatter cones, an elongate crater (L. Surprise) and flows. Lava caves.
Mt Eckersley	8	537	400	Bell's Hill	Low angle tuff cone. Elongate crater.
Ecklin	38	500	100		Maar, outlet to NW. Swamp filled.
Mt Elephant	54	1294	780	Clarke	Steep-sided scoria cone. Breach to NE. Stony rises around.
Elingamite	47	500	50		Maar. Lake filled. Cliff to E. side. Thin bedded tuff.
Ewans Hill	45	893	500	Gnarogein, Emu, Mt Ewen	Double scoria cone, with partial maar rim on E. side.
Mt Gellibrand	74	56	350		Irregular cone breached to S. Mostly basalt.
Gnotuk	49	600	100		*Maar. Lake 103′ deep.*

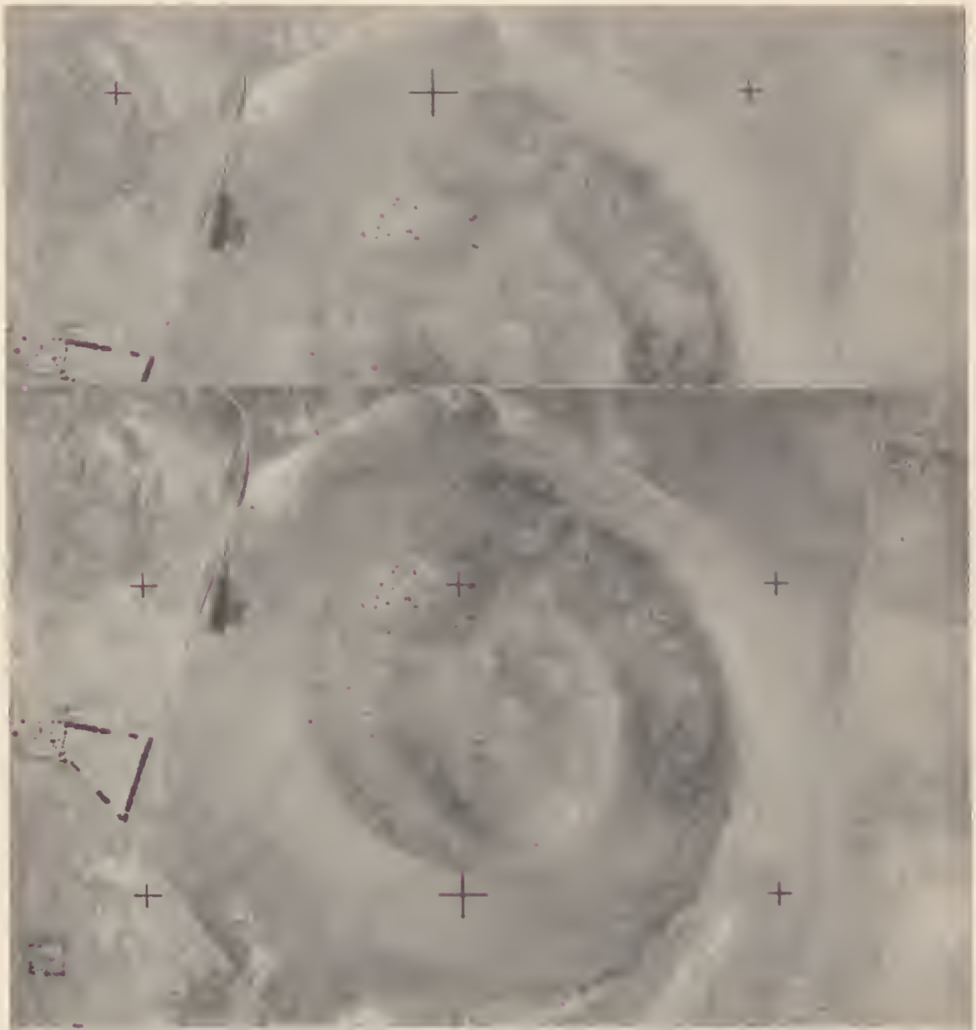
TABLE 2—*continued*

GOW'S HILL	77	577	75	Green Hill	Low basalt hill.
CAPE GRANT	11	200	200	Cape Sir William Grant	Eroded remnant of volcanic complex or caldera. Basalt and tuff.
GREEK HILL	90	293	75		Remnant of basalt cone.
GREEN HILL	88	476	100	Mt Mary	Scoria cone with breached crater.
GREEN HILLS (Winslow)	24	400	100		Crater with low, irregular wall.
GREEN HILLS (Penshurst)	23	701	100		Irregular hill with many humps and depressions, composed of vesicular basalt and agglomerate. Some basalt squeeze-ups.
MT HAMILTON	42	1035	250		Low basalt cone. Perfect crater. Lava caves.
MT HESSE	73	542	200		Lava cone. Crater, breached to E.
L. KEILAMBETE	34	450	30		Maar.
MT KINCAID	4	664	200		Rounded hill, mostly basalt.
MT KOANG	48	894	300	Together with Kurweeton makes Cloven Hills	Scoria hill, breached crater open to W.
KOROROIT	92	782	200	Mt Misery	Basalt hill showing successive points of eruption.
MT KURWEETON	55	890	400	Kurtweeton. Cloven Hills with Mt Koang	Scoria cone with a few basalt flows.
LADY JULIA PERCY	15	152	152		An island, much eroded, originally with a centre of eruption (tuff cone).
LAWALUK	76	1213	100		Flat topped disc of basalt. 200 yds across.
LAWRENCE ROCKS	12	almost	submerged		Possibly remnants of Cape Grant caldera.
MT LEURA	56	1027	500		Outer maar with nested scoria cones. Crater 300′ deep.
LITTLE ELEPHANT	59	611	100		Simple scoria cone.
LITTLE KINCAID	3	560	50	Piccaninny Mt	Basalt cone, largely obscured.
MENINGOROT	44	759	250	Meningoort Miningorat Meningoret	Elongate scoria cone with several subsidiary craters.
MT MERCER	75	1404	200		Scoria cone with well defincd crater ½ mile across breached to N.
MONDILIBI	31		50		Steep-sided, elongate basalt hill with no crater, and many squeeze-ups.
MONMOT	57		200		Twin scoria cones, breached in opposite directions.
MT MORIAC	82	834	350		Rounded basalt hill.
L. MUNDERONG	28	400	50		Crater or maar, ¼ mile across, with swamp and some open water. Open to N.
MT MYRTOON	60	701	200		Scoria cone with some basalt. Well defined crater.
MT NAPIER	18	1453	500		Multiple scoria cone, with some basalt, especially in lower parts.
CAPE NELSON	10	300	300		Eroded remnant of volcanic complex or caldera.
NOORAT	39	1026	500	Nooat	Scoria cone with large, perfect crater 500′ deep. Some basalt tongues, and radial gullies.
ONE TREE HILL	86	505	100		Lava cone.

TABLE 2—*continued*

The Peak	43	957	50	Mt Fyans	Low scoria hill amongst stony rises.
Mt Pierrepoint	17	936	100		Rounded basalt hill, with a crater breached to N.
Mt Pleasant	78	550	150		Elongate lava cone.
Mt Pollock	80	609	200		Basalt cone, much eroded.
Mt Porndon	63	949	350		Multiple scoria cone, overlying a disc-like lava flow with caves. Stony rises around.
Purrumbete	62	600	100		Maar, highest to E. Lake 150′ deep.
Quarry Hill	71	622	100		Composite hill with basalt over scoria.
Mt Rebecca	72	523	70		Low basalt hill, featureless except for a lava squeeze-up near summit.
Red Rock	69	700	300	Red Hill	Multiple scoria cone with some bedded tuff. Several craters occupied by lakes.
Mt Richmond	5	710	250		Composite hill, largely obscured by sand.
Ripponhurst	19	700	100		Low basalt hill, well weathered.
Robertsons Hill	70	715	250	Kerang-e-Moorah	Basalt hill.
Mt Rouse	22	1213	300		Composite hill, main part scoria cone. Well defined basalt crater to S.
Mt Shadwell	32	965	450		Multiple scoria cone.
The Sisters	33	600	150	Sister Rises	Multiple tuff cone, with small amounts of basalt.
Spring Hill	87	700	150		Lava dome with large crater.
Staughtons Hill	37	600	200	Mt Cunnies Hill (E. Peak) & Keayang Swamp (maar)	Complex hill with a maar, and also a smaller crater in basalt.
Sugarloaf	7	468	250		Composite hill. Crater facing S.
Tank Hill	29	400	100		Possible maar, with outcrops of bedded tuff on low, E. side, and larger hill to W. of flat-bottomed crater.
Mt Taurus	25	396	150		Irregular low basalt hills, with possible crater open to E.
Terang	35	579	150		A scoria cone with a few thin basalt flows. Crater breached to SE.
L. Terang	36	500	50		A maar. Now dry. Mostly tuff, but some agglomerate and basalt.
Tower Hill	26	323	250		Nested caldera or maar.
Vandyke	1	606	300	Good Hill	Elongate tuff cone, largely obscured.
Vaughans Island	65	400	50		Scoria cone, now an island in L. Corangamite.
Vine Bank	20	400	100		Low basalt hill of reddish vesicular lava.
Vite Vite	53	942	100		Low basalt cone. Stony rises.
Wallinduc	64	850	100		Asymmetric basalt hill.
Wangoom	27	243	100	L. Wangoom	Maar, with mostly country rock. Also ash and basalt.
Warrion Hill	67	922	400	abo. Labaam	Basalt plateau. No crater. Stony rises to N.
Mt Warrnambool	30	712	400		Composite scoria hill, nested within maar.
Weejort	41	1211	150		Irregular multiple hill. Basalt, and possibly scoria.
Mt Widderin	58	1132	200		Low basalt cone. Stony rises around, especially to SW. Lava caves.
Wiridgil	61	700	250	Wiridgil Hills Woridgil	Multiple scoria cone. Many humps and depressions. Bedded ash and scoria, with bombs. Faults and contorted ash.
Wurdi Buloc	81	550	50		Basalt hill.





14

THE FORMER EXTENT OF LAKE CORANGAMITE

By D. T. Currey

State Rivers and Water Supply Commission

Abstract

The present area of L. Corangamite is 100 square miles. Lacustrine deposits above the lake indicate that it formerly covered an area of 700 square miles. The origin and mode of occurrence of the lake deposits and the drainage pattern changes in the area are discussed.

Introduction

L. Corangamite, the largest lake in the State of Victoria, is situated 100 miles W. from Melbourne.

Lake terraces exist, from the W. of L. Corangamite to the E. of the Barwon R., at approximately reduced level 396. The terraces occur at least 10 ft above the bed levels of the various lakes in the area. The absence of continuous land barriers of similar age to the terraces, above R.L. 396, indicates that a lake surface extended over an area of approximately 700 square miles.

Skeats and James (1937) recorded pre-basaltic and post-basaltic lake sediments at the S. extremity of L. Corangamite, the post-basaltic at approximately R.L. 395, 15 ft above the lake level. Grayson and Mahoney (1910), and later Gill (1953), recorded lake terraces 10 ft above the L. Colongulac water level, 8 miles to the W. of L. Corangamite.

In order to supply the water for this lake at R.L. 396, the Barwon R. and Leigh R. would have had to be diverted into the area, and according to calculations by J. Sutcliffe, Hydrologist, State Rivers and Water Supply Commission, based on present run-off and evaporation, the annual rainfall over the catchment would have had to be 13 in. above the present average. The diversion of the Barwon R. was to the NW. at Birregurra. Hall and Pritchard (1903) earlier suggested that the Barwon R. and the Leigh R. flowed to the S. of the Moorabool Hills, before being defeated in the L. Modewarre area. After defeat the valleys were flooded and the lake formed.

Eventually the river valleys were drained when the rising lake level overtopped the former Leigh R.-Moorabool R. divide, downstream from Inverleigh. Capture of the Barwon by the Leigh R. eliminated the lake's major water supply.

As barriers emerged, during the valley drainage phase, a basin of internal drainage formed to the W. of the valley area. Evaporation in the basin area lowered the lake level below the general terrace level, thus leaving chains of lakes. The prevailing winds initiated the formation of lunettes on the emerging lake terraces and land barriers, between the lake chains.

Drainage Pattern Changes

Pre-Basaltic Drainage

During the late pre-basaltic period the S. slopes of the highlands near Ballarat were drained by the southerly flowing Woady Yallock R., the Warrambine Ck, and the Leigh R. (Fig. 1). The drainage systems eroded valley sections in the Palaeozoic sediments in the N., and the Tertiary marine sediments in the S. Bowler (1963) suggested that Moorabool Viaduct sands were distributed over a wide area during the Pliocene epoch. The sands were deposited on the eroded surface.

The Woady Yallock R. flowed S. to Cressy, then SW. to Foxhow, as indicated by cemented river gravels beneath a Newer Basalt flow at Foxhow. The Warrambine Ck eroded a valley parallel to its present course. The Leigh R. followed a southerly course from Inverleigh to Winchelsea (Hall and Pritchard 1903) and joined the Barwon R. in the L. Modewarre Gap. A buried river valley exposed on the Warrambine Ck, 5 miles W. from Inverleigh, indicates that the Leigh R. by-passed the present Inverleigh Gap.

The Barwon R. drained the S. slopes of the Otway Ra. The river followed a northerly course to Winchelsea and turned eastward to the sea. The Barwon R. may have passed through the Wurdi Boluc Gap, R.L. 430, before diversion through the L. Modewarre Gap at an elevation below R.L. 390. The Wurdi Boluc Gap course would be diverted by either the early lava flows of the Newer Basalt or by movements along the Moorabool Hills Monocline.

Newer Basalt

The pre-basaltic land surface, between Camperdown, Colac, Birregurra, and Winchelsea in the S., and Foxhow, Cressy, and Inverleigh to the N., was an area of low relief. The area will be referred to as the lake area.

Lava flows from the numerous active volcanoes in the lake area destroyed the drainage pattern and partially covered the land surface. The valleys of the Woady Yallock R., the Warrambine Ck, and the Leigh R. were infilled. The Leigh R. eroded its present valley to Inverleigh and continued S. to join the Barwon R. in the L. Modewarre area.

Late lava flows blocked the Barwon R. in the L. Modewarre Gap and diverted the waters from the Barwon R. and the Leigh R. into the lake area at Birregurra.

Post-Basaltic Drainage

The waters from the obstructed N. and S. streams were shed into the lake area. A lake, with a water level at approximately R.L. 396, was subsequently formed. The drowned area acted as a sump, receiving water-borne sediments from a 2,500 square mile catchment. Lacustrine sediments were derived from pre-basaltic and basaltic sources. Sands and gravels were supplied by the Palaeozoic sediments and the widespread Moorabool Viaduct sands in the N. Sand was also derived from the Miocene sediments around the periphery of the lake area. Clays and loams were eroded from the volcanics in the area, and from the 'Jurassic' sediments in the Otway Ra.

Overflow from the lake area into an adjacent river system occurred when the lake level reached a gap in the water-shed between the former Leigh R. and the former Moorabool R. catchment, 3 miles E. from Inverleigh. The flooded valleys of the Leigh R. and Barwon R. were drained through the breach below Inverleigh. Lacustrine deposits and lake terraces emerged as the water level fell. Lunettes, formed above the high-water level, remained in a stranded position (Fig. 2).

As the lake level fell, a divide emerged between the W. and E. parts, and eventually the main water supply was diverted from the W. lake area. The Lough Calvert-L. Murdeduke watershed emerged to the N. of Mt Hesse. The two catchments were connected later by the Mt Hesse Ck. The Lough Calvert-Barwon R. watershed emerged at Warncoort and was subsequently added to by lunettes. The catchments were connected by a drainage channel constructed by the State Rivers

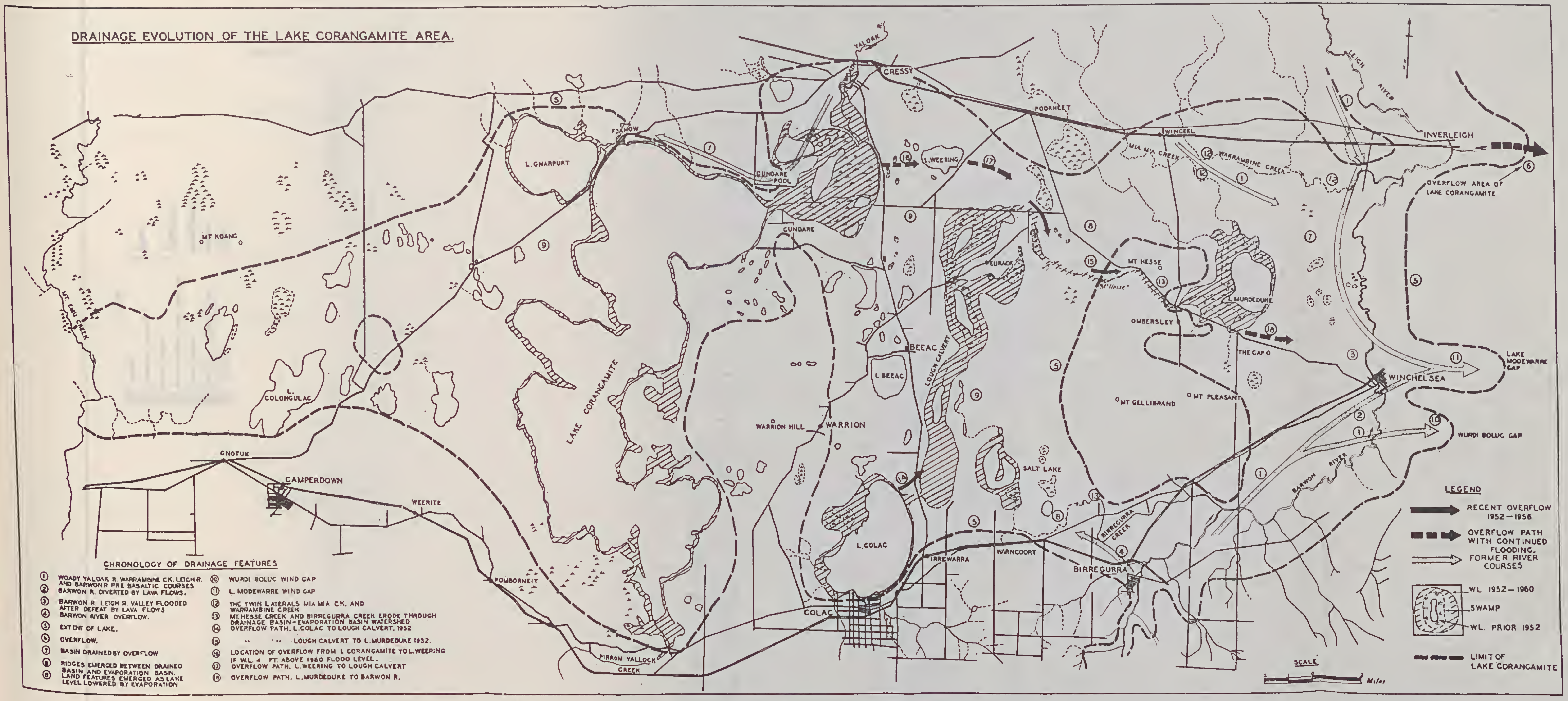


FIG. 1—Plan showing former extent of L. Corangamite.

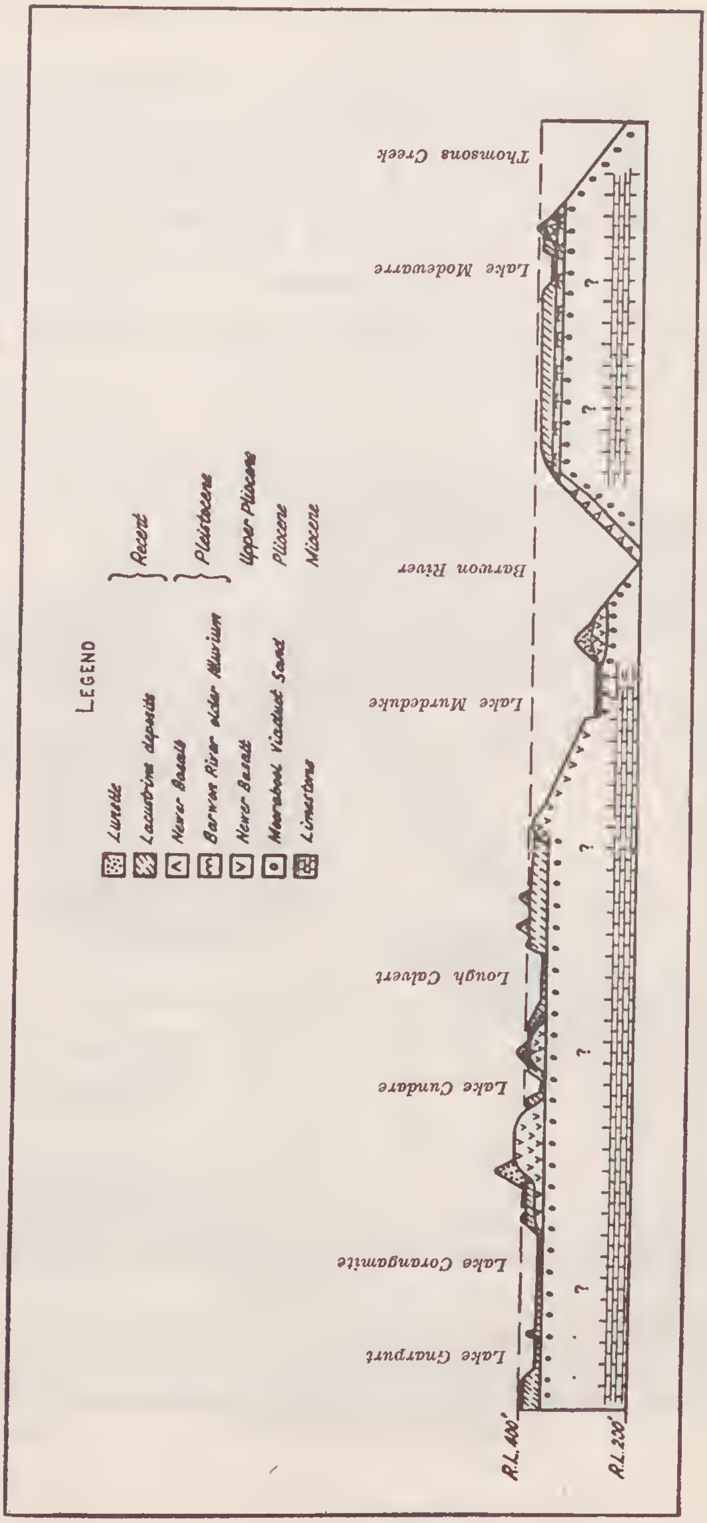


FIG. 2—Section from L. Gnarpurt in the W. to L. Modewarre.

and Water Supply Commission in 1952. The L. Murdeduke-Barwon R. watershed emerged N. and W. of The Cap.

The precipitation of the time was not sufficient to retain the water level in the W. lake area. As the lake level fell, lake terraces and lava flows emerged as land forms. During high water level stillstands, lunettes were built up on the emerged surfaces between the lakes. As the shoreline of the individual lakes receded, multiple lunettes were formed successively from E. to W. in each basin.

Present-day lake fluctuations result in cliff formation, by wave erosion, and lunette formation from wind-eroded swash zone material.

Lunette Formation

The lake level fluctuated, with a falling trend through evaporation. The lacustrine sediments of varying thickness comprised clay, loam, coxiella shells, and sodium chloride crystals as an evaporite.

Successive lines of lunettes were formed on barriers, immediately outside the swash zone, from wind-eroded dry swash material. The typical land form consists of a lunette, deposited on a lava barrier, and a lake terrace apron to the W. The apron contains a smaller lunette above a wave-cut cliff terminating the terraces (Fig. 3). The inner lunette often forms part of the wave-cut cliff section.

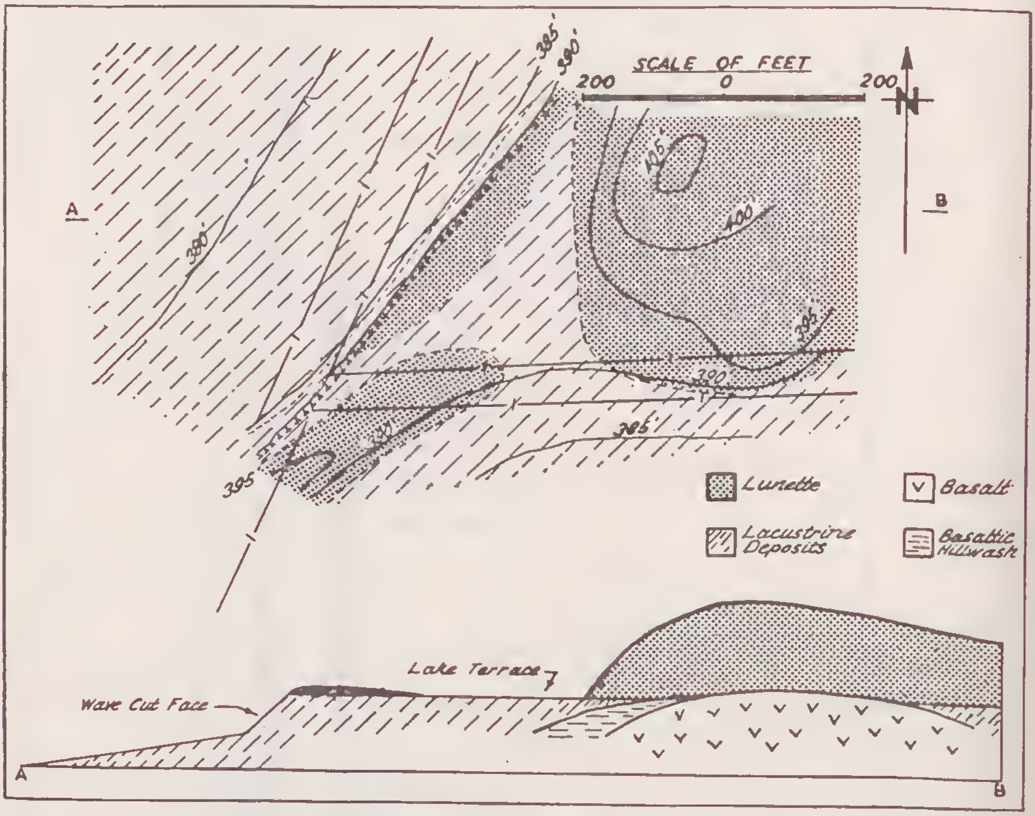


FIG. 3—Typical land form: lunettes, lake terrace, and wave-cut cliff. Parish of Turkeeth, allotment 50.

The lunettes in the lake area vary in composition. In the S., E. of L. Colac, the lunettes are composed of sand. Similarly to the E., in the vicinity of 'Mt Hesse' homestead, the lunettes are of sand, capped by a 9 in. layer of sand cemented with calcium carbonate. From L. Corangamite to Lough Calvert the lunettes are usually composed of loam. Lunettes, 60 ft high, on the NE. shoreline of L. Corangamite, are capped by a consolidated layer of coxiella shells, at R.L. 445 (Fig. 4). A lunette of coxiella shells and loam exists at the N. extremity of L. Corangamite. A number of similar lunettes were formed from swash material during the 1875 high water level, approximately R.L. 388. The high water level of 1960, R.L. 391, destroyed all but the most northerly 1875 lunette (Fig. 5). Coxiella shells are being deposited on the dune at present. The shells are derived from lunette material and the shell lenses exposed in the wave-cut cliff faces.

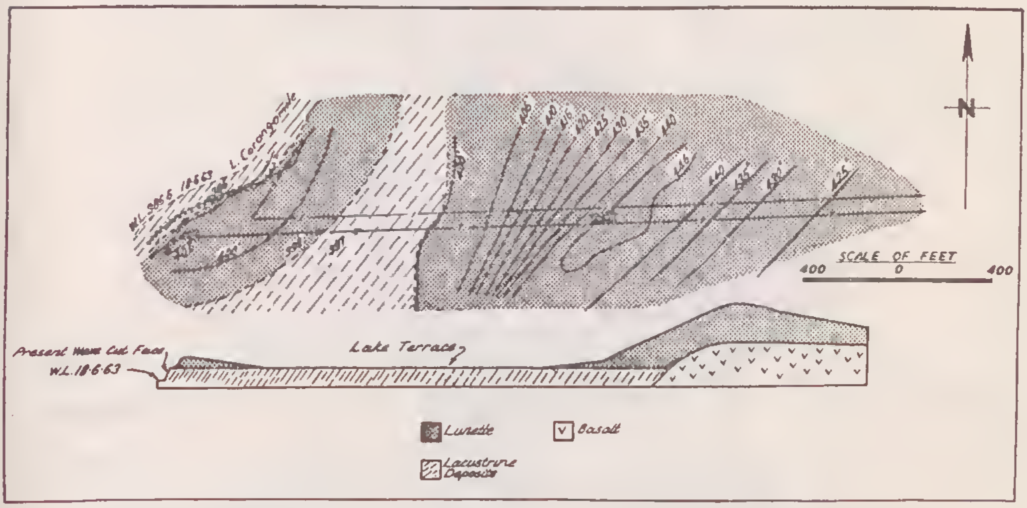


FIG. 4—Lunettes above L. Corangamite N. Parish of Cundare, allotment 74a.

Stephens and Crocker (1946) suggested that lunettes were formed during a period when the lake beds were dry. In the lake area it appears that wind action and high water levels governed the location of a lunette formation. Successive lunette suites were formed contemporaneously with the shifting E. shoreline, migrating to the W., or up wind. To the N. of Lough Calvert successive barriers emerged over a distance of 600 ft (Fig. 6). The E. barrier, the first barrier exposed, contains a lunette 2 ft high. A lunette to the W., the second barrier to emerge, is 12 ft high. The third and last barrier to emerge to the W. and in front of the others has a lunette 7 ft high. The lunettes formed on each barrier as it emerged. As the water level fell, the new lunettes formed in the front W. position starved the formation to the E.

The lunettes existing above the highest water level were formed during the suggested wet period. Hills (1940) considered that lunettes in N. Victoria could have been formed in a relatively wet late Recent epoch. In the lake area lunettes were formed throughout the suggested wet period, from the final stages of vulcanicity to the present.

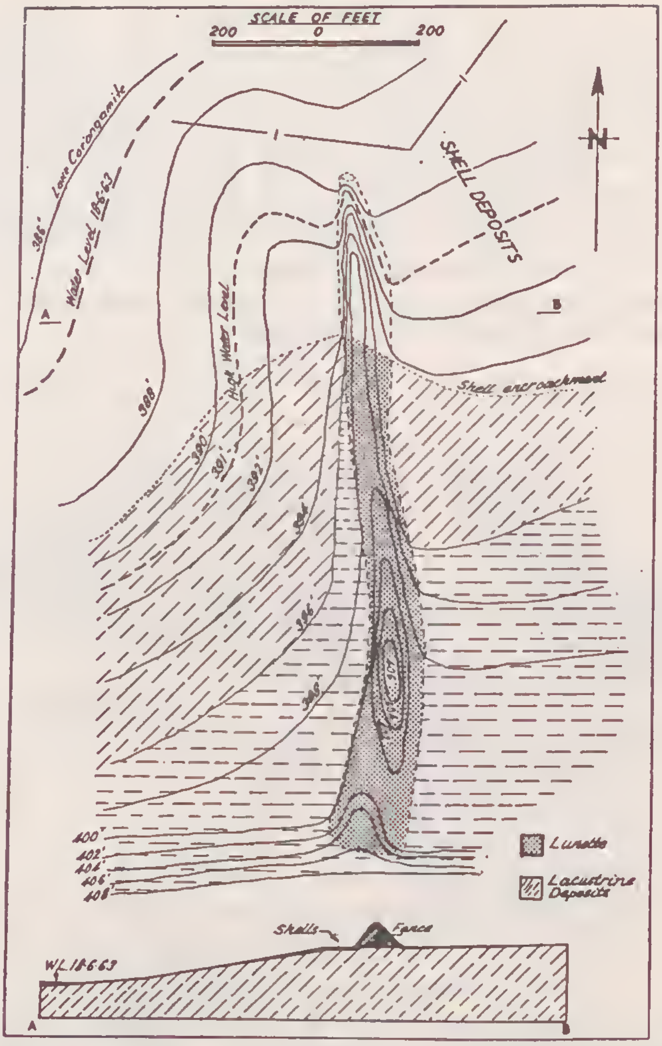


Fig. 5—Coxiella shell dune, formed in 1875. L. Corangamite N. Parish of Cundare, allotment 87b.

The Present Lake Area

(Fig. 7)

The Mt Emu Ck drains the W. flats of the area to the sea. The exact elevation of the area is uncertain. The flats between Mt Emu Ck and L. Corangamite contain scattered lakes and high-level lake terraces. Lunette formations occur above the E. shorelines of numerous lakes to the W. of L. Corangamite.

L. Corangamite receives the Woady Yallock R. in the N. and Pirron Yallock Ck in the S. L. Gnarpurt in the NW. is separated from L. Corangamite by a narrow bar containing a low lunette, rising to R.L. 394. A coxiella shell bed occurs below

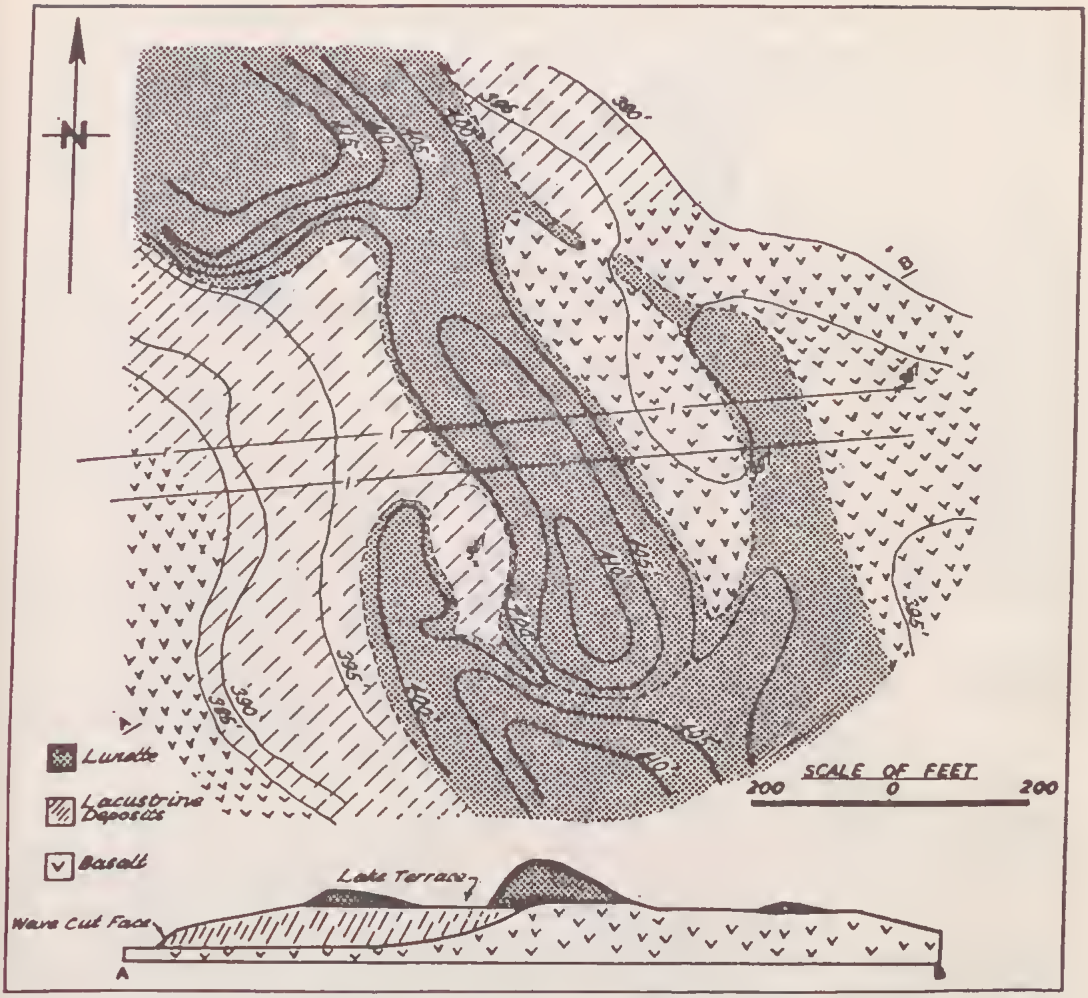


FIG. 6—Multiple lunettes. Parish of Cressy, allotment 66.

the lunette at R.L. 387. The Cundare Pool forms the N. extension of L. Corangamite. A lake deposit to the W. of the L. Corangamite-Cundare Pool channel rises to R.L. 420 and dips gently to the NE. The mode of formation of this deposit is not understood.

There are three lake systems in the E. area including L. Corangamite, each being oriented N.-S. The central lake system includes L. Weering in the N., L. Beeac and L. Colac in the S. Lough Calvert in the E. area is connected in the N. with smaller depressions around 'Mt Hesse' homestead, farther to the E. Long sinuous lunettes separate the various lakes and lake systems.

Lacustrine deposits cover a flat surface of Moorabool Viaduct sand at the N. extremity of L. Gnarpurt to a depth of 6 ft. Coxiella shell beds occur 8 ft below natural surface from the Cundare Pool to L. Weering. A tuff bed occurs above the W. shoreline of Lough Calvert. An examination of the tuff was made by Dr Spencer-Jones at the Mines Department. He reported that the tuff contained detrital sand.

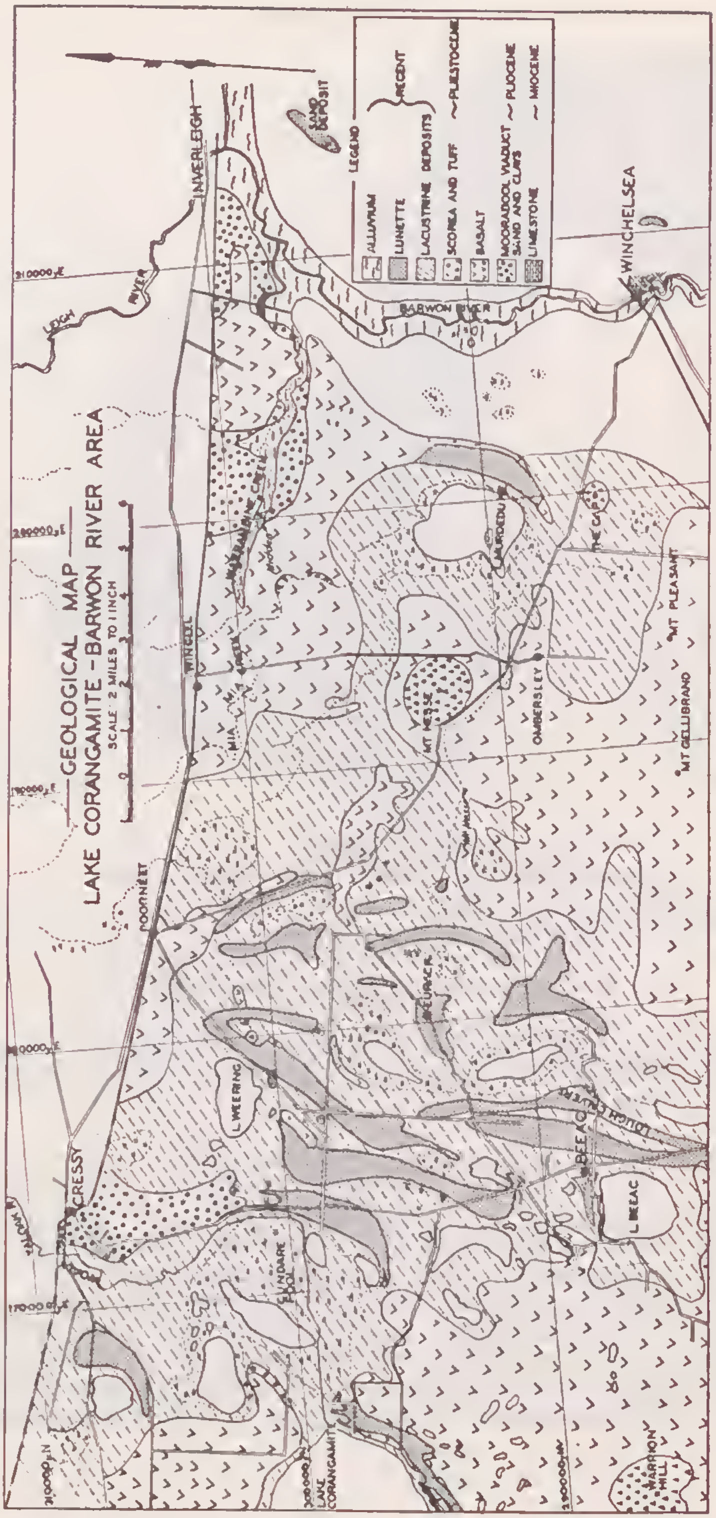


FIG. 7—Geology, L. Corangamite to Barwon R.

This finding suggests that the tuff was deposited during lake sedimentation. Lake sediments cover Moorabool Viaduct deposits of gravel to a depth of 5 ft at 'Mt Hesse' homestead. Coxiella limestone deposits occur to the E. of L. Beeac and in the Lough Calvert-'Mt Hesse' homestead connection. Bone fragments were observed in the cliff faces above the various lakes in the W. area. Lunette formations exist above Birregurra and Winchelsea in the SE. area.

L. Murdeduke occupies a depression approximately 100 ft below the general level of the W. lake area. The Mia Mia Ck drains into L. Murdeduke from the N. Mt Hesse and The Cap, volcanic cones rise above L. Murdeduke in the S. Mt Gellibrand, a centre of eruption, forms a prominent feature to the S. of Mt Hesse. In 1962, a cloud burst precipitated 8 in. of rain in one hour to the immediate NW. of Mt Gellibrand. Accumulations of red sand, 18 in. thick, resulted from the flash flooding initiated by the rain storm. Leeper, Nicholls, and Wadham (1936) suggested that the derivation of the water-worn sand fraction in the Mt Gellibrand area was most likely from explosive material emanating from the volcano. It is suggested that the sand is wind-eroded material from the lake area, deposition taking place at the higher water levels. Red sand occurs in the swash material of the present lakes.

The Warrambine Ck, the lateral twin of Mia Mia Ck, drains into the Barwon R. A midden exists on an alluvium flat above the Warrambine Ck, 7 miles upstream from the Barwon R. The Barwon R. flows N. to Inverleigh and turns E. at the Barwon-Leigh R. junction. Red sand deposits exist above the Barwon R. bed level on the E. valley side, S. from Inverleigh.

L. Modewarre occupies a depression in a wide valley in the SE. area, E. of Inverleigh. A saddle, 2½ miles long, at R.L. 393 occurs between the Moorabool Hills Monocline in the W. and Lake Modewarre in the E.

Recent Flooding

The L. Colac water level rose to R.L. 390 in 1952 and overflowed into Lough Calvert. At R.L. 381, Lough Calvert overflowed in the N., passing the 'Mt Hesse' homestead, down the Mt Hesse Ck into L. Murdeduke. With continued flooding, L. Murdeduke would overflow in the SE. into the Barwon R.

The L. Corangamite water level rose to R.L. 391 in 1960 and flooded the Cundare Pool. A channel excavated in 1959 from the Cundare Pool to the Warrambine Ck, diverted flood waters into the Barwon R. With continued flooding, L. Corangamite would have overflowed at R.L. 394, through the Cundare Pool, E. into L. Weering. The L. Weering overflow would drain into L. Murdeduke after entering the N. extension of Lough Calvert.

Summary

1. The pre-basaltic Leigh R. joined the Barwon R. and flowed S. of the Moorabool Hills to the sea.
2. Basalt infilled the major river valleys. The Leigh R. and Barwon R. established courses parallel to the infilled valleys.
3. A late lava flow blocked the river courses in the L. Modewarre gap area.
4. An area between Camperdown, Winchelsea, Cressy, and Inverleigh, covering 700 square miles, was inundated by water from the defeated rivers. The lake water level rose to approximately R.L. 396. It has been calculated that an additional annual rainfall of 13 in. would be necessary to fill the lake.
5. Overflow occurred E. of Inverleigh across the Leigh R.-Moorabool R. Divide, leading to drainage of the lake.

6. Lunettes were formed above the high water level. Lacustrine deposits emerged as terraces as the water level fell.
7. Barriers emerged between the Barwon R. and the W. lake area.
8. The W. lake area became an evaporation basin after the main water supply had ceased.
9. Lunette suites were formed as the lake level fell and isolated lakes remained.
10. Present lake overflows occurred in 1952 when L. Colac water passed into Lough Calvert. Lough Calvert overflowed into L. Murdeduke. Continuous flooding in the L. Corangamite area would find an outlet to the sea, passing down the Barwon R., through the overflow area near Inverleigh.

Acknowledgements

In making this study the writer has received assistance from many sources. The work was carried out during investigations for the State Rivers and Water Supply Commission.

Thanks are due to Mr R. A. Horsfall, Commissioner, for initiating the study. Valuable information was supplied by my colleagues, and assistance was given by Mr J. J. Jenkin of the Mines Department, throughout the survey. Assistance was derived from the many discussions with Mr C. D. Ollier and Mr J. M. Bowler, Department of Geology, University of Melbourne.

Grateful acknowledgement is due to Mr L. R. East, Chairman, State Rivers and Water Supply Commission, Victoria, in granting me the permission necessary to publish this information.

References

Bowler, J. M., 1963. Tertiary stratigraphy and sedimentation in the Geelong-Maude area, Victoria. *Proc. Roy. Soc. Vict.* 76: 69-140.

Grayson, H. J., and Mahoney, D. J., 1910. The geology of the Camperdown and Mt Elephant districts. *Geol. Surv. Vict. Mem.* 9.

Hall, T. S., and Pritchard, G. B., 1903. The geology of the Barwon about Inverleigh. *Proc. Roy. Soc. Vict.* 16: 292-305.

Hills, E. S., 1940. The lunette, a new land form of aeolian origin. *Aust. Geographer* 3 (7).

Leeper, G. W., Nicholls, Ann, and Wadham, S. M., 1936. Soil and pasture studies in the Mount Gellibrand area, Western District of Victoria. *Proc. Roy. Soc. Vict.* 49: 77-138.

Skeats, E. W., and James, A. V. G., 1937. Basaltic barriers and other surface features of the New Basalts of Western Victoria. ibid. 49: 245-292.

Stephens, C. G., and Crocker, R. L., 1946. Composition and genesis of lunettes. *Trans. Roy. Soc. South Aust.* 70: 302-312.

Explanation of Plates

Plate LVI

Fig. 1—Looking W. from L. Corangamite-L. Cundare connection. Cliff faces in foreground 4 ft high. Eroding cliff sections. Black shelly loam resting on a flat surface of grey loam. Lake terrace in background rises to R.L. 420. Terrace in foreground dips gently to the NE.

Fig. 2—Looking E. from the N. shore of L. Corangamite. High lunette in background, inner lunette in foreground and lake terrace in middle distance.

Plate LVII

Aerial photograph by Adastra for State aerial survey, taken from 25,000 ft. (scale about 1·2 mile to inch), 1952 flooding of Lough Calvert around Eurack (lower centre of photograph). L. Weering on left margin of plate, lake terraces and lunettes in N. Lough Calvert overflow area appears black, connecting to Mt Hesse Ck as a drain in the SE. Numerous suites of lunettes are evident in the lower half of plate, the tops of smaller lunettes appearing above the water in the S. 5 elongated lunette formations in the SW., representing the former shoreline of L. Beeac to the W. (not in photo).

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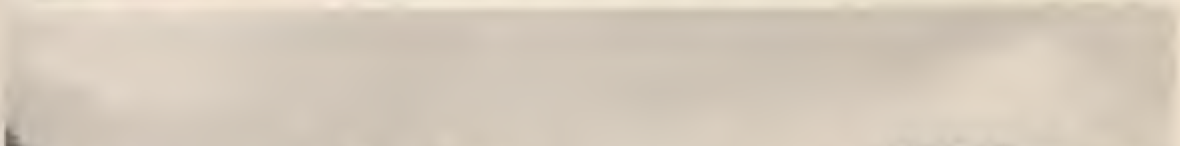

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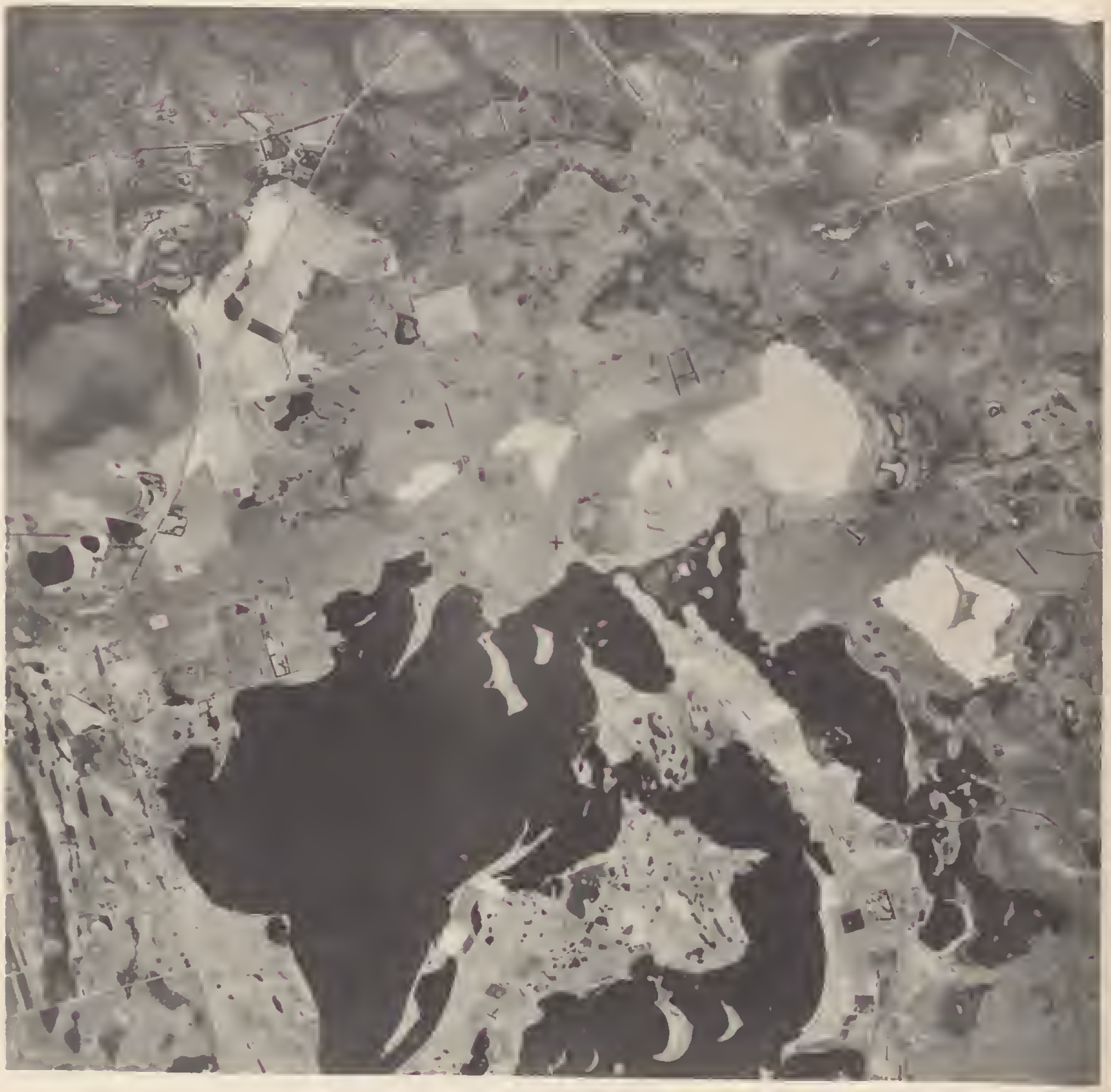

15

TERRAINS AND SOILS OF THE BASALTIC PLAINS OF FAR WESTERN VICTORIA

By Frank R. Gibbons
Soil Conservation Authority of Victoria
and Edmund D. Gill
National Museum of Victoria

Abstract

Nine land-systems covering 1200 square miles of the basaltic plains in SW. Victoria are described and their distribution shown. These land-systems are areas where there is a consistent pattern of various features of the natural environment—climate, parent material, topography, soils, and vegetation, and the description is in terms of these. The evidence for the age of the basalts of the various land-systems is discussed, particularly the significance of the residual weathering-formations and soils. The six patterns of soils and weathering-products suggest six periods of extrusion of basalt, each linked with one or more land-systems, the earliest having been in the Middle or Upper Pliocene and the latest in the Holocene. It is suggested that the approach could be applied to the rest of the basaltic plains.

Basis of Approach

The area discussed covers about 1200 square miles at the W. extremity of the basalt plains, about 13% of the total area of the plains. It lies in the SW. corner of Victoria, W. of Penshurst and S. of Cavendish. During surveys conducted there by the Soil Conservation Authority (Gibbons and Downes 1964 in press), different kinds of land were recognized, mapped, and described. Each is characterized by a consistent pattern of natural features such as topography, rocks, soils, and native vegetation. On the broad scale the patterns are called **land-systems,** and these form the basis of the following description of terrains and soils on basalt (Fig. 1).

Different land-systems have been derived from the same geological material, and this indicates that the land-systems have been subject to different conditions.

The present climate varies over the area from 25 in. to more than 36 in. average annual rainfall, with slight differences in the temperature régime. However, the climate of former periods may have differed from that of the present by much more than this range. Consequently, factors which may be responsible for the differences between the land-systems are the present climate, the time during which the basalt has been subject to the present climate, and the age of the basalt, which controls the former climatic régime(s) to which it has been subjected. One of us (F.R.G.) considers that some differences between the patterns, particularly between the Cobbobboonee land-system and the other land-systems, are the result of the present climatic differences. However, because the patterns are consistent within relatively sharp boundaries, and differ considerably from each other, it is believed that the last of the above-mentioned factors, namely the age of the basalt, is the most important. This conclusion is supported by the fact that widely-different times of extrusion can be proved in certain places.

Consequently, the areas of the various patterns are considered to indicate the areas of different flows or series of flows of basalt and the areas to which relative or absolute datings may be applied.

Nine land-systems associated with basalt have been recognized and mapped in the area of survey, and in the rest of this paper they are described and the evidence for their age is considered.

The Land-Systems and Their Features

HAMILTON AND BRANXHOLME LAND-SYSTEMS

Around Hamilton, and particularly to the S. of it, is a basaltic terrain that has been dissected to depths of 200 ft, thus exposing underlying sedimentary rocks. Areas where dissection has not reached these rocks have been mapped as the Hamilton land-system, and areas where these rocks have been widely exposed have been mapped as the Branxholme land-system.

On the highest parts of both these land-systems is a zone of kaolinitic weathering which may be over 30 ft thick. Where thickest, this zone has an upper strongly reddened and friable sub-zone, an intermediate mottled sub-zone, and a lower pallid sub-zone overlying the altered basalt. To this extent, it strongly resembles a classical profile of laterite (Prescott and Pendleton 1952), but nowhere in the basalt of these land-systems has there been found an indurated sub-zone characteristic of such a profile. Lateritic profiles with indurated sub-zones have been described for other areas in W. Victoria, as over the Dundas Tablelands (Stephens 1946) and at Camperdown (Gill 1953); the lateritic peneplain of the Dundas Tablelands is adjacent to the Hamilton land-system and at a lower level.

Soils in the Hamilton and Branxholme land-systems form a characteristic sequence with topography according to catenary position and to the rocks exposed by dissection. On the kaolinitic sub-zone, soils are either transitional krasnozems (**Hamilton** Series), red solodic soils (**Monivae** Series) or their intermediates. Middle and lower slopes on basalt dissected below the level of kaolinitic weatherings support brown solodic soils (**Normanby** family) which are usually gilgaied. Prairie soils or chernozems are in drainage lines, with peats in the wettest sites. In the Branxholme land-system, dissection below the level of the basalt exposes sandy sediments (e.g. around Macarthur) which support sandy solodic soils. Near Branxholme, Lower Cretaceous sediments give rise to prairie soils (**Whyte** Series). Kaolinitic nodules are common in soils in higher catenary positions but progressively less frequent in the lower sites, while ironstone nodules (buckshot) become increasingly frequent in the A2 horizons of lower sites.

Although the land-systems are now widely cleared of trees, there is evidence that the original vegetation was a dry sclerophyll forest dominated by swamp gum (*Eucalyptus ovata*) thinning to a savannah woodland and eventually to a grassland on heavier soils and lower sites. In drainage lines and on the peats were wet scrubs of tea-tree (*Melaleuca pubescens*) and most of this still remains. In the NW. part of this land-system, red gum (*Eucalyptus camaldulensis*) was mixed with swamp gum, or was dominant, forming savannah woodlands.

COBBOBBOONEE AND GREENWALD LAND-SYSTEMS

NW. of Portland and W. of Heywood are areas of basalt which cover the W. parts of the Normanby Platform (Boutakoff 1952). This platform has Miocene sediments for its base and it shelves gently to the E. Most of the basalt has been mildly dissected by easterly flowing streams which expose the underlying sediments in a few places. Only where streams are cutting back into fault-scarps, such as the

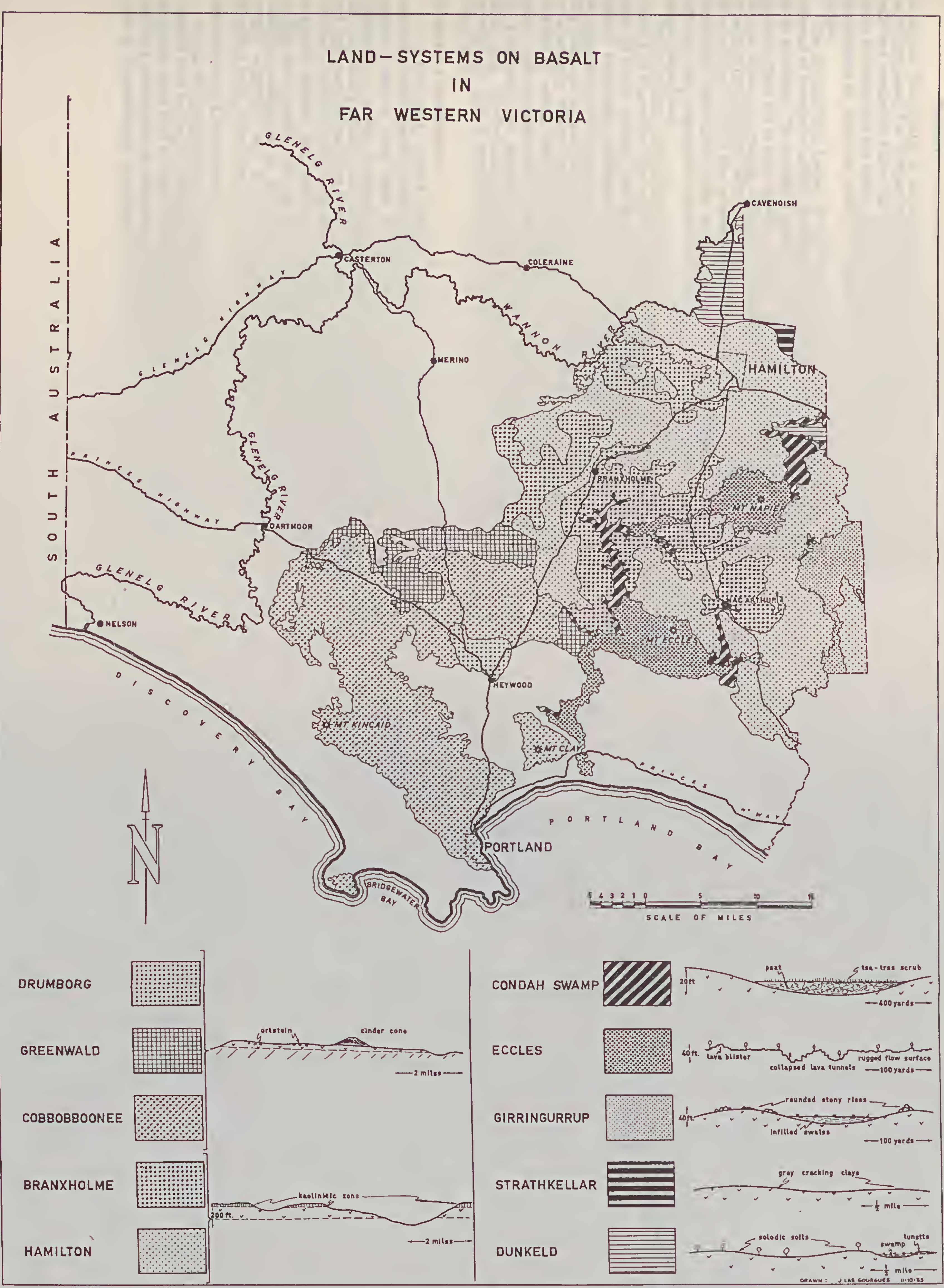

Fig. 1—Land-systems on basalt in far-W. Victoria. (Adapted from 'A Study of the land in South-western Victoria' by Gibbons and Downes 1964 in press.)

Kentbruck Fault-scarp, is the dissection deep or the exposure of underlying sediments extensive. The Cobbobboonee land-system is where the dissection has generally not penetrated below the basalt, while the Greenwald land-system is formed where the dissection has widely exposed the underlying sediments. There are a few cinder-cones of which the chief is Mt Eckersley, mapped as the Drumborg land-system.

The characteristic feature of the basalt on these land-systems is the common presence of ortstein, a nodular ironstone, which is found mostly on the upper parts of the landscape. The ortstein is pisolitic, rarely more than 2 ft thick, and may be a cemented mass but is more usually a loosely cemented and decomposing gravel in the soil. Under the ortstein, either unweathered basalt or, more often, a thin layer of mottled clay is found. Where there is no ortstein, there is usually an orange and red tenacious clay with fine, prominent and concentric mottles, and weak ironstone concretions. Mottled and pallid sub-zones which are deep, reddened and kaolinitic have not been encountered except along the cliffs at Portland; shallow dissection exposes fresh basalt.

The soils form a topographic sequence and are closely linked with the materials exposed by dissection. The ortstein, mottled clay, and fresh basalt give rise to two series of clayey podsolic soils (**Gorae** Series and **Cobbobboonee** Series) and transitional krasnozems (**Midwood** Series) respectively. **Gorae** Series has abundant buckshot gravel which has been derived probably from the ortstein; **Midwood** Series may have smaller quantities of gravel, probably formed at a later stage than that in the ortstein. Where Tertiary sediments are exposed, the soils on them are usually podzolic or solodic while, in drainage lines, prairie or meadow soils are formed. Much of the original timber remains. Because of the comparatively high rainfall, the 4 dominant tree species are messmate (*E. obliqua*), peppermint (*E. vitrea*), manna gum (*E. viminalis*), and swamp gum. The first named is restricted to the gravelly soils and is dominant thereon, while the last named is dominant in the wetter sites.

DUNKELD LAND-SYSTEM

S. of Cavendish, around Dunkeld, and between Penshurst and Hamilton are tracts of basaltic country which are little dissected and possess a few swamps with lunettes, scattered stony rises, and a broadly undulating topography. No deep weathering or massive ironstone has been observed. The chief feature is that the soils are mostly solodic soils (similar to the **Normanby** family), weakly gilgaied, and with abundant buckshot in the A2 and top of the B1 horizon. Less commonly, there are reddish chocolate soils which closely resemble the **Corangamite stony loam** of Leeper, Nicholls, and Wadham (1936) on stony rises, break-aways to streams, or flow edges; prairie soils are in depressions and on lunettes. Boulders of fresh basalt are common in the soil profile and on the surface. In the survey area, the original vegetation was an open savannah woodland of red gum with a low, spreading habit. Note: stony rises are ridges of basalt with very stony surfaces.

STRATHKELLAR LAND-SYSTEM

To the NE. of Hamilton is basaltic country of similar topography to that of the Dunkeld land-system, but without swamps, and with very slight dissection. On the occasional stony rises the soils are **Corangamite stony loam,** and in the depressions are black prairie soils or chernozems; over the long gentle slopes which constitute most of the countryside are gilgaied brown prairie soils (dark greyish-brown cracking clays). Neither deep kaolinitic weathering, nor massive ortstein, nor abundant loose buckshot gravel have been observed, but small to moderate amounts of buckshot gravel (magnetic iron pisolites) are encountered in the surface horizons of the chief soils. The original vegetation over much of the land-system appears to have been a dry tussock grassland but, over some parts, swamp gum may have been lightly scattered.

This land-system and its characteristics were first recognized and mapped by G. T. Sibley Esq. to whom acknowledgement is made.

Girringurrup Land-System

Some stony rises have very rugged topography with unweathered angular blocks of basalt covering the surface, while others have a smoother and more gentle topography with rounded boulders partly weathered and more buried in soil. Rises of the latter type are associated with Mt Rouse and extend southwards in the direction of Port Fairy, being bounded on the W. by the Eumerella R. The difference in height between rise and contiguous hollow varies up to 40 ft, while the distance between rises varies from 50 ft to a few hundred yards. These stony rises constitute the Girringurrup land-system.

The pattern of soils is a simple catena. On the rises are thin reddish chocolate soils (**Corangamite stony loam**) with abundant rounded basalt boulders half buried in the soil and with onion weathering. These soils become darker further down the sides of the rises until, in the swales, they are black, heavy and cracking, sometimes with free carbonate and usually gilgaied; they may be regarded as prairie soils or chernozems, and resemble the **Mooleric clay** of Leeper, Nicholls, and Wadham (ibid.). The whole catena is part of one described by those authors. No evidence of deep weathering, massive ortstein, nor buckshot has been encountered, as in the previous land-systems, nor evidence of stream-dissection.

The land-system is generally treeless now, but the original parish plan of Tallangoork, compiled in 1862, gives descriptions which can be interpreted to mean that the vegetation was a sparse savannah woodland of manna gum and blackwood (*Acacia melanoxylon*) or lightwood (*A. implexa*) on the rises, with a wet tussock grassland of snow-grass (*Poa australis*) in the swales.

Eccles Land-System

Surrounding Mt Napier, and covering a large area to the W. of Mt Eccles, are stony rises mapped as the Eccles land-system.

Large, angular and almost unweathered boulders cover the surface. In places the topography is very rugged, with sudden rises and with precipitously-sided hollows up to 30 ft deep and 100 ft across. In both areas of the land-system there are steep-sided scoria cones up to 350 ft high, with some tuff and ropey lava, while layers of diatomite from a few inches to 7 ft thick are found in basins of former lakes and around existing lakes.

The lithology of the stony rises varies. At one extreme is moderately-vesicular basalt with discontinuous vesicles having walls over 10 mm thick as a rule; the boulders are big, solid, and closely packed. At the other extreme is highly-vesicular scoriaceous basalt with continuous vesicles having thin walls usually less than 5 mm thick and often less than 2 mm. Boulders are commonly only 6 to 9 in. in diameter, jagged, and poorly packed. These two groups tend to be mutually exclusive, suggesting two distinct volcanic products.

Two similar but distinguishable types of soil, brown earths, are referable to these two rock types, the **Napier stony loam** and the **Dunmore organic loam** respectively. The **Dunmore organic loam** is found also on the steep sides of hollows or lava blisters. Both soils have unusually high levels of exchangeable calcium, potassium, and phosphorus, probably because of lack of leaching. This is true of the **Dunmore organic loam** even more than of the **Napier stony loam** and the difference is doubtless a result of the more rapid weathering of the more vesicular rocks, or else the input of drainage waters highly-charged with metallic cations from weathering basalt above. The only other soils in this land-system are brown-earths on scoria cones and the deposits of diatomite.

Throughout the land-system, the original vegetation was a tall woodland of manna gum with occasional blackwood and wild cherry (*Exocarpus cupressiformis*), with an understorey of snow-grass. The stands on the shallow phase of the **Napier stony loam** are more open. As a result of fires, bracken now dominates the understorey.

CONDAH SWAMP LAND-SYSTEM

On any of the abovementioned land-systems, the blocking of the natural drainage, such as by lava flows, has resulted in the development of swamps and alluvial flats. These frequently support wet scrubs of tea-tree which, in turn, have produced earr-peats or peaty prairie soils and peaty meadow soils. Such areas have been mapped as the Condah Swamp land-system after the chief example; others are Buckley's Swamp, L. Gorrie Swamp and Homerton Swamp.

The Ages of the Land-Surfaces and Basalts

Nine different land-systems have been described which are all developed on basalt. The differences are not of equal degree—e.g. the difference between Hamilton and Branxholme land-systems on the one hand, and the Cobbobboonee and Greenwald land-systems on the other, is much greater than the difference between the Girringurrup and the Eccles land-systems. Also, while the first eight land-systems are developed directly on basalt, the Condah Swamp land-system is developed on materials now accumulating on the basalt, but it is included to complete the picture.

The weathering of the parent material in the land-systems developed directly on basalt differs in both kind and degree. The basalt of Girringurrup and Eccles land-systems may have been weathered under climates similar to that prevailing now. The Hamilton and Branxholme land-systems, however, present characteristics which could not be formed under the present type of climate, and so it may be inferred that some of the land-surfaces and all of the basalts in those land-systems are of some antiquity.

It is important to discriminate what is being dated. Different land-surfaces may have been formed progressively on any one basalt and the age of the land-surface, as indicated by the soil, is not necessarily the age of the basalt. It is necessary, therefore, to consider each land-system both as a whole and as a series of lesser land-surfaces.

HAMILTON AND BRANXHOLME LAND-SYSTEMS

The age of the basalt can be determined 4 miles W. of Hamilton. There, Grange Burn has cut through the lava to an underlying marine bed of Kalimnan (Lower Pliocene) age, in which a palaeosol has been developed (Gill 1955, 1957). In this fossil soil are preserved stumps of Celery Top Pine (*Phyllocladus*) which is now limited to Tasmania and parts of New Zealand, and a tooth of a euscus possum which is now limited to Cape York and New Guinea. The climate during Kalimnan times was warmer than at present, as shown by the foraminifera and other fossils of the Kalimnan beds, and the climate of post-Kalimnan times was wetter and warmer than at present, as shown by the *Phyllocladus* and cuscus respectively. The local volcanoes began to be active during Kalimnan times, as is demonstrated by the presence of tuff in the Kalimnan beds at Muddy Ck nearby (Gill 1957a). Tuff also overlies those beds, and is present in the palaeosol under the basalt at Grange Burn. Thus, a great deal of time did not pass between the deposition of the Kalimnan beds, their emergence from the sea-floor, and the extrusion of the basalt. On this basis, the basalt may be dated as Middle Pliocene, and was extruded when the climate was warmer and wetter than at present.

This conclusion is supported by the presence of the kaolinitic zone on the upper parts of the basalt. One of us (E.D.G.) has studied the presence of laterite (*sensu strictu*) in Victoria and has found that laterite, which is a terrestrial formation, has developed on dateable marine beds as young as uppermost Miocene (Cheltenhamian) but nowhere on Kalimnan marine beds, which are mutually exclusive in distribution with lateritized areas. It is inferred, therefore, that, in Victoria, lateritization occurred during Lower Pliocene times. Furthermore, it has been noted that, in the Upper Pliocene (using a twofold division of that period), the waning lateritizing conditions have deeply leached and reddened the sediments but have not produced a proper lateritic profile with an indurated sub-zone. It was apparently during this time that the deeply leached kaolinitic profile found on the basalts of the Hamilton-Branxholme landscape was produced.

If the age of both the basalt and the kaolinitic zone be Pliocene, then it is to be anticipated that the palaeosol will have been modified at the surface by Quaternary climates, and also that different soils will be found in the valleys cut into this landscape. Both these, in fact, have happened.

The basalt within the area of the Hamilton and Branxholme land-systems, therefore, is considered to have been extruded during Middle Pliocene or Upper Pliocene times, although areas of later flows, too small to map, are known to be included also.

Cobbobboonee and Greenwald Land-Systems

This terrain is much less dissected by erosion than the Hamilton-Branxholme terrain and, considering the dissecting potential of the streams, this may be admitted as evidence of relative age. Also, the Cobbobboonee terrain does not have the deep kaolinitic weathering that is a feature of the Hamilton basaltic terrain, and this also may be admitted as evidence of a later date for the extrusion of the Cobbobboonee basalt than for the Hamilton basalt.

There is positive dating for the basalt at one locality, Portland, within these land-systems (Boutakoff 1963). There, the basalt overlies the Maretimo Member (Upper Pliocene) and is younger than the Werrikoo Member, the base of which has been considered by Gill as the base of the Pleistocene (Gill 1957b, 1961). The basalt at Portland, therefore, was extruded at about the time of the Plio-Pleistocene boundary.

Further evidence of the age of the basalt is the nature of the soils and relic formations, the chief of which are the krasnozem variants, the ortstein, and the buckshot-bearing soils.

The krasnozem variants at Portland, which Boutakoff (1963, p. 30) refers to as a product of 'lateritization' are developed on fresh basalt but, at Hamilton, they are developed only on the deep kaolinitic zone and not on fresh basalt on dissected slopes. One of us (E.D.G.), who considers that in Victoria krasnozems are commonly palaeosols formed at about the time of the Plio-Pleistocene boundary, regards these facts as evidence that the basalt of the Hamilton land-system was extruded long before that time and that the basalt of the Cobbobboonee land-system was extruded at about that time. This agrees with geological evidence. The other author (F.R.G.), however, thinks that in Victoria krasnozems can be developed under existing climates where the leaching potential is high. Thus, at Portland, the krasnozems may have developed relatively recently under climates similar to that of the present, whereas, at Hamilton the much lower leaching potential (Hallsworth 1952) precludes their development now on fresh basalt.

In water-logged conditions, with abundant organic matter, iron-oxide may be mobilized and then concentrated in numerous loci to form pisolites and, eventually, a massive nodular horizon of ironstone known as 'ortstein' (Hallsworth and Costin 1954). These authors consider that, on basalt, ortstein indicates cold and wet conditions in poorly-drained areas; they postulate an early-Pleistocene or mid-Pleistocene age for examples on basalt in New South Wales. The presence of such material in perched positions on the Cobbobboonee land-system agrees with the other evidence of an early Pleistocene age for the Cobbobboonee basalt.

The buckshot-bearing soils may have been developed under similar conditions and, therefore, perhaps at a similar time to those on the dissected basalt of the Hamilton land-system and to those widely found in the Dunkeld land-system.

DUNKELD LAND-SYSTEM

The dissection of the basalt of the Dunkeld land-system is much less than in the previous two land-systems, neither does it have their kaolinitic zone nor ortstein. On the other hand, there has been differentiation of the soil profile and development of buskshot to a more marked degree than in the soils of succeeding land-systems. Consequently, it seems that the basalt was extruded later than the Hamilton and Cobbobboonee basalts but earlier than the basalts of the other three land-systems.

Stratigraphy indicates the relative age of the basalts in some places. At Tarrington, e.g., the Dunkeld basalt occupies a valley in the Hamilton basalt.

Two pedological approaches are useful here, namely the content of magnetic iron oxide, and the nature of the soil fabric.

One of us (E.D.G.) has worked out a means of dating basaltic tuffs. Where the factors of parent material, climate, and slope are equated by studying soils on low slopes of basaltic tuff in the one general area, the differences in the accumulation of gamma iron oxide are then a function of time. The series can be supported in their relative dating by the degree of profile development and the amount of dissection. Absolute dating is available by the radio-carbon method for some of the series. The youngest tuffs develop dust-size magnetic iron oxide, those of greater age develop micro-pisolites up to about 2 mm in diameter, while the next stage (10,000 to 12,000 years old) develops a full solodic soil profile with pea-sized buckshot gravel. If this type of relative dating can be extended to the basalts, then the dominant soils on the basalts of the Dunkeld, Strathkellar, Girringurrup, and Eccles land-systems are in that order of decreasing age.

Butler (1959) considers that the degree of organization of the soil fabric is controlled by the length of time for which a soil has been subject to weathering, and hence can indicate the 'K' cycle to which that soil belongs, within a limited area. In general, the greater degree of fabric organization is associated with soils of earlier K cycles. The dominant soils on the basalts of the Dunkeld, Strathkellar, Girringurrup, and Eccles land-systems have decreasing degree of organization of soil fabric in that order, supporting the conclusions from the approach using magnetic iron oxide. A full application of Butler's approach, however, would require a more detailed examination of the soils than has been made.

Strathkellar Land-System

Because of the lack of dissection pattern, zone of kaolinitic weathering, massive ortstein, marked differentiation of the soil profile, intense organization of the soil fabric, and abundant buckshot, the basalt of this land-system is considered to have been extruded later than the three groups mentioned previously. By reason of deeper weathering, moderate buckshot formation, and less unweathered basalt on the surface, the basalt of the Strathkellar land-system is thought to be earlier than those of the following two land-systems.

Girringurrup Land-System

The basalt of this land-system has no dissection pattern, none of the alteration-forms characteristic of the above-named basalts and with a much greater proportion of the catena occupied by soils with a high content of exchangeable metallic cations. On the other hand, the basalt boulders on the stony rises are more weathered than those in the Eccles land-system and the hollows are filled in with alluvium. Consequently, it is thought to have been extruded earlier than the Eccles basalt and later than the others. It may, however, be within the range suitable for radio-carbon methods of dating.

Eccles Land-System

The basalt of this land-system is the latest of all and Holocene in age on the following grounds. The original topography has been largely preserved, with the surface blocks angular and closely fitting together. The amount of weathered material is scarcely enough to fill the cracks between the boulders and the degree of leaching is very low, as shown by the extraordinarily high amounts of phosphorus and potassium and exchangeable calcium and potassium in the weathered material. The soils show the least degree of organization of fabric, and it appears that trees are

TABLE 1

The Distinguishing Features of the Land-Systems and their Significance for the Age of the Basalts

Land-Systems	Distinguishing Features of the Patterns	Possible Age of Basalt
Eccles	Rugged stony rises with skeletal brown earths	Holocene, and the most recent of the series
Girringurrup	Smoothly-rounded stony rises with infilled swales	Holocene and earlier than Eccles basalt
Strathkellar	Undifferentiated soil profiles with moderate buckshot	Middle- or Upper-Pleistocene, and later than Dunkeld basalt
Dunkeld	Solodic soils with abundant buckshot	Middle- or Upper-Pleistocene
Cobbobboonee and Greenwald	Residual ortstein, in perched positions, together with krasnozems	Lower-Pleistocene
Hamilton and Branxholme	Thick zone of kaolinitic weathering in upper positions of landscape	Middle- or Upper-Pliocene

still in the late stages of their first colonization on parts of the land-system. A radiocarbon dating of the bottom of the peat in the Condah Swamp would probably indicate the age of the basalt, because the extrusion of the latter caused the blocking of drainage which started the formation of the peat.

Further Applications of This Approach

The relative order of what may prove to be six periods of extrusion of basalt on the W. edge of the basaltic plains has been suggested by considering the patterns of soil and residual weathering products. The distinguishing features of these patterns, and the age of basalt which they suggest, are given in Table 1.

It is suggested that this kind of approach, using consistent patterns of a number of features of the environment, may be usefully applied to the whole extensive basaltic plain of W. Victoria.

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References

BOUTAKOFF, N., 1952. The structural pattern of South-Western Victoria. *Min. Geol. Journ. Vict.* 4 (6).

————, 1963. Geology and geomorphology of the Portland area. *Memoir No. 22, Dept of Mines, Victoria.*

BUTLER, B. E., 1959. Periodic phenomena in landscapes as a basis for soil studies. *CSIRO Austr. Div. of Soils Soil Publ.* No. 14.

GIBBONS, F. R., and DOWNES, R. G., 1964. A study of the land in South-Western Victoria. *Soil Conservation Authority of Victoria.* (in press)

GILL, E. D., 1953. Buckshot gravel as a time and climate indicator. *Vict. Nat.* 70: 72-74.

————, 1955. Fluorine-phosphate ratios in relation to the age of the Keilor skull and Tertiary marsupial and other fossils from Western Victoria. *Mem. Nat. Mus. Melb.* 19: 106-125.

————, 1957a. The stratigraphical occurrence and palaeoecology of some Australian Tertiary marsupials. ibid. 21: 135-203.

————, 1957b. The Plio-Pleistocene boundary in Australia. *Aust. J. Sci.* 20: 86-87.

————, 1961. The Pliocene-Pleistocene boundary in Australia. *Internat. Geol. Congr. 20th Sess.*, Sect. 7: 389-395.

HALLSWORTH, E. G., 1952. An interpretation of the soil formations found on basalt in the Richmond-Tweed region of New South Wales. *Aust. J. Agric. Res.* 2: 411-428.

HALLSWORTH, E. G., and COSTIN, A. B., 1953. Studies in pedogenesis in New South Wales; IV. The ironstone soils. *J. Soil Sci.* 4: 24-47.

LEEPER, G. W., NICHOLLS, ANN, and WADHAM, S. M., 1936. Soil and pasture studies in the Mount Gellibrand area, Western District of Victoria. *Proc. Roy. Soc. Vict.* 49: 77-139.

PRESCOTT, J. A., and PENDLETON, R. L., 1952. Laterite and lateritic soils. *Comm. Bur. Soil Sci. Tech. Comm.* 47.

STEPHENS, C. G., 1946. Pedogenesis following the dissection of lateritic regions in Southern Australia. *CSIRO Bull* No. 206.

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VEGETATION OF THE BASALT PLAINS IN WESTERN VICTORIA

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Introductory

Of all the major vegetational provinces in Victoria, the basaltic plains of the W. District are poorest in plant species. From the whole volcanic tract, stretching unbroken for 190 miles between Yan Yean on the extreme E. and Hotspur-Lyons district in the far SW., the total recorded number of higher indigenous plants is at present only 543 species; and it is most unlikely that any future investigations will alter this figure substantially. By comparison, the Brisbane Ra. (a small 'island' of sedimentary Palaeozoic rocks in the E. part of the basaltic area) has 420 species, while the Grampians sandstone (abutting to the NW.) has an exceedingly rich flora embracing 750 species of higher plants—almost one-third of the State's indigenous vegetation.

It may be tempting to explain this poverty in terms of early and sustained pastoral activity. Certainly, the volcanic plains were the first pieces of land to be taken up by squatting families in the late 1830s and early 1840s, and their natural plant cover has been subjected to greater changes than anywhere else in the State. Through much of the basaltic region, native plants are now completely replaced by alien pasture grasses and clovers, crop plants, and a continuing influx of aggressive weeds; even to visualize the original ecological patterns has become difficult. Some basalt species are presumed already extinct, while about 100 others (or 18% of the whole) are now either very rare or localized—e.g. most of the 30 ferns and all but two or three of the 24 orchids. However, the various plant communities in equilibrium before white settlement are indicated by surviving remnants along roadsides and railway tracks, in paddocks too rocky to be cultivated, on a few permanent reservations of forest land, and in the shelter of gorges, cliff crevices or caves. It is apparent that the basalt plains, with associated lava or cinder cones, stony barriers, lakes and streams, never did carry the wealth of species so characteristic of adjoining forests on auriferous hills to the N. and of sandy heathlands toward the coast.

The same lack of variety obtains also among lower cryptogams on basaltic land. E.g., a diligent survey of the moss flora has been rewarded by only about 85 species, compared with more than 120 species in the County of Normanby (at the W. boundary of the plains), and 140 in the County of Buln Buln which includes Wilson's Promontory. Figures are not available for fungi or lichens, but casual inspection would strongly suggest a similar paucity. Only among the land and freshwater algae does diversity of kind seem to approach, or exceed, that in other vegetation provinces.

Land Forms and Plant Cover within the Volcanic Belt

If the volcanic terrain of W. Victoria is young geologically and rather deficient from a floristic point of view, it is at least of equal or greater structural complexity than either the sandy coastal plains carrying heathland or the forested hills of Palaeozoic sedimentary rocks. Plant formations vary all the way from tussock grassland through savannah to woodland and high forest, depending upon physiography and climate. On the basaltic tract between Melbourne and L. Corangamite, the annual rainfall does not rise above 20 in., with an average at Little R. of only 16·6 in.; but westward from Camperdown there is a significant increase to 32·6 in. at Heywood. In a small area around Lyonville and Trentham, the more elevated basalt at 2,000-2,300 ft receives an annual precipitation exceeding 40 in. (it is 43·6 at Lyonville), and mean winter temperatures here are about 10°F. lower than on basalt plains against the coast. This wide climatic range is paralleled by an improvement in soil quality, from stony drylands N. and W. of Port Phillip to the deep, very fertile chocolate loams of Bungaree, Newlyn, and Trentham districts along the Divide. The effects of climate, soil, and topography are dramatically portrayed in vegetational cover. It is convenient to summarize the characteristics of plant life on the volcanic tracts of W. Victoria with reference to major physiographical features, thus:

DRIER STONY BASALT PLAINS

The Keilor Plains through which flow the Maribyrnong R., Werribee R., and Little R., also the plains extending between Geelong and Cressy, are and always have been open, dry tussock grassland, without any arboreal growth or even tall shrubs. A few trees of stunted habit and poor form (viz. *Eucalyptus camaldulensis* and *E. ovata*) occur along streams or in depressions where water may tend to persist. Windbreaks of Monterey Cypress, pines, or various eucalypts have been rather extensively planted and are now a landscape feature on private holdings throughout the region.

R. T. Patton (1930), in discussing the factors responsible for tree growth in Victoria, described the basaltic plains as 'strongly antagonistic to trees', while C. S. Sutton (1916-17) emphasized that 'a rainfall of at least 20 inches in about 100 days is required to favour forest growth'. No part of this drier E. sector of the volcanic belt receives 20 in. in 300 days and, during the 7 months of September to March (inclusive), evaporation greatly exceeds precipitation. A long summer drought is normal, temperatures of more than 100°F. may be experienced in January and February, strong dry winds are frequent, and soils are often shallow with sheets of volcanic rock or boulders outcropping at the surface. However, under even hotter, drier conditions prevailing in the Mallee there is an extensive development of eucalypts, acacias, and other woody plants of great variety; e.g. some 60 species of taller shrubs and trees inhabit the sand-hills of the Kulkyne National Park (N. from Ouyen). The virtual treelessness of the Keilor and Cressy lava plains cannot be attributable to climate alone, but rather to its unfavourable combination with heavier clayey soils and a general flatness of terrain. Over the whole volcanic region, whether moist or dry, the woody species number less than 14% of the total flora. The State's most northerly and driest area of Late Tertiary to Recent lava flows is to be found along the Loddon Valley, northwesterly from Bendigo, where the rainfall at Bridgewater registers only 16·3 in.—an environment even harsher for woody plants than obtains on the W. of Port Phillip.

As in all large grasslands of the world, trees occur wherever these Victorian plains abut on mountain ranges, and a slow transition from grassland to woodland is apparent along some boundaries; even species belonging to other provinces (e.g. coastal heath or box forest) may encroach upon the basalt plain.

The herbaceous perennial is characteristic and dominant everywhere on basalt grassland, taking the life form of a dense tussock (with much reduced leaf surfaces), a rosette plant or creeping mat, a low semi-shrub or perennating tuber (as in the sundews, lilies, and orchids). A small percentage (about 9%) of species consists of annuals or minute emphemerals which can grow and flower during the few months that moisture is available. The grasses and associate herbs do not form a continuous turf, but are disposed in isolated tufts with much bare ground between individuals. Humus is rarely present in appreciable amounts.

It is in floristic composition, however, that the Keilor basalt plains contrast so strikingly with adjoining formations. The families Compositae and Gramineae are by far the largest groups, and together their representative species make up 23·2% —almost a quarter—of the whole flora. In numbers of individual plants they are also preeminent and, as Patton (1936) remarked, 'each dominates the landscape at its respective flowering period'. The genus *Danthonia* has no fewer than 12 species on the basalt, while the daisy genus *Brachycome* has 10. These two families happen also to be the largest throughout the State; but families consisting wholly of woody plants, e.g. *Myrtaceae, Mimosaceae, Proteaceae,* and *Epacridaceae,* are very feebly if at all represented on the plains. Such large Victorian genera as *Pultenaea* and *Hibbertia* are absent altogether; indeed, to quote Patton (1936) again, 'the uniqueness of this flora lies in the absence or sparseness of characteristic Australian genera and families'. Only about 10 species (including the showy but now rare *Rutidosis leptorhynchoides*) appear to be confined to the basalt plains; by far the greater number of species are plants of very wide range in and beyond Victoria, some being ecological 'wides'.

Vegetative activity commences when autumn rains thoroughly moisten the dry, cracked soil, and it continues rather slowly through the colder days of winter; but growth is much accelerated during spring, and there is a burst of floral activity from early October when evaporation begins greatly to exceed the rainfall. It is then that the monotonous facies of the grassland is transformed into carpets of colour—chiefly yellow or white from the massed bloom of *Bulbine, Anguillaria, Goodenia, Brachycome, Calocephalus, Craspedia, Podolepis, Leptorhynchos,* and *Helichrysum* species. Most grasses bloom in November and may cover the landscape with waving inflorescences to 2 ft high or more. From then, as the season advances, floral colour is provided only by late yellow everlastings (*Helichrysum*), the metallic-hued 'blue devil' (*Eryngium*), and austral bluebells (*Wahlenbergia*) which may persist throughout the heat of summer. Growth is practically dormant from December to April when the parched clay opens up in numerous fissures.

WEATHERED BASALT PLAINS, WITH HIGHER RAINFALL

There is no line of demarcation between the dry tussock grassland just described and the wet tussock grassland that may succeed it with increasing rainfall toward the W. Many species are common to both but, in general, *Poa australis* tends to replace *Themeda australis* and *Stipa* species as a dominant grass on moister country. The most noteworthy difference lies in the gradual appearance of tree growth to form either savannah, woodland or forest, and in the greater frequency of lakes or swampy depressions. Around Hamilton, large spreading trees of *Eucalyptus camaldulensis* give a pleasing park-like aspect to the countryside. At Branxholme, 14 miles SW., the basalt has broken down into ironstone rubble that supports a woodland of *E. viminalis* while, at Heywood, forests of *E. obliqua* and other eucalypts become the climax vegetation on basalt. Poorly drained ground with high water-table is, or was, occupied by *E. ovata.*

BASALT BARRIERS (OR 'STONY RISES')

Between Colac and Camperdown, around Mt Napier and Mt Eccles and along Darlot's Ck. the lava flows became broken into alternating ridges and hollows of loose rocks; these fragments, often large and angular, are piled irregularly into barriers (from 10 to 50 ft high) and movement over such terrain can be exceedingly difficult. The basalt has not yet weathered into heavy blackish clay, as usual, and soils are skeletal or lacking, so that these tracts were virtually useless for agriculture. Excepting damage by occasional fires, and the depredations of rabbits, the basaltic barriers probably remain in much the same condition as they were before discovery by white men. Good moisture supply and adequate drainage among the stones have favoured the development of *Eucalyptus viminalis* in extensive pure woodlands. The only associate tree is *Acacia melanoxylon*, but shrubberies of *Helichrysum dendroideum* or the hardy divaricate *Hymenanthera dentata* may be locally conspicuous—particularly around the shore-line of L. Corangamite. Occasional bushes of *Solanum aviculare* are often part of the alliance, while *Plagianthus pulchellus* and even *Olearia argophylla* may be present in deep sheltered hollows. *Pteridium esculentum* and yellow-flowered *Senecio lautus* are ubiquitous and usually prolific after a fire. Shade-loving herbs, several small ferns, and many bryophytes occupy moist rock crevices.

ELEVATED POINTS OF ERUPTION

The gently undulating surface of the volcanic tract is dotted with lava or cinder cones, rising to as much as 1,000 ft above the level of the plain. The last phases of vulcanicity in Victoria seem to have been marked by ejection of scoria or ash—perhaps even within the last few thousand years—and some such depositions are so new geologically as to have precluded the natural establishment of trees. Thus the craters of Red Rock near Colac, Mt Leura at Camperdown, and Mt Greenock near Talbot were virtually bare at the time of their discovery. But the scoria of Mt Franklin near Daylesford carried *Eucalyptus viminalis*, with *Casuarina stricta* and *Banksia marginata*, while Mt Napier was also well timbered with *E. viminalis*.

Breached crater walls, from which the lava flows have now weathered into deep rich loams, were heavily forested. Much of this valuable land has long since been cleared to farming, but reserves of *Eucalytus obliqua* and *E. viminalis* on the steep slopes of Mt Warrenheip and Mt Buninyong (near Ballarat) are indicative of the lofty, good-quality forests that once clothed many volcanic hills. The principal understorey tree, as on the 'Stony Rises', was *Acacia melanoxylon*. Such occasional shade-tolerant shrubs as *Pimelea axiflora, Coprosma hirtella, C. quadrifida*, and *Olearia argophylla* were an adumbration of fern-gully conditions on the higher volcanic slopes; *Dicksonia antarctica* did formerly grow in a few shaded valleys on the sides of lava cones. Some eminences just N. of the Divide, e.g. Spring Hill near Creswick, and Eastern Hill near Eganstown, carried stands of *Eucalyptus pauciflora* with or without *E. obliqua*.

CANYONS AND CAVES

Stream action has often cut deep, gorge-like valleys or canyons through the higher volcanic plateaux. In such situations, and also along the steep 'frozen' edge of some lava flows, thickets of *Hymenanthera dentata* have taken advantage of shelter from wind and of the more abundant moisture supply. This tough bush is frequently accompanied by *Bursaria spinosa*, the herbs *Urtica incisa* and *Sambucus gaudichaudiana*, while *Callistemon paludosus* may be present at the water's edge. The interesting *Discaria pubescens* is a much rarer inhabitant of rocky valleys in basalt, e.g. on Creswick Ck and at Lal Lal Falls; its incidence was discussed by Willis (1955).

In the crevices of escarpments and cliff-faces grow several plants that would be too tender to survive exposure to wind and insolation of the surrounding plains above, notably *Asplenium flabellifolium, Adiantum aethiopicum, Pleurosorus rutifolius, Echinopogon ovatus, Parietaria debilis, Scutellaria humilis,* and *Sigesbeckia orientalis,* also a number of bryophytes. On more exposed ledges, *Bulbine bulbosa, Carpobrotus rossii* (often trailing), *Pelargonium australe,* and *P. rodneyanum* may be conspicuous perching plants. At waterfalls, such as the Wannon, Hopkins, Lal Lal, Moorabool, Glenlyon, Trentham, and Turpin's Falls on the Campaspe, grow a few moisture-loving plants not found elsewhere on the basalt; these embrace several ferns (*Doodia* spp.) and aquatic mosses (species of *Tridontium, Cratoneuropsis, Drepanocladus,* etc.).

The still, cool, humid air of collapsed lava tunnels and caves provides a microclimate in which fern growth may be luxuriant and spectacular. Beauglehole and Learmonth (1957) have given an informative account of the fern flora inhabiting 11 basaltic caves near North Byaduk, where at least 20 species are represented; tree-ferns with trunks up to 18 ft long once flourished in these sheltered caverns, and a few large specimens have still managed to escape despoliation by local residents. Even more remarkable is the very rich moss flora of Byaduk Caves. Among the 62 species recorded from these by A. C. Beauglehole, *Anoectangium bellii* is not known from any other locality in Australia and, until its discovery at Byaduk in 1956, was considered endemic in New Zealand. The saltbush *Rhagodia nutans* may hang from walls and ceilings of open caves, as long festoons or curious curtains of growth up to 10 ft in length.

FRESHWATER STREAMS AND SWAMPS, LAKES, AND PONDS

Water plants comprise true submerged aquatics, marsh species that have only their rooting parts in free water, creeping mud-plants and inhabitants of temporary shallow ponds. All these types are well exemplified on the volcanic tracts of W. Victoria, wherever water is present, but most species are of wide distribution in the State and none is confined to the basalt. Notwithstanding the relatively small area that they occupy in this province, the marsh plants and aquatics make up a considerable portion of the total flora—viz. 84 species, or 15·5% of all higher plants. The two large families Gramineae and Compositae, however, have very few representatives here—only three of the former (*Glyceria australis, Phragmites communis, Amphibromus neesii*) and one of the latter group (viz. *Cotula coronopifolia*). By contrast, the sedge family Cyperaceae, which numbers 37 species in the whole volcanic belt, has 14 species restricted to swamps, marshy ground along streams, or to shallow water at the edge of lakes. Together with *Triglochin procera* and rushes (*Juncus* spp.), these dominate the more westerly swamps such as Black, Wild Dog, Condah, and Buckley's.

Water-loving *Ranunculus* species (e.g. *R. rivularis, R. inundatus,* and *R. glabrifolius*) provide a touch of colour on drying margins during late spring. Through the summer months *Lythrum salicaria* rears decorative magenta flower-spikes to 4 ft.

A dense shrubbery of *Leptospermum lanigerum* frequently marks out waterways through swampy land. It may provide a habitat for *Gahnia clarkei* (probably the largest cyperaceous plant in Australia), as at Hawkesdale, Tower Hill, and L. Condah. A surprising occurrence at L. Elingamite, near Terang, is *Notelaea ligustrina*—usually a shrub of mountain gullies.

All 5 species of *Myriophyllum* are aquatic and in the very deep waters of L. Purrumbete, occupying an explosion crater near Camperdown, the robust floating stems of *M. propinquum* may stretch for yards.

SALINE LAKES AND SALT-MARSHES

Associated with brackish water or lakes of high salinity, e.g. L. Corangamite, are 16 species of halophytes most of which normally grow within the influence of the sea. These belong to a dozen different plant families, but are usually modified for such an environment by developing succulent foliage (or stems) and high osmotic pressures in the cell-sap, viz. *Salicornia australasica, Suaeda australis, Pratia platycalyx, Wilsonia rotundifolia,* and *Selliera radicans. Angianthus preissianus* and *Cotula vulgaris* are ephemerals of drying saline mud; *Mimulus repens*, with attractive mauve blooms, may form extensive mats over the mud around saline depressions, while *Ruppia maritima, Lepilaena preissii* and *Potamogeton pectinatus* are totally submerged aquatics of brackish water.

Brief Outline of Botanical Investigation

The earliest white man to see Victorian basalt plains was Surveyor-General Charles Grimes who discovered the Yarra R. on 2 February 1803. Hamilton Hume and William E. Hovell were the first to walk across these plains, proceeding from Beveridge to Corio Bay in the middle of December 1824. Neither party collected botanical specimens, nor made any significant observations on the flora. It remained for Major Thomas L. Mitchell (1838) to publish the first account of basaltic vegetation in W. Victoria. Mitchell spent a total of 28 days on volcanic terrain from the time he entered it, along the upper Crawford R. (near present Hotspur) on 23 August 1836, until he left the 'trap rocks' in Redesdale district, near the Campaspe R., on 5 October. He was thus fortunate to observe the lush growth and abundant flowering through early spring, and in a good season.

On the Crawford R. basalt, Mitchell found rich soil carrying stringybark eucalypts 'of enormous size'; around Heywood, Mitchell's 'trap ranges' were also well timbered. Between 4 & 10 September he climbed lofty Mt Napier on four occasions, commenting on the luxuriant growth of trees and shrubs almost to the crater rim —the whole summit of the mountain is now bare, showing the effects of successive fires and unrestricted grazing by stock and rabbits. On 7 September, Mitchell collected the type material of an undescribed native pea, *Dillwynia hispida*, at Camp Ck (about half-way between Branxholme and Byaduk). This showy flower has been noted recently at Shelford on the Leigh R., but it is far from common on volcanic soils.

Whilst journeying from Grange Burn Ck toward Mt Sturgeon at the S. extremity of the Grampians, he was impressed by the 'flowery plains' which yielded several kinds of orchids in the genus *Caladenia* (blue, yellow, pink and brown). The 20-22 September found Mitchell between Greenvale and Buangor on 'open downs thickly clothed with excellent grass'. At Middle Ck, toward the Loddon R. at Newstead, he discovered the curious Anchor plant (*Discaria pubescens*), also *Caladenia dilatata*, and a species of *Diuris* growing on 'open plains'.

During the second week of May 1854, William Howitt traversed the elevated volcanic lands between Castlemaine and Creswick. He published (1855) a short account of 'these high green downs', with some references to the 'thinly scattered' she-oaks, banksias, and acacias then present. Five months later, Professor W. H. Harvey—visiting algologist from Dublin—made a hurried excursion to Tower Hill near Koroit, commenting (1869) on 5 plant species that he saw growing around the crater lake. A picture of the unoccupied Camperdown district, in June 1839, emerges from reminiscences written down by George Russell during 1881-84 and published under the editorship of P. L. Brown (1935):

> We were struck with the great extent of deep rich soil, many hundred acres being almost without a tree on them and ready to be turned over by the plough. They were covered with a rich sward of kangaroo-grass. The country around had been all burnt by bush-fires during the previous summer, and the grass that was now growing on the ground was as green and luxuriant as if it had been a field of grain. The kangaroos here were very numerous; I saw more than I had ever seen before. They came down from the wooded hills near Mount Leura in the afternoons to feed on the green grass.

After Mitchell's pioneering work of 1836, there had been no substantial botanizing anywhere in Victoria throughout the next 16 years, except for a few collections (now at Kew, England) made in the vicinity of Melbourne by F. M. Adamson during the 1840s and a larger simultaneous collection (also at Kew) assembled by J. G. Robertson of Wando Vale near Casterton. Then came Dr Ferdinand J. H. Mueller, who reached Victoria in August 1852, and was appointed first Colonial Botanist the following January. Within a very few months he had studied the vegetation surrounding Melbourne, including representative basalt plants at Darebin Ck and Merri Ck. Earlier in January 1853, he traversed and collected on the volcanic area 'between the Loddon River and Creswick Ck', also around Ballarat and Ballan.

From 1-13 November 1853, Mueller passed through the greater part of the W. District plains, visiting Bacchus Marsh, L. Colac, and Hopkins R. on his way from Melbourne to the Grampians. For a week in February 1874 and a month in March 1875, he was again in the volcanic region between Colac and Mt Elephant. Among the many plants collected were the minute duckweed *Wolffia arrhiza* on swamps near Mt Emu (a new Australian record) and, from near L. Corangamite, the type of a new peppercress *Lepidium dubium* which has never been rediscovered. In September 1875, Mueller visited Warrnambool and Belfast, and six months later he was on Mt Warrenheip near Ballarat—apparently his last collecting on a volcanic area W. of Melbourne.

C. Whilhelmi, also en route to the Grampians, collected a few plants on Mt Rouse at Penshurst in January 1857. During the 1850s, and later, Dr Daniel Curdie (of 'Tandarook' near Camperdown) was in contact with Mueller, sending collections from his district—chiefly along Curdie's R. These specimens have been preserved in the National Herbarium of Victoria, as have those of William Allitt who collected around Portland in the 1860s and 1870s. Allitt was the first Curator of Portland Botanic Garden, and among his numerous consignments to Mueller were specimens from the basalt barriers and swamps along Darlot's Ck; many of the Allitt collections are cited throughout the 7 volumes of G. Bentham's *Flora Australiensis* (1863-78). Between 1860 and 1884, Rev. W. T. Whan gathered plants from a wide area around Skipton, where he was in charge of the Presbyterian Church, and some of his specimens (in Melbourne) are from the basalt plains.

The Rev. F. R. M. Wilson (1887), in the three years 1884-87, made a lichen collection of about 10,000 specimens from many parts of the Colony, including basaltic tracts at Birregurra, Lismore, Camperdown, Cobden, Terang, and Warrnambool. His main collection is now in the Sydney Herbarium, but there are numerous duplicates in Melbourne. Between 1892 and 1905, R. A. Bastow collected bryophytes and lichens extensively in S. Victoria. His material (at Melbourne Herbarium) includes many specimens from basalt rocks at Merri Ck (1892 and 1896), Braybrook (1900 and 1905), Buninyong (1898), and Rowsley (1901).

The Rev. H. M. R. Rupp (of later orchidological fame) prepared local plant lists for the Buninyong and Kingston districts (including volcanic tracts) in 1896 and, in 1898, for the Beeac area which is almost entirely basaltic. These valuable MS. records are also housed at Melbourne Herbarium.

H. B. Williamson, a country school teacher stationed at Hawkesdale for 12 years

(1893-1904 inclusive), made a large district collection. Many plants of the basalt were incorporated and, at his death in January 1931, this material all came to the National Herbarium.

Interest in plants of basaltic areas was greatly stimulated by the researches of Dr C. S. Sutton (1916-17), whose 'Sketch of the Keilor Plains Flora' (with appended 'Census of Keilor Plains Flora') is a pioneering work on the ecology of this major vegetation province. Sutton listed 444 species from the Keilor section of the W. District plains; but his figure is inordinately high, including, as it does, some old and very dubious records—viz. the genera *Phylloglossum, Tetraria, Scleranthus, Blennodia, Lasiopetalum, Hibbertia, Prostanthera,* and *Podosperma*—as well as a large number of non-basaltic plants from adjacent formations. Of the latter may be mentioned: littoral and entirely coastal genera (e.g. *Disphyma* which occurs also on Mallee salt-pans, *Tetragonia, Cakile, Limonium, Avicennia,* and several marine phanerogams), plants peculiar to Palaeozoic inliers in the basalt, whether granitic or sedimentary (notably species of *Aphelia, Chamaescilla, Glossodia, Grevillea, Bassia, Geococcus, Daviesia, Pultenaea, Templetonia, Xanthosia,* and *Lissanthe*), and a few species now regarded as naturalized aliens (*Parapholis, Monerma, Emex,* and *Polycarpon*). Altogether, Sutton's list can be reduced by 114 species; so that the number of undoubtedly basaltic species for the Keilor sector would stand at 330.

The most advanced ecological paper on the basaltic flora is by R. T. Patton (1935) who discusses in detail its characteristics, composition, and habitat. The present writer has drawn freely from information summarized in this important paper. Both Patton and Sutton describe the vegetation of the Basalt Plains as 'Steppe', but there are difficulties in applying the term here. True Steppe of the northern hemisphere is subject to a dormancy both in late summer and again in winter (which is severe); the Victorian basalt grasslands, on the other hand, are dormant only during the droughty summer-autumn period. Two records published by Patton (1935, p. 176) are open to question and may be the result of misidentifications, viz. *Thysanotus tuberosus* (listed as of frequent occurrence) and *Bredemeyera ericinum.* No other collector seems ever to have noted either plant on Newer Basalt, and they are prefixed by a query in the census herewith appended.

The plant life on Lady Julia Percy Is. (a detached point of eruption in Portland Bay 12 miles W. of Port Fairy) was investigated by the McCoy Society from Melbourne University in the summer of 1935-36. Notes on the general vegetation were compiled by A. G. Edmonds (1937), a list of vascular plants and algae being contributed by R. T. Patton (1937). The indigenous vasculares were recorded as 26 species, but 5 of these (viz. his *Asplenium scleroprium, Mesembryanthemum australe, Lepidium foliosum, Alyxia buxifolia, Calocephalus brownii*) are coastal plants growing only within the influence of salt spray and independent of any particular geological formation; they are excluded from the present survey of basalt plants. The McCoy Society also carried out extensive hydrological studies, including a survey of the aquatic and marginal flora, at L. Purrumbete near Camperdown in 1952; but no account of this work has yet been published.

Floristic explorations throughout the County of Normanby have been made by A. Cliff. Beauglehole (of Gorae West) since 1940. His paper 'Ferns of the Portland District' (1944) includes items peculiar to the basalt region of the far SW. In collaboration with Noel F. Learmonth (1949 & 1956), he has recorded observations on the fern floras of the Darlot's Ck and Byaduk lava caves. Beauglehole has also lodged at the National Herbarium MS. lists of species noted at Mt Eccles (Apr. & Oct. 1960) and at Mt Napier (Dec. 1960). Miss H. I. Aston has listed the present floras of Mt Eccles (Oct. 1960) and Tower Hill near Koroit (Dec. 1960). Her lists and those of the present writer (for Maribyrnong R. and Sydenham wildflower sanctuary, Inverleigh and Shelford, Lal Lal and Moorabool Falls, Creswick, Colac and Stony Rises, Mt Napier and Mt Eccles, Byaduk Caves, Wannon Falls, and the Loddon R. at Bridgewater) are also available in MSS. at the Melbourne Herbarium. Finally, Willis (1962), while discussing the 'Land Flora of Victoria', has notes on the W. volcanic plains; and in 1963 he gives some account of the past and present vegetation on Mt Napier.

References

Beauglehole, A. C., 1944. Ferns of the Portland District. *Vict. Nat.* 60: 193-195.

Beauglehole, A. C., and Learmonth, N. F., 1949. Rediscovery of a long-lost fern. ibid. 66: 129-131.

————, 1956. Fern flora of the Portland District. ibid. 73: 40-42.

————, 1957. The Byaduk Caves. ibid. 73: 204-210.

Brown, P. L., 1935. *Narrative of George Russell*, p. 190.

Edmonds, A. G., 1937. Reports of McCoy Society Expedition to Lady Julia Percy Island, 6. Vegetation. *Proc. Roy. Soc. Vict.* 49: 349-351.

Harvey, W. H., 1869. *Memoir of W. H. Harvey, with Selections from his Journal and Correspondence.*

Howitt, W., 1855. *Land, Labour and Gold; or Two Years in Victoria.* 2: 278-279.

Mitchell, T. L., 1838. *Three Expeditions into the Interior of Eastern Australia.* 2: 229-285.

Patton, R. T., 1930. Factors controlling the distribution of trees in Victoria. *Proc. Roy. Soc. Vict.* 42: 154-210.

————, 1936. Ecological studies in Victoria; Part IV—Basalt Plains Association. ibid. 48: 172-190.

————, 1937. Reports of McCoy Society Expedition to Lady Julia Percy Island, 9. List of vascular plants & 10. List of Algae. ibid. 49: 362-363.

Sutton, C. S., 1916-1917. A sketch of the Keilor Plains flora. *Vict. Nat.* 33: 112-123, 128-143.

Willis, J. H., 1955. The Australian Anchor Plant (*Discaria pubescens*). ibid. 72: 51-55.

————, 1962. Land flora of Victoria. *Victorian Year Book* 76: 13-14.

————, 1963. Notes on the history and vegetation of Mount Napier. *Vict. Nat.* 80: 162-168.

Wilson, F. R. M., 1887. Notes on a few Victorian lichens. ibid. 4: 83-87.

CENSUS OF VASCULAR FLORA INDIGENOUS TO VOLCANIC TRACTS OF WESTERN VICTORIA

The present enumeration of families, genera, and species conforms to the systematic arrangement adopted by Engler and Prantl in *Die Natürlichen Pflanzenfamilien* (1887-1902), but nomenclature has been brought up to date. Known occurrences in 15 representative areas throughout the basaltic region are indicated by the following abbreviations which follow the author citation for each name:

KP	Keilor Plains (bounded approximately by Melbourne, Yan Yean, Beveridge, Sunbury, Melton, Rowsley, Ripley, You Yangs and Little R.)
S	Shelford district (including Inverleigh and Warrambine Ck)
LF	Lal Lal and Moorabool Falls
P	Piggoreet and Devil's Kitchen
LB	L. Burrumbeet
SR	Stony Rises (between Pirron Yallock and Weerite) and Mt Porndon
TH	Tower Hill near Koroit
H	Hawkesdale district
N	Mt Napier Reserve
BC	Byaduk Caves
E	Mt Eccles National Park
JP	Lady Julia Percy Island
WF	Wannon Falls near Hamilton
C	Creswick-Clunes-Campbelltown area
B	Bridgewater

aq. signifies an aquatic or marsh plant (including halophytes)

Other localities are written in full against species having a very restricted range on the basalt.

PTERIDOPHYTA

OPHIOGLOSSACEÆ	
Ophioglossum coriaceum A. Cunn.	KP, BC, E, C
HYMENOPHYLLACEÆ	
Hymenophyllum cupressiforme Labill.	SR, BC
Mecodium australe (Willd.) Copeland	BC
Polyphlebium venosum (R. Br.) Copeland	BC, E
DICKSONIACEÆ	
Dicksonia antarctica Labill.	SR, BC
DENNSTÆDTIACEÆ	
Hypolepis rugosula (Labill.) J. Sm.	BC
Pteridium esculentum (Forst. f.) Nakai	KP, S, LF, P, LB, SR, TH, N, BC, E, JP, WF, C
Histiopteris incisa (Thunb.) J. Sm.	BC
ADIANTACEÆ	
Anogramma leptophylla (L.) Link	LF, LB, SR, Hexham, N, BC, E
Adiantum aethiopicum L.	KP, LF, SR, TH, N, BC, E
Pteris tremula R. Br.	SR, TH, BC
Pellaea falcata (R. Br.) Fée	KP, LF, SR, BC, E, Darlot's Ck, Kooroocheang Falls, Turpin's Falls
Cheilanthes tenuifolia (Burm. f.) Swartz	KP, S, LF, TH, N, BC, E, WF, C
POLYPODIACEÆ	
Microsorium diversifolium (Willd.) Copeland	BC
ASPLENIACEÆ	
Asplenium flabellifolium Cav.	KP, LF, LB, SR, N, BC, E, WF, C
A. adiantoides (L.) Lam.	BC, Darlot's Ck
A. bulbiferum Forst. f.	SR, BC, E, Mt Rouse
Pleurosorus rutifolius (R. Br.) Fée	KP, S, LF, LB, SR, N, BC, E, WF, C
ATHYRIACEÆ	
Athyrium australe C. Presl	BC

ASPIDIACEÆ	
Polystichum proliferum (R. Br.) C. Presl	SR, BC, E
Lastreopsis shepherdii (Kunze ex Mett.) M. D. Tindale	SR, BC, Tyrendarra caves
BLECHNACEÆ	
Blechnum aggregatum (Colenso) M. D. Tindale	BC
B. minus (R. Br.) Ettings.	LF
Doodia caudata (Cav.) R. Br.	KP (Broadmeadows), LF, WF
D. media R. Br.	KP (Somerton)
MARSILEACEÆ	
Marsilea drummondii A. Br.	aq., KP, S, B
M. hirsuta R. Br.	aq., LF, Darlot's Ck, Carisbrook
Pilularia novæ-hollandiæ A. Br.	aq., KP
AZOLLACEÆ	
Azolla filiculoides Lam.	aq., KP, SR, C (Kooroocheang)
ISOËTACEÆ	
Isoëtes drummondii A. Br.	aq., H, C (Glendonald Ck)
SPERMATOPHYTA—GYMNOSPERMÆ	
CUPRESSACEÆ	
Callitris columellaris F. Muell.	KP (Jackson's Ck), B
SPERMATOPHYTA—ANGIOSPERMÆ	
TYPHACEÆ	
Typha angustifolia L.	aq., KP, S, SR, TH, C
SPARGANIACEÆ	
Sparganium ramosum Huds.	aq., Mt Emu Ck, Merri R.
POTAMOGETONACEÆ	
Potamogeton sulcatus A. Bennett	aq., C
P. tricarinatus F. Muell. & A. Bennett	aq., KP, C (Australasian Mine)
P. ochreatus Raoul	aq., KP, Shaw R. near Orford
P. pectinatus L.	aq., KP, TH, Moyne R.
P. crispus L.	aq., S, L. Colac, Moyne R., Merri R.
P. perfoliatus L.	aq., Hopkins R. Falls, Panmure
RUPPIACEÆ	
Ruppia maritima L.	aq., KP, TH, L. Corangamite and nearby lakes, L. Learmonth, Nerrin Nerrin swamps
ZANNICHELLIACEÆ	
Lepilaena bilocularis T. Kirk	aq., L. Calvert, L. Colac, Derrinallum
L. preissii (Lehm.) F. Muell.	aq., KP (Altona), L. Modewarre
L. cylindrocarpa (Körnicke) Benth.	aq., near You Yangs, L. Martin near Cressy, Nerrin Nerrin swamps, L. Murdeduke
JUNCAGINACEÆ	
Triglochin procera R. Br.	aq., KP, S, LF, TH, WF, C, etc.
T. striata Ruiz & Pav.	KP, S, SR, TH, C
T. centrocarpa Hook.	H, WF
ALISMATAECEÆ	
Alisma plantago-aquatica L.	aq., KP
Damasonium minus (R. Br.) Buch.	aq., KP (Little R.)
HYDROCHARITACEÆ	
Ottelia ovalifolia (R. Br.) L. C. Rich.	aq., KP, SR (Pirron Yallock Ck), C (Kingston)
Vallisneria spiralis L.	aq., KP, S, L. Elingamite, Hepburn's Lagoon
GRAMINEÆ	
Microlæna stipoides (Labill.) R. Br.	KP, S, LF, P, TH, E
Puccinellia stricta (Hook f.) C. Blom	KP (salt marshes), Colac
Poa australis R. Br. (agg.)	KP, S, LF, P, SR, TH, N, BC, E, JP, WF, C
Festuca hookeriana F. Muell. ex Hook. f.	H

Glyceria australis C. E. Hubbard	aq., KP, LF, SR, Ballan, C
Agropyron scabrum (Labill.) Pal. Beauv.	KP, S, LF, P, LB, SR, N, E, WF, C
Amphibromus neesii Steud.	aq., KP, C, B
Dichelachne crinita (L. f.) Hook. f.	KP, LF, N, E, JP, C
D. sciurea (R. Br.) Hook. f.	Mt Buninyong
Deyeuxia quadriseta (Labill.) Benth.	KP
Agrostis rudis Roem. & Schult.	L. Corangamite
A. venusta Trin.	KP
A. aemula R. Br.	KP
A. avenacea J. F. Gmel.	KP, S, LF, LB, SR, TH, N, E, JP, WF, C
Alopecurus geniculatus L.	Penshurst
Echinopogon ovatus (Forst. f.) Pal. Beauv.	KP, LF, SR, N, BC, E
Pentapogon quadrifidus (Labill.) Baill.	H
Eragrostis brownii (Kunth) Nees ex Steud.	KP, S, LF, Colac, C
E. australasica (Steud.) C. E. Hubbard	L. Murdeduke near Winchelsea, L. Goldsmith near Beaufort
Tripogon loliiformis (F. Muell.) C. E. Hubbard	Lara
Chloris truncata R. Br.	KP, S, B
Cynodon dactylon (L.) Pers.	KP, S, LB, SR, C, B
Sporobolus virginicus (L.) Kunth	S
Phragmites communis Trin.	aq., KP, S, LB, SR, TH, C
Enneapogon nigricans (R. Br.) Pal. Beauv.	KP, B
Danthonia induta J. W. Vickery	KP, B
D. geniculata J. M. Black	KP, S, LF, P, LB, SR, H, BC, C
D. carphoides F. Muell. ex Benth.	KP, B
D. richardsonii A. B. Cashmore	KP (Sydenham)
D. linkii Kunth	KP
D. auriculata J. M. Black	KP, C
D. duttoniana A. B. Cashmore	KP, S, C, B
D. procera J. W. Vickery	Tylden
D. eriantha Lindl. in Mitch.	C, B
D. cæspitosa Gaudich.	KP, S, SR, ?N, ?BC, WF, C
D. pilosa R. Br.	KP, LF, P, SR, N, E
D. penicillata (Labill.) Pal. Beauv.	KP, S, LF, P, N, E
Aristida behriana F. Muell.	B
Stipa setacea R. Br.	KP
S. semibarbata R. Br.	KP, S, B
S. aristiglumis F. Muell.	KP, S, B
S. blackii C. E. Hubbard	KP (near Mt Cottrell)
S. variabilis D. K. Hughes	KP, S, LB, SR, C, B
S. compacta D. K. Hughes	TH
S. eremophila F. M. Reader	C (near Cattle Station Hill)
Panicum prolutum F. Muell.	KP, B
P. effusum R. Br.	KP (Little R.), Lara
Paspalum distichum L.	aq., KP, S, C, B
Hemarthria uncinata R. Br.	KP, E, C
Dichanthium sericeum (R. Br.) A. Camus	KP, C (Creswick Ck Gorge)
Themeda australis (R. Br.) Stapf	KP, S, LF, E, C, B
Imperata cylindrica (L.) Pal. Beauv.	SR

CYPERACEÆ

Cyperus tenellus L. f.	KP, P, H
C. lucidus R. Br.	aq., SR, Colac, WF
C. gunnii Hook. f.	LF
C. sanguinolentus Vahl	Lara
Scirpus americanus Pers.	aq., KP, P, SR, TH, Mt Emu Ck
S. nodosus Rottb.	KP, S, P, LB, TH, JP, WF
S. validus Vahl	aq., KP, S, LF, E
S. maritimus L.	aq., KP, S, SR, Colac
S. fluitans L.	aq., KP
S. antarcticus L.	KP, N, E, C
S. cernuus Vahl	TH, E

S. victoriensis N. A. Wakefield	KP (Werribee), C (Glendonald Ck)
S. inundatus (R. Br.) Poir.	aq., KP, LF, P, SR, WF, C
S. platycarpus S. T. Blake	KP (Sydenham), Turpin's Falls
Eleocharis sphacelata R. Br.	aq., KP
E. acuta R. Br.	aq., KP, S, LF, LB, TH, C, B
E. pusilla R. Br.	KP (Sydenham), Mt Emu Ck, H, C, B
E. gracilis R. Br.	H
Schœnus breviculmis Benth.	KP (St Albans—rare)
S. nitens (R. Br.) Poir.	TH, Mt Emu Ck
S. apogon Roem. & Schult.	KP, LF, WF, C
S. latelaminatus Kükenth.	H
Cladium procerum S. T. Blake	aq., TH
C. articulatum R. Br.	aq., L. Terang
Gahnia clarkei G. Benl	TH, H, L. Condah, L. Elingamite
G. filum (Labill.) F. Muell.	aq., KP, H
Lepidosperma laterale R. Br.	KP
Carex appressa R. Br.	aq., KP, LF, P, SR, TH, E, WF, C
C. tereticaulis F. Muell.	KP, H, C
C. inversa R. Br.	KP, E, B
C. gaudichaudiana Kunth	LF, C
C. iynx E. Nelmes	L. Corangamite
C. fascicularis Soland. ex Boott	aq., KP, SR, C (Birch's Ck)
C. breviculmis R. Br.	KP, S, LF, H, N
C. bichenoviana Boott	KP (St Albans, Little R.), Mt Emu Ck
C. brownii Tuckerm.	H
C. gunniana Boott	aq., H
LEMNACEÆ	
Lemna minor L.	aq., KP, S, SR (Kooroocheang)
L. trisulca L.	aq., H, L. Terang, L. Purrumbete, Merri R.
Wolffia arrhiza (L.) Hork. ex Wimm.	aq., KP, Mt Emu Ck, SR, L. Terang
CENTROLEPIDACEÆ	
Trithuria submersa Hook. f.	aq., Mt Emu Ck, H
Centrolepis strigosa (R. Br.) Roem. & Schult.	KP (near You Yangs), H
C. aristata (R. Br.) Roem. & Schult.	H
C. glabra (F. Muell.) Hieron.	Mt Emu Ck, H
Aphelia gracilis Sond.	H
JUNCACEÆ	
Luzula campestris (L.) DC.	KP, S, SR, N, E, C
Juncus pauciflorus R. Br.	LF, P, TH, WF
J. pallidus R. Br.	KP, LF, P, SR, TH, JP, WF, C
J. polyanthemos Buch.	KP, SR, TH, E, ?WF
J. australis Hook. f.	LF, P
J. filicaulis Buch.	?S, LF
J. radula Buch.	KP, SR
J. subsecundus N. A. Wakefield	B
J. cæspiticius E. Mey. in Lehm.	TH, H, WF
J. bufonius L.	KP, LF, P, E, B
J. plebeius R. Br.	KP, LF, C
J. holoschoenus R. Br.	aq., KP, C
J. prismatocarpus R. Br.	aq., H
LILIACEÆ	
Lomandra micrantha (Endl.) Ewart	KP (Stony Ck)
L. filiformis (Thunb.) Britten	KP, S, H, B
L. longifolia Labill.	LF, P, SR, C
L. glauca (R. Br.) Ewart	KP (Werribee), H
Caesia vittata R. Br.	KP, H
Arthropodium minus R. Br.	KP, C (Australasian Mine)
Dichopogon strictus (R. Br.) J. G. Baker	KP
Thysanotus patersonii R. Br.	KP
? *T. tuberosus* R. Br.	KP
Bulbine bulbosa (R. Br.) Haw.	KP, LF, Hamilton, C

Tricoryne elatior R. Br.	KP, Colac, C
Dianella tasmanica Hook. f.	LF, SR, WF
D. revoluta R. Br.	KP, S, SR, BC, E, WF
D. lævis R. Br.	KP, S, H
Anguillaria dioica R. Br.	KP, S, N, C
Burchardia umbellata R. Br.	KP, H
HYPOXIDACEÆ	
Hypoxis glabella R. Br.	KP, E, C
ORCHIDACEÆ	
Thelymitra aristata Lindl.	KP
T. ixioides Swartz	KP
Gastrodia sesamoides R. Br.	Mt Buninyong
Diuris punctata Sm.	KP, WF (? extinct)
D. palustris Lindl.	KP (Sydenham, Laverton & Lara)
D. sulphurea R. Br.	KP (Little R.)
D. pedunculata R. Br.	KP, H
D. fastidiosa R. S. Rogers	KP (Tottenham—? extinct)
Microtis unifolia (Forst. f.) Reichenb. f.	KP (Sydenham), H
Prasophyllum fuscum R. Br.	KP, C (N. Creswick)
P. odoratum R. S. Rogers	KP, Lara
P. gracile R. S. Rogers	H
Chiloglottis reflexa (Labill.) Druce	E
Acianthus exsertus R. Br.	KP, H, ?E
Eriochilus cucullatus (Labill.) Reichenb. f.	KP (Bulla)
Corybas sp.	E
Pterostylis truncata R. D. FitzG.	KP (Tottenham-Sunshine)
P. pedunculata R. Br.	E
P. nutans R. Br.	E, WF
P. curta R. Br.	LB, WF
P. cycnocephala R. D. FitzG.	KP
P. mutica R. Br.	KP, H
Spiranthes sinensis (Pers.) Ames	H, Condah Swamp
Dipodium punctatum (Sm.) R. Br.	SR
CASUARINACEÆ	
Casuarina stricta Dryand. in Ait.	KP, S, P, SR, TH, E, C
C. luehmannii R. T. Baker	KP (between Mt Cottrell and Balliang)
C. paludosa Sieber ex Spreng.	Kirkstall near Port Fairy
URTICACEÆ	
Urtica incisa Poir.	KP, LF, SR, TH, BC, E, WF
Parietaria debilis Forst. f.	KP, P, N, BC, E
PROTEACEÆ	
Hakea microcarpa R. Br.	'Towards Mt Elephant'
Banksia marginata Cav.	KP, LF, E, C, Mt Franklin
SANTALACEÆ	
Exocarpos cupressiformis Labill.	KP, Beeac, SR, E
Thesium australe R. Br.	KP (Braybrook, Lancefield)
LORANTHACEÆ	
Amyema preissii (Miq.) van Tiegh.	KP, SR
A. pendula (Sieber ex DC.) van Tiegh.	P, SR, N, E, WF
A. quandang (Lindl.) van Tiegh.	H
Lysiana exocarpi (Behr) van Tiegh.	KP
Muellerina eucalyptoides (DC.) B. A. Barlow	KP, S, E
POLYGONACEÆ	
Rumex brownii Campd.	KP, S, LF, P, LB, SR, TH, N, BC, E, WF, C
R. dumosus A. Cunn. ex Meissn.	KP, S, C
R. bidens R. Br.	aq., KP, S, SR, C (Birch's Ck)
Polygonum plebeium R. Br.	KP, E
P. prostratum R. Br.	KP, S, LF, P, WF, C
P. hydropiper L.	aq., KP
P. minus Huds.	aq., KP, S, LF, E

P. subsessile R. Br.	KP, C (Kingston)
P. strigosum R. Br.	aq., H, C (Kingston)
Muehlenbeckia cunninghamii (Meissn.) F. Muell.	KP, C (? extinct)
CHENOPODIACEÆ	
Rhagodia nutans R. Br.	KP, S, LF, SR, N, BC, E, WF, C
R. parabolica R. Br.	KP
R. baccata (Labill.) M	KP, SR, TH, JP
Chenopodium glaucum L.	KP, S, LB, SR, TH, E, JP
C. pseudomicrophyllum Aellen	KP, E
C. pumilio R. Br.	KP, S, SR
Atriplex semibaccata R. Br.	KP, SR
A. muelleri Benth.	KP
Bassia quinquecuspis (F. Muell.) F. Muell.	KP
Kochia crassiloba R. H. Anderson	KP
K. villosa Lindl.	KP
Enchylaena tomentosa R. Br.	KP (Little R.), JP
Suæda australis (R. Br.) Moq.	KP, SR
Salicornia australasica (Moq.) Hj. Eichler	aq., KP, S, SR, TH, JP, Streatham
AMARATHACEÆ	
Ptilotus spathulatus (R. Br.) Poir.	KP, S, LF, C (Ullina), B
P. macrocephalus (R. Br.) Poir.	KP, S, Cressy
P. erubescens Schlechtendal	Streatham
Alternanthera denticulata R. Br.	KP, LF, C, B
FICOIDACEÆ	
Carpobrotus ? rossii (Haw.) N. E. Br.	KP, S, LF, P, E, JP, WF
PORTULACACEÆ	
Portulaca oleracea L.	KP
Calandrinia calyptrata Hook. f.	KP, N, BC, E, C
Claytonia australasica Hook. f.	aq., KP, SR, Terang, WF, C
Montia fontana L.	aq., H
CARYOPHYLLACEÆ	
Stellaria pungens Brongn.	KP, P
S. palustris Ehrh. ex Retz.	KP, S
Sagina apetala L.	KP, N, E, JP, B
S. procumbens L.	H, E
Spergularia rubra (L.) J. & C. Presl	KP, S, JP, C
S. media (L.) C. Presl	KP (Merri Ck), Colac
? *Scleranthus diander* R. Br.	KP (Werribee)
CERATOPHYLLACEÆ	
Ceratophyllum demersum L.	aq., L. Terang
RANUNCULACEÆ	
Clematis microphylla DC.	KP, S, SR, Beeac
C. aristata R. Br. ex DC.	SR
Myosurus minimus L.	aq., Mt Emu Ck
Ranunculus trichophyllus Chaix	aq., KP, H, Belfast Lough
R. lappaceus Sm.	KP, SR, E
R. rivularis Banks & Soland. ex DC.	aq., KP, SR, E, Belfast Lough, WF
R. inundatus R. Br. ex DC.	aq., LB
R. glabrifolius Hook.	Mt Mercer, 8 mls S. of Beaufort at L. Goldsmith
R. sessiliflorus R. Br. ex DC.	KP, N, BC, E, WF, C
LAURACEÆ	
Cassytha melantha R. Br.	KP (Djerriwarrh Ck), SR
CRUCIFERÆ	
Lepidium dubium Thel.	'Near Mt Elephant' (TYPE)
L. aschersonii Thell.	KP (Williamstown), Cressy, L. Corangamite, Mortlake, Streatham
L. hyssopifolium Desv.	KP, Beeac, H, E, C, B

Cardamine laciniata F. Muell.	KP
C. debilis Banks ex DC.	LF, E
Rorippa islandica (Oeder) Borb.	S
Hymenolobus procumbens (L.) Nutt. ex J. M. Black	KP
Cuphonotus antipodus (F. Muell.) J. M. Black	KP (Werribee), Carisbrook
Droseraceæ	
Drosera whittakeri Planch.	KP, S, WF
D. glanduligera Lehm.	KP
D. auriculata Bakh. ex Planch.	KP
D. peltata Sm. ex Willd.	KP, S
Crassulaceæ	
Crassula peduncularis (Sm.) Meigen	KP, C, B
C. macrantha (Hook. f.) Diels & Pritz.	KP, E, B
C. sieberiana (Schult. & Schult. f.) Druce	KP, S, LF, P, LB, N, E, WF, C
C. helmsii (Kirk) Cockayne	aq., KP, S, LF, SR, TH, WF, C
Pittosporaceæ	
Bursaria spinosa Cav.	KP, S, LF, P, SR, TH, BC, E, WF, B
Rosaceæ	
Rubus triphyllus Thunb.	S, LF, SR, N, E, WF
Aphanes australiana (Rothm.) Rothm.	H, E
Acæna ovina A. Cunn.	KP, S ,LF, SR, N, E
A. anserinifolia (Forst. & Forst. f.) Druce	KP, S, LF, P, SR, TH, N, E, WF, C
Mimosaceæ	
Acacia armata R. Br.	KP, S, H
A. acinacea Lindl.	KP, B
A. retinodes Schlechtendal	KP, P, C (Creswick Ck Gorge)
A. melanoxylon R. Br.	KP, S, LF, P, LB, SR, TH, N, BC, E, WF, C
A. implexa Benth.	KP, Mt Kooroocheang
A. verticillata (L'Hérit.) Willd.	KP, SR, H, WF
A. mearnsii De Wild.	KP, S, LF, P, Colac, N, WF
A. dealbata Link.	KP
Cæsalpiniaceæ	
Cassia eremophila A. Cunn. ex Vog.	KP (Jackson's Ck)
Papilionaceæ	
Daviesia latifolia R. Br. in Ait. f.	H
Eutaxia microphylla (R. Br.) J. M. Black	KP, S, C
Dillwynia hispida Lindl.	S, Camp Ck E. of Branxholme (TYPE)
D. sericea A. Cunn. in Field	KP (Braybrook)
D. cinerascens R. Br.	KP
Bossiæa prostrata R. Br.	KP, H
Goodia lotifolia Salisb.	SR
Lotus australis Andr.	KP, C (Kingston)
L. corniculatus L.	LB, C
Indigofera australis Willd.	KP, Koroit
Psoralea tenax Lindl.	KP
P. parva F. Muell.	KP, Lara, S
Swainsona procumbens (F. Muell.) F. Muell.	C (Lawrence & near Racecourse)
S. oroboides F. Muell. ex Benth.	Lara, Beeac
Desmodium varians (Labill.) Endl.	LF
Glycine clandestina J. Wendl.	KP, LF, E
G. latrobeana (Meissn.) Benth.	KP (Little R.), H, C (N. Creswick)
G. tabacina (Labill.) Benth.	KP (Werribee), Lara, Beeac
Kennedya prostrata R. Br. in Ait. f.	KP, S
Hardenbergia violacea (Schneev.) Stearn	KP
Geraniaceæ	
Geranium pilosum sens. lat. (non. certe Forst. f.)	KP, S, LF, P, LB, SR, TH, N, BC, E, WF, C
Erodium crinitum R. C. Carolin	KP, C

Pelargonium australe Willd.	KP, LF, P, LB, SR, N, BC, E, JP, WF, C
P. rodneyanum Lindl.	KP, S, LF, P
OXALIDACEÆ	
Oxalis corniculata L.	KP, S, LF, P, SR, TH, N, BC, E, WF, C, B
LINACEÆ	
Linum marginale A. Cunn. ex Planch.	KP
ZYGOPHYLLACEÆ	
Zygophyllum glaucum F. Muell.	KP (Jackson's Ck, Werribee)
Tribulus terrestris L.	KP
RUTACEÆ	
Correa glabra Lindl.	KP, P
POLYGALACEÆ	
Comesperma volubile Labill.	H
? *C. ericinum* DC.	KP (St Albans)
C. polygaloides F. Muell.	KP (St Albans, 'near Station Peak')
EUPHORBIACEÆ	
Euphorbia drummondii Boiss.	KP
Poranthera microphylla Brongn.	KP, N, E
STACKHOUSIACEÆ	
Stackhousia monogyna Labill.	KP, H, N
S. viminea Sm. in Rees	KP
SAPINDACEÆ	
Dodonæa cuneata Sm. in Rees	KP, P, SR
RHAMNACEÆ	
Discaria pubescens (Brongn.) Druce	LF, C (Creswick Ck & Birch's Ck)
Cryptandra amara Sm. in Rees	KP (Digger's Rest & Bulla)
Pomaderris aspera Sieber ex DC.	KP (Digger's Rest)
MALVACEÆ	
Lavatera plebeia Sims	KP (Werribee), BC, E
Plagianthus pulchellus (Willd.) A. Gray	KP, S, SR, Mt Emu Ck
Sida corrugata Lindl.	Bacchus Marsh, B
HYPERICACEÆ	
Hypericum gramineum Forst. f.	KP, S, SR, TH, N, BC, E, WF, C
ELATINACEÆ	
Elatine gratioloides A. Cunn.	aq., KP, Colac, H
VIOLACEÆ	
Viola hederacea Labill.	KP, SR, TH, N, E, WF
V. betonicifolia Sm. in Rees	Mt Buninyong, N
Hymenanthera dentata R. Br. ex DC.	KP, S, LF, P, SR, N, BC, WF, C
THYMELÆACEÆ	
Pimelea glauca R. Br.	KP, S, C
P. humilis R. Br.	KP, S
P. serpyllifolia R. Br.	KP, C (Lawrence)
P. curviflora R. Br.	KP, C, B
P. axiflora F. Muell. ex Meissn.	Mt Buninyong
LYTHRACEÆ	
Lythrum salicaria L.	aq., KP (Werribee), LF, H, C (Birch's Ck)
L. hyssopifolia L.	KP, S, SR, TH, C, B
MYRTACEÆ	
Eucalytus ovata Labill.	KP, LF, SR, TH, WF, C
E. viminalis Labill.	KP, LF, P, SR, N, E, WF, Mt Franklin
E. camaldulensis Dehnh.	KP, S, LB, WF, B
E. pauciflora Sieber ex Spreng.	C (Spring & Eganstown Hills)
E. obliqua L'Hérit.	LF, Mt Warrenheip, Clarke's Hill & Spring Hill
E. radiata Sieber ex DC.	KP (Bulla), LF
E. microcarpa (Maiden) Maiden	KP, B

E. melliodora A. Cunn. ex Schauer	KP, B
Leptospermum lanigerum (Ait.) Sm.	KP, S, LF, SR, TH, WF, C (Birch's Ck)
L. juniperinum Sm.	SR
L. obovatum Sweet	WF
Callistemon paludosus F. Muell.	KP, P, C (Birch's Ck)
Melaleuca squarrosa Donn ex Sm.	SR
Calytrix tetragona Labill.	KP (Jackson's Ck & Digger's Rest)
ONAGRACEÆ	
Epilobium junceum Forst. f. ex Spreng.	KP, LF, P, SR, TH, N, E, JP, C, B
E. billardierianum Ser. ex DC.	KP, P, SR, BC, WF, Turpin's Falls
E. hirtigerum A. Cunn.	Turpin's Falls
HALORAGACEÆ	
Haloragis heterophylla Brongn.	KP, S, C, B
H. tetragyna (Labill.) Hook, f.	KP
H. brownii (Hook. f.) Schindl.	aq., H
Myriophyllum propinquum A. Cunn.	aq., KP, LF, TH, L. Purrumbete, WF, C
M. elatinoides Gaudich.	aq., TH, near L. Learmonth
M. verrucosum Lindl.	aq., KP, LB
M. muelleri Sond.	aq., KP, L. Calvert, L. Terangpom
M. integrifolium (Hook. f.) Hook. f.	aq., H
UMBELLIFERÆ	
Centella asiatica (L.) Urban	KP, WF
Hydrocotyle vulgaris L.	aq., TH
H. laxiflora DC.	KP, S, N, E, C
H. pterocarpa F. Muell.	H
H. hirta R. Br. ex A. Rich.	KP, SR, TH, N, E
H. sibthorpioides Lam.	S, LF, TH, E, WF, C
H. tripartita R. Br. ex A. Rich.	KP
H. muscosa R. Br. ex A. Rich.	aq., H
H. callicarpa Bunge in Lehm.	KP, E
H. capillaris F. Muell.	KP
Oreomyrrhis eriopoda (DC.) Hook. f.	KP, C (near Newlyn Reservoir)
Eryngium rostratum Cav.	KP, S, C, B
E. vesiculosum Labill.	KP, S
Daucus glochidiatus (Labill.) Fisch. et al.	KP, N, E
Sium latifolium L.	aq., L. Corangamite, Mt Elephant, Mortlake
Lilaeopsis polyantha (Gandoger) Hj. Eichler	KP, Turpin's Falls
Apium leptophyllum (Pers.) F. Muell. ex Benth	KP (Darebin Ck)
A. prostratum Labill.	aq., KP, S, LF, E, JP, WF
EPACRIDACEÆ	
Astroloma humifusum (Cav.) R. Br.	KP (Bulla)
Acrotriche serrulata (Labill.) R. Br.	LF
A. prostrata F. Muell.	LF, Mt Buninyong
MYRSINACEÆ	
Myrsine howittiana (F. Muell. ex Mez) D. Prain	KP
PRIMULACEÆ	
Samolus repens (Forst. et Forst. f.) Pers.	aq., KP, L. Learmonth, Warrion, L. Goldsmith
OLEACEÆ	
Notelæa ligustrina Vent.	L. Elingamite near Terang
LOGANIACEÆ	
Mitrasacme paradoxa R. Br.	KP (Werribee), Beeac
M. distylis F. Muell.	KP ('beyond Little R.'), H
GENTIANACEÆ	
Centaurium spicatum (Pers.) Druce	KP, L. Goldsmith near Beaufort
Sebaea ovata (Labill.) R. Br.	KP, N, E, C
S. albidiflora F. Muell.	KP, Mt Emu Ck

Menyanthaceæ	
Nymphoides crenatum (F. Muell.) O. Kuntze	aq., 'near L. Colac'
Convolvulaceæ	
Convolvulus erubescens Sims	KP, S, LF, P, C, B
Calystegia sepium (L.) R. Br.	S, Mt Emu Ck, Heywood, C (Kingston)
Dichondra repens Forst. et Forst. f.	KP, S, SR, TH, N, BC, E, JP, WF
Wilsonia rotundifolia Hook.	aq., KP (saline marshes), LB, L. Corangamite, L. Calvert, L. Goldsmith
Cuscutaceæ	
Cuscuta australis R. Br.	KP (Werribee)
C. tasmanica Engelm.	KP (Altona & Laverton), L. Goldsmith
Boraginaceæ	
Cynoglossum australe R. Br.	TH, E
C. suaveolens R. Br.	KP, S, SR, N, E, C
Myosotis australis R. Br.	KP (Little R.), LF, N, E
Plagiobothrys elachanthus (F. Muell.) I. M. Johnston	Lara
Verbenaceæ	
Verbena officinalis L.	KP (Deep Ck), S, C (Kingston)
Labiatæ	
Ajuga australis R. Br.	KP, SR, TH, N, BC, E
Teucrium racemosum R. Br.	KP (Little R.)
Mentha australis R. Br.	KP, S, LF, P, E, WF
M. diemenica Spreng.	KP (Bulla), LB, SR
M. laxiflora Benth.	E
Lycopus australis R. Br.	LF, Daylesford
Scutellaria humilis R. Br.	KP (Jackson's Ck), TH, E
Prunella vulgaris L.	KP, LF, C
Solanaceæ	
Solanum nigrum L.	KP, S, LF, P, LB, SR, TH, N, BC, E, WF, C
S. aviculare Forst. f.	KP, LF, SR, N, BC, E, JP
S. laciniatum Ait.	P, TH, WF, C (Kooroocheang Falls)
Nicotiana suaveolens Lehm.	KP
Scrophulariaceæ	
Mimulus repens R. Br.	aq., KP, S, SR, TH, B
Gratiola peruviana L.	KP, LF, SR, C
Limosella aquatica L.	aq., KP, SR, Colac, Beeac, C
Veronica derwentia Andr.	LF, TH, E, C
V. gracilis R. Br.	KP, Beeac
V. calycina R. Br.	KP (Little R.), SR
Lentibulariaceæ	
Utricularia dichotoma Labill.	aq., KP
U. flexuosa Vahl	aq., 'swamps between L. Colac and Birregurra'
Myoporaceæ	
Myoporum deserti A. Cunn. ex Benth.	KP
M. viscosum R. Br.	KP, E
M. insulare R. Br.	KP, TH
M. parvifolium R. Br.	aq., KP ('once at Newport'), Colac, Camperdown
Plantaginaceæ	
Plantago varia R. Br.	KP, S, LF, N, C
Rubiaceæ	
Coprosma hirtella Labill.	Mt Warrenheip & Mt Rouse, E
C. quadrifida (Labill.) Robinson	WF
Asperula conferta Hook. f.	KP, S, SR, E
A. scoparia Hook. f.	N, E
Galium gaudichaudii DC.	KP, S, SR, BC, E, WF, C
Nertera reptans (F. Muell.) Benth.	Colac, H

CAPRIFOLIACEÆ	
Sambucus gaudichaudiana DC.	KP, LF, SR, TH, E, WF, C (Creswick Ck Gorge)
CAMPANULACEÆ	
Wahlenbergia bicolor Lothian	KP, S, LF, P, LB, SR, C, B
W. consimilis Lothian	KP, E
W. tadgellii Lothian	KP, N, E
W. quadrifida (R. Br.) Alph. DC.	KP, LF, N, E
LOBELIACEÆ	
Lobelia alata Labill.	aq., KP, S, TH, WF
L. pratioides Benth.	KP, L. Corangamite, Mt Elephant, Mt Emu Ck, H
Pratia concolor (R. Br.) Druce	aq., KP, Colac, B
P. platycalyx (F. Muell.) Benth.	aq., TH, L. Corangamite, Mt Elephant, Penshurst
P. pedunculata (R. Br.) Benth.	Mt Elephant, N, E
Isotoma fluviatilis (R. Br.) F. Muell. ex Benth.	aq., KP, LF, WF, C
GOODENIACEÆ	
Goodenia ovata Sm.	KP, Heywood
G. geniculata R. Br.	KP (Little R.)
G. pinnatifida Schlechtendal	KP, S, C
G. heteromera F. Muell.	KP (Little R.)
G. gracilis R. Br.	KP (Little R.)
G. humilis R. Br.	KP (Werribee), H
Velleia paradoxa R. Br.	KP, S
Selliera radicans Cav.	aq., KP, TH
STYLIDIACEÆ	
Stylidium despectum R. Br.	KP ('beyond Little R.')
S. graminifolium Swartz	KP, S
Levenhookia dubia Sond. in Lehm.	KP, Beeac
COMPOSITÆ	
Lagenophora stipitata (Labill.) Druce	H, N, E
Solenogyne bellioides Cass.	KP, S, LF, C
Brachycome decipiens Hook. f.	KP
B. cardiocarpa F. Muell. ex Benth.	KP (Darebin Ck), H
B. leptocarpa F. Muell.	KP, C
B. graminea (Labill.) F. Muell.	KP
B. parvula Hook. f.	KP (Little R.)
B. diversifolia (R. Graham ex Hook.) Fisch. et C. Mey.	KP (Braybrook), Beeac
B. readeri G. L. Davis	Penshurst
B. debilis Sond.	KP (Little R.), Beeac
B. marginata Benth.	KP
B. perpusilla (Steetz) J. M. Black	KP (Werribee), Beeac, H
Minuria leptophylla DC.	KP
Calotis scapigera Hook.	KP
C. scabiosifolia Sond. et F. Muell.	KP (Werribee & Little R.)
Vittadinia triloba (Gaudich.) DC.	KP, S, C, B
Olearia argophylla (Labill.) Benth.	SR, TH
O. decurrens (DC.) Benth.	KP (Bulla)
Sigesbeckia orientalis L.	KP, E
Cotula coronopifolia L.	aq., KP, S, Colac, TH, JP, WF, C
C. vulgaris Levyns	KP, Mt Emu Ck, Beeac
C. australis (Sieber ex Spreng.) Hook. f.	KP, N, E
C. reptans (Benth.) Benth.	KP, S. Colac, Mt Elephant
Centipeda minima (L.) A. Br. & Aschers.	H
C. cunninghamii (DC.) A. Br. & Aschers.	KP, LF, P, WF, C
Isoëtopsis graminifolia Turcz.	KP, H, C
Stuartina muelleri Sond.	KP, BC, E
Gnaphalium luteo-album L.	KP, P, SR, TH, N, E, WF

G. japonicum Thunb.	LF, SR, N, E
G. involucratum Forst. f.	KP, LF, SR, E
G. purpureum L.	KP (Sydenham)
G. indutum Hook. f.	JP, C
Cassinia longifolia R. Br.	KP (Werribee), BC, E
C. aculeata (Labill.) R. Br.	KP, SR
Helipterum albicans (A. Cunn.) DC.	KP (Little R.), Streatham
H. anthemoides (Sieber ex Spreng.) DC.	KP (Sydenham)
H. corymbiflorum Schlechtendal	KP (Sydenham)
H. australe (A. Gray) Druce	KP
H. demissum (A. Gray) Druce	KP (Werribee)
Ixiolæna leptolepis (DC.) Benth.	KP, C
Helichrysum scorpioides Labill.	KP, C
H. rutidolepis DC.	KP (Little R.)
H. apiculatum (Labill.) DC.	KP, S, C, B
H. semipapposum (Labill.) DC.	KP, LF, P, BC, B
H. dendroideum N. A. Wakefield	SR, TH, N, E, WF
H. rosmarinifolium (Labill.) Benth.	H
Leptorhynchos tenuifolius F. Muell.	KP, S
L. squamatus (Labill.) Lessing	KP, S, LF
L. panætioides (DC.) Benth.	KP (Sydneham)
L. elongatus DC.	C (N. Creswick)
Millotia tenuifolia Cass.	KP
Rutidosis leptorhynchoides	KP (St Albans & Sydenham), Craigie
R. multiflora (Nees) Robinson	KP, S, C
Podolepis jaceoides (Sims) Druce	KP
Myriocephalus rhizocephalus (DC.) Benth.	KP, H, C
Angianthus preissianus (Steetz) Benth.	KP (Altona), Streatham
Calocephalus lacteus Brongn.	KP, S
C. citreus Brongn.	KP, S, C
Craspedia uniflora Forst. f.	KP, Beeac, C
C. chrysantha (Schlechtendal) Benth.	KP
Senecio lautus Forst. f. ex Willd.	KP, LF, SR, TH, N, BC, E, JP, WF
S. linearifolius A. Rich.	KP, LF
S. platylepis DC.	Beeac
S. glossanthus (Sond.) R. O. Belcher	KP
S. cunninghamii DC.	KP (Little R., Digger's Rest)
S. odoratus Hornem.	SR, TH, E
S. biserratus R. O. Belcher	H
S. minimus Poir.	LF, SR, E
S. hispidulus A. Rich.	KP, P, ? SR.
S. glomeratus Desf. ex Poir.	SR, N
S. quadridentatus Labill.	KP, S, LF, P, LB, SR, BC, E, WF, C
S. squarrosus A. Rich.	KP (Little R.), H
Cymbonotus preissianus Steetz	KP, Beeac, E, WF, C
Microseris lanceolata (Walp.) Schult.-Bip.	KP, near Mt Warrenheip & Mt Elephant, Beeac, L. Calvert

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RECENT MAMMALIAN SUB-FOSSILS OF THE BASALT PLAINS OF VICTORIA

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Abstract

Details are given of 8 W. Victorian sites which have yielded mammalian sub-fossils, and some corrections are made to previously published identifications of specimens. A table shows the species represented in each of these deposits and the approximate number of individuals of each species in the respective collections. Evidence is presented which suggests a post-Pleistocene period more arid than the present. Details are given of the virtual disappearance during the past century of the modern mammalian fauna of the basalt plains, particularly as regards members of the Macropodidae and the Muridae.

Introduction

The study covers native mammals of species which have been known as living animals during European occupation of Australia. The dingo (*Canis familiaris dingo*) is not included, however, as the local fossil record of this form needs further examination.

During the past three years (1961-1963), several large collections of sub-fossil mammalian bones have come to hand from caves in W. Victoria. Material from these has been classified specifically and assessment made in each case of numbers of individuals of each species. In almost all cases, the lower jawbones (dentaries) have been used for these purposes. Some of the results have already been published (Wakefield 1963a, b, c, 1964).

Literature has been examined for lists of mammalian fossils and sub-fossils from sites in or about the basaltic areas of W. Victoria. Material upon which these reports were based has been examined in the palaeontological collections of the NMV (National Museum of Victoria). Further identifications have been made and, in a few cases, old ones corrected. This material has been analysed quantitatively also.

The species which have been identified from the main sites, and the numerical analysis of each major collection, are set out in Table 1.

Sub-fossil Sites

The location of each site which is discussed in this paper is indicated by reference to places marked on the geological map of the basalt plains which accompanies this article.

TOWER HILL BEACH (7 miles WNW. of Warrnambool)

Mahony (1912) identified a number of mammals from this site, and Gill (1951) added some names to the list. Three more macropodids—*Protemnodon greyi, P. rufogrisea*, and *Aepyrymnus rufescens*—have now been identified in the collections, and the material of *Perameles* has been determined specifically partly as *P. gunnii* and partly as *P. nasuta*.

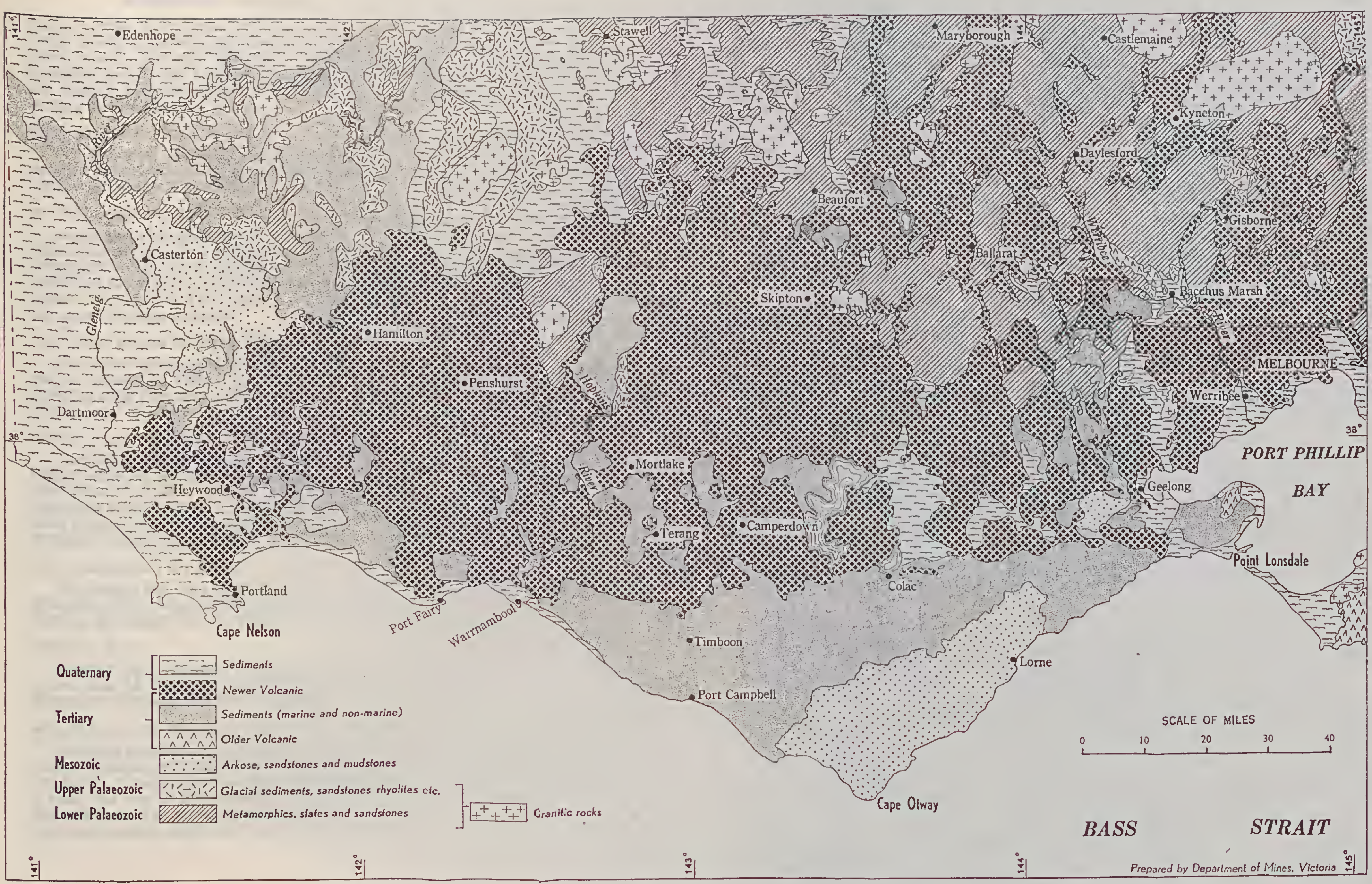
BUSHFIELD (5 miles N. of Warrnambool)

The description of this site by Gill (1953b) included a list, based on identifications by C. W. Brazenor, of 11 species of marsupial and 2 murids. During the present

Table 1

Analysis of Sub-fossil Mammalian Collections from W. Victoria, Showing Approximate Numbers of Individuals Identified from Each Site

	Fern Cave, Lower Glenelg	Natural Bridge, Mt Eccles	Byaduk Caves	Mt Hamilton	Bushfield	Tower Hill Beach	Swain's Cave, Mt Porndon
DASYURIDAE							
Antechinus flavipes	—	2	8	—	—	—	—
Antechinus stuartii	46	44	8	—	1	—	—
Antechinus swainsonii	79	36	15	—	4	—	—
Phascogale tapoatafa	7	—	1	—	—	—	—
Sminthopsis crassicaudata	30	8	4	3	—	—	—
Sminthopsis leucopus	63	34	10	—	1	—	—
Dasyurus quoll	22	16	6	20	8	1	1
Dasyurops maculatus	19	—	—	2	2	7	1
Sarcophilus harrisii	2	—	—	60	2	1	—
Thylacinus cynocephalus	—	—	—	1	—	—	—
PERAMELIDAE							
Isoodon obesulus	250	1	8	5	1	18	—
Perameles gunnii	11	22	30	80	12	8	—
Perameles nasuta	7	—	—	—	—	2	—
PHALANGERIDAE							
Acrobates pygmaeus	14	11	—	—	—	—	—
Cercartetus nanus	18	28	18	—	—	—	—
Petaurus norfolcensis	—	—	10	—	—	—	—
Petaurus breviceps	15	6	10	—	1	—	—
Pseudocheirus peregrinus	6	—	12	—	4	4	—
Trichosurus vulpecula	21	2	1	5	2	1	6
PHASCOLOMIDAE							
Phascolomys mitchellii	1	1	—	3	7	11	1
MACROPODIDAE							
Bettongia gaimardi	4	—	—	2	—	—	—
Bettongia lesueur	—	—	—	7	6	—	—
Aepyprymnus rufescens	1	—	—	20	—	4	—
Potorous tridactylus	47	1	—	1	2	5	2
Lagorchestes leporides	3	—	—	1	—	—	—
Onychogalea unguifer	—	—	—	6	—	—	—
Onychogalea fraenata	—	—	—	1	—	—	—
Petrogale penicillata	—	—	1	—	—	—	—
Thylogale billardieri	15	—	—	—	3	44	—
Protemnodon bicolor	2	—	—	—	—	—	—
Protemnodon rufogrisea	33	1	1	—	4	8	1
Protemnodon greyi	—	—	—	7	—	2	—
Macropus cangaru (= *major*)	4	—	—	1	1	8	—
MURIDAE							
Hydromys chrysogaster	3	—	4	1	1	—	—
Rattus lutreolus	189	108	18	3	14	1	—
Rattus greyii	157	103	63	—	—	—	—
Pseudomys auritus	125	157	4	12	1	—	1
Pseudomys sp.	—	581	11	30	17	—	—
Thetomys cf. *gracilicaudatus*	72	61	73	—	—	—	—
cf. *Gyomys novaehollandiae*	34	17	5	—	—	—	—
Mastacomys fuscus	209	306	89	—	10	—	2
Conilurus albipes	43	24	23	12	—	—	—



Geological map of south-western Victoria, featuring Newer Volcanic plain

study, a further 7 marsupials and 3 murids have been recognized, namely: *Antechinus stuartii, Dasyurops maculatus, Perameles gunnii, Petaurus breviceps, Bettongia lesueur, Thylogale billardieri, Hydromys chrysogaster, Rattus lutreolus, Pseudomys auritus*, and a second species of *Pseudomys*. However, 2 species originally listed by Gill—*Protemnodon bicolor* and *Rattus assimilis*—were not found amongst the material.

SKENE STREET CAVE (Warrnambool)

Two specimens which had been identified for Gill (1953a) as *Aepyprymnus rufescens* are, in fact, of *Bettongia lesueur*. This site, like the Mt Hamilton lava caves, was evidently a 'death trap'.

MT HAMILTON LAVA CAVES (22 miles WSW. of Skipton)

An account of the mammalian sub-fossils from this locality was given, and the misidentification of a piece of *Lagorchestes leporides* (as *Thylogale billardieri*) was subsequently corrected (Wakefield 1963a, b). A second amendment is needed to the original account: on p. 325, the sentence about 'an adult maxilla . . . with heavier dentition than in other adult Victorian specimens' belongs under *Bettongia lesueur,* not under *Bettongia gaimardi*.

FERN CAVE, LOWER GLENELG AREA (10 miles S. of Dartmoor)

The mammalian remains from this site have been documented (Wakefield 1963b) and are included in Table 1 for comparison with the faunas of other sites. The formation at the Fern Cave is dune limestone, carrying a medium forest with thickets of shrubbery.

BYADUK CAVES (11 miles S. of Hamilton)

There were several collections from various parts of the series of caves. The largest deposit, in the cave known as 'Harman Two', was an accumulation of owl pellet material. A minor amount of the bone material in the caves was probably taken there by the quoll or 'native cat' (*Dasyurus quoll*). An analysis of the Byaduk caves material, showing the composition of each collection, has been published by Wakefield (1964), but in Table 1 all this material is treated as a unit.

'NATURAL BRIDGE', MT ECCLES (16 miles E. of Heywood)

The locality has been described and an analysis of the deposit published by Wakefield (1964). Much of the deposit was certainly owl pellet material but some elements of it suggest that the place was also a den of *Dasyurus quoll*.

GISBORNE CAVE

Mahony (*l.c.*) discussed mammalian sub-fossils which had been collected in a cave near Mt Gisborne, approximately 30 miles NW. of Melbourne. J. A. Mahoney is discussing this fauna elsewhere.

SWAIN'S CAVE, MT PORNDON (11 miles SE. of Camperdown)

Sub-fossil material was collected in 1960 by members of the Field Naturalists Club of Victoria, in a small cave at the southernmost portion of the Mt Porndon ring barrier, 1 mile S. of the mountain and 4 miles SW. of Stonyford. The collection is small, and most of it is probably of animals that have used the cave as a shelter and died there. The same applies to occasional specimens of wallaby and possum which are found in collections from other sites under study.

Distributional Data

Sarcophilus harrisii

Besides the several C. and SW. Victorian records in the literature cited, there is a specimen from L. Weeranganuk (NMV, P.22773, *leg.* A. House, 1962). As a modern animal, the 'devil' is known only from Tasmania, but it was evidently widespread and abundant formerly on and about the W. District basalts. There is no record of it from E. Victoria.

Perameles nasuta

There are no data of the Long-nosed Bandicoot as a living animal W. of the Otway Ra. area. The Tower Hill beach record provides a link with the sub-fossil record of it at the Fern Cave S. of Dartmoor.

Petaurus norfolcensis

The distribution of the Squirrel Glider in this State is not well known, but it appears to belong to the more open forests of N. and west-central Victoria. The Byaduk records evidently represent its westernmost occurrence, as it is absent from the numerous sub-fossil deposits of the Portland-Glenelg area.

Bettongia lesueur

The sub-fossil specimens from the Warrnambool area (Skene Street and Bushfield) are of a small form of the species. At Mt Hamilton a single specimen of a large form was found, as well as several of the small form. A fossil skull (NMV, P.22772), which appears to be of the small form, was found at Deep Ck, '1½ miles below Carisbrook'. There is scope for a valuable study of variation between populations of this species, both geographically with modern specimens and through time with fossil material.

Petrogale penicillata

The Byaduk specimen was found in 1961 by L. K. M. Elmore, in the Bridge Cave 'on rocks in cavern behind bat chamber'. It comprises most of a skull, with adult dentition, and large pieces of post-cranial bones. The specimen appears to be older than other Byaduk sub-fossils, and it is the sole indication that the species ever occurred in W. Victoria. As the locality is some 300 miles outside the known modern distribution of the species and is in a different habitat (Wakefield 1963d), the material should eventually be accurately dated.

Onychogalea unguifer

As the species is known as a living animal only from N. Australia (Troughton 1941), the sub-fossil specimens from Victoria are of considerable interest.

Onychogalea fraenata

There is no authentic record of the Bridled Nail-tail Wallaby as a living Victorian animal, but a sub-fossil skeleton was found near L. Hindmarsh in 1959 by M. W. Johns and C. R. Lawrence (Mines Department Geological Museum, Melbourne).

Protemnodon greyi

The Tower Hill beach record is a useful adjunct to the recent discovery of remains of the Toolach Wallaby at Mt Hamilton, as each locality is about 100 miles E. of the previously known range of the species. Distributional data for the species were documented fully by Finlayson (1927).

Rattus greyii

As a modern animal, Grey's Rat appears to be confined in Victoria to the

Portland-Lower Glenelg area. Its previous occupation of the Grampians was demonstrated recently by Wakefield (1963c), and its presence in the W. end of the basalts indicates that it had a general range from the Grampians to the sea.

Pseudomys auritus

The records now available show that the species was widely distributed on and lateral to the basaltic areas. *P. auritus* has not been recorded as a living animal since the type specimen was obtained at L. Albert, South Australia, in 1853 (Troughton 1941).

Pseudomys sp.

This species, not yet identified, was larger than *P. auritus*. It was apparently very abundant on the basaltic plains but has not been found in deposits in adjacent sedimentary formations.

Microchiroptera (Small Bats)

The Fern Cave and the Natural Bridge deposit each contained remains of several specimens of *Miniopterus schreibersi* (Bent-wing Bat). This is the common Victorian cave bat. At the Natural Bridge site there were also fragments of several kinds of forest-frequenting bats but these have not yet been identified. A jawbone of *Tadarida australis* was found in the Byaduk material.

Different Mammalian Faunas

The Tower Hill beach deposit and that at Bushfield are accumulations at aboriginal middens. They contain mammalian faunas similar in actual species but strikingly different when analysed numerically. At Tower Hill beach, several species which favoured a densely vegetated habitat were more strongly represented than at Bushfield, e.g. *Dasyurops maculatus, Isoodon obesulus*, and *Thylogale billardieri*. By contrast, *Dasyurus quoll* and *Perameles gunnii*, which frequent open country, were more plentiful in the Bushfield midden than at Tower Hill beach. To some extent this may reflect differences between the precise sites.

Remains of *Perameles nasuta* and *Aepypyrmnus rufescens* were found in the Tower Hill beach midden but not at Bushfield. These are animals of the wetter, more heavily vegetated areas of SE. Australia. On the other hand, *Bettongia lesueur* is recorded from Bushfield but not Tower Hill beach. This bettong is an animal of the desert regions of Australia.

The data in these two paragraphs suggest that the Bushfield site contained a fauna of more arid general conditions than those pertaining when the more recent Tower Hill beach accumulation took place.

Gill (1953b) noted that the mammalian fossils of W. Victoria represented two distinct groups, the Pleistocene 'giant forms' and a 'post-tuff fauna which consists entirely of living species'.

Of the sites which are dealt with in this paper, the Skene Street cave at Warrnambool and the Mt Hamilton lava caves each contained elements of both groups. Each also contained *Bettongia lesueur*, which is now a desert species and therefore a possible indicator of comparatively arid conditions. If the occurrence of *Bettongia lesueur* in S. Victoria was associated with an arid period, the sub-fossil faunas with which its remains are associated indicate that such period occurred between the time of the Pleistocene 'giant forms' and that of the modern 'post-tuff fauna'.

Disappearance of the Modern Fauna

Jones (1923-25) gave full data of the early disappearance of many South Australian mammals. Brazenor (1950) listed species which no longer occurred in

Victoria. Marlow (1958) gave dates of the latest records of the individual mammals of New South Wales.

During the present decade, an intensive survey of the mammals of Victoria has been carried out by wildlife research officers of the Fisheries and Wildlife Department and members of the Fauna Survey Group of the Field Naturalists Club of Victoria. This has provided a reasonably clear picture of the present mammalian fauna of this State and of the general distribution of each species.

Of the 42 species listed in Table 1, only 27 are known to survive in Victoria, and less still are known to occur now in the basaltic areas. Of the 13 macropodids, no more than the 3 largest are known to frequent parts of this formation now, and none of the 6 pseudomid murids is known to survive there.

Thylacinus cynocephalus presumably died out on the Australian mainland along with the giant Pleistocene marsupials. It is evident that *Sarcophilus harrisii* and *Onychogalea unguifer* disappeared from Victoria before European occupation, and that *Petrogale penicillata* withdrew from the W. Victorian basalts at a similarly remote period.

Of the other macropodids, one or more of *Bettongia lesueur, Lagorchestes leporides, Onychogalea fraenata*, and *Protemnodon greyi* may have been present in Victoria during the earliest years of white settlement, but any of these that were native of this State disappeared from it so early that no modern Victorian specimen exists of any one of them.

In the National Museum, Melbourne, there are Victorian specimens of *Bettongia gaimardi, Aepyprymnus rufescens*, and *Thylogale billardieri*, but all 3 evidently disappeared from Victoria by about the turn of the century.

A similar story applies to the pseudomid group of murids. *Conilurus albipes, Gyomys novaehollandiae*, and the 2 species of *Pseudomys* are evidently now extinct, and these 4 too disappeared from the State without, as far as is known, a modern Victorian specimen being retained of any one of them.

Marlow (*l.c.*) emphasized that, whereas forest species survive, the mammalian fibula: There is a slight bony deformity just below the upper end of the bone, past century. The recent dramatic reduction of the basaltic plains mammalian fauna has been part of the same general trend.

Acknowledgements

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References

BRAZENOR, C. W., 1950. *The Mammals of Victoria*, Melbourne.

FINLAYSON, HEDLEY HERBERT, 1927. Observations on the South Australian members of the subgenus 'Wallabia'. *Trans. & Proc. Roy. Soc. S. Aust.* 51: 363-377.

GILL, E. D., 1951. Aboriginal kitchen middens and marine shell beds. *Mankind* 4 (6): 249-254.

————, 1953a. Geological evidence in western Victoria relative to the antiquity of the Australian aborigines. *Mem. Nat. Mus. Melb.* 18: 25-92.

————, 1953b. Distribution of the Tasmanian devil. the Tasmanian wolf, and the dingo in SE. Australia in Quaternary time. *Vict. Nat.* 70 (5): 86-90.

JONES, FREDERICK WOOD, 1923-25. *The Mammals of South Australia*. Pt I-III. Adelaide.

MAHONY, D. J., 1912. On the bones of the Tasmanian devil and other animals associated with human remains near Warrnambool: with a note on the dune sand. *Vict. Nat.* 29 (3): 43-46.

MARLOW, B. J., 1958. A survey of the marsupials of New South Wales. *CSIRO Wildlife Research* (3) 2: 71-114.

TROUGHTON, ELLIS, 1941. *Furred Animals of Australia.* Sydney.

WAKEFIELD, N. A., 1963a. Sub-fossils from Mount Hamilton, Victoria. *Vict. Nat.* 79 (11): 323-330.

————, 1963b. Mammal sub-fossils from near Portland, Victoria. ibid. 80 (2): 39-45.

————, 1963c. Mammal remains from the Grampians, Victoria. ibid. 80 (5): 130-133.

————, 1963d. Notes on rock-wallabies. ibid. 80 (6): 169-176.

————, 1964. Mammal sub-fossils from basalt caves in south-western Victoria. ibid. 80 (9): 275-280.

18

PREHISTORY OF THE BASALT PLAINS

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A century after Major Mitchell traversed the basalt plains, they carried over 500 sheep to the square mile. In 1836, the natural resources possibly supported one aboriginal to every 5 square miles. Contemporary estimates (Smyth 1878, 1: 31-38) populated Victoria with between 3,000 and 7,500 aborigines, an average density ranging from 12 to 30 square miles for each native. (The first official census was not taken until 1877, when there were 774 Victorian full-bloods, of whom 170 lived in the entire W. District.) As the plains constitute a tenth of the State, on an arithmetical basis this allows a population of from 300 to 750. Yet the region was amply stocked with game, varied marine and lake foods, and permanent water, making it a most favourable area for hunting-fishing-gathering exploitation. By what factor should the estimate be increased on this account?

In coastal and riverine regions of N. and NW. Australia, presumably comparable in their food potential, informed estimates (Meggitt 1962: 32) of population density range between 6·5 and 9 square miles a head. Therefore, 5 square miles for each W. District aboriginal seems not unreasonable, and it accords with vital statistics for hunting societies elsewhere (Krzywicki 1934). A total population of 1,800, therefore, is probably a more reliable figure than extrapolation from estimates made for specific areas by early settlers (Bride 1898: 33, 42, 114, 140) or by Dawson (1881: 3), who made a devious calculation that 2,500 aborigines from the hinterland between Colac and the Wannon periodically assembled near Mt Rouse.

The conversion of tribal territory to sheep-runs was rapid and decisive (Kiddle 1961). Unfortunately, Dawson (1881) was the only European to attempt a comprehensive record of the W. District aborigines and, although sympathetic, he lacked critical understanding. It is significant that, when in the 1880s, A. W. Howitt (1904: 69) commenced his diligent collection of data on tribal organization, no aboriginal informant seems to have been available to him, and he was almost entirely dependent upon Dawson for his knowledge of the W. District. For this symposium it is more appropriate to examine problems of prehistory and past and future field research, than to summarize the history of race relations or the social structure and material possessions of the aborigines. The basic information on such subjects is contained in Dawson, Brough Smyth, Kiddle, and Foxcroft (1941).

In the absence of systematic archaeological excavations, no definitive comment concerning the cultural sequence is possible. To judge from the analysis of stone implements collected on surface sites, which assemblages represent mixed industries of different ages, the shapes and technology of the W. District artefacts resembled those current elsewhere in Victoria. Microlithic implements are particularly common, especially geometric and backed blade (Bondi point) forms. Mitchell (1949) has described the main areas, and the numbers he collected are impressive—e.g. at sites adjacent to Inverleigh, Glenthompson, L. Bolac, L. Burrumbeet, and Willaura, he found 1,542 geometrics and 411 Bondi points. The edge-ground axe was widely distributed and one type meriting detailed investigation is the hammer-dressed, grooved variety which appears characteristic of the W. District. In common with the rest of the State, two basic prehistoric implement types are unrepresented, although they are distributed widely throughout the rest of the continent. These are the pirri point and tula adze, which appear inexplicably to observe the State boundaries in their occurrence.

Using excavations on the Lower Murray R. and Cape Otway (Mulvaney 1962) as the yardstick, it appears that aboriginal stone craftsmanship was more highly skilled and diversified 2,000 to 5,000 years ago than at the time of European settlement. By 1835 the production of most specialized implement types had ceased. This is a reminder that, although the aborigines are known as a stone age people, stone utilization played a relatively minor role in their life. The environment furnished them with a variety of plant and animal raw materials, whose archaeological survival is uncommon.

When Europeans occupied the plains, they found aboriginal relics which were more substantial than those in most areas of Australia, and which indicated the environmental adaptation of their society. The aborigines on the Stony Rises utilized basalt boulders to construct circular hut walls, possibly roofed with brushwood. Most of these structures had been demolished by 1875, by settlers seeking building stone for fences (Smyth 1878, 11: 235). No plan of these huts appears to have been made by contemporaries, but field survey might recover traces of them. One extensive series of small stone alignments, presumably a ceremonial ground, has been located and surveyed on an island in L. Wongan, near Skipton (Smyth ibid., Casey 1938). This site should be scheduled as a national monument.

Field survey may locate aboriginal fish and eel traps constructed of stone which were functioning at the time of European settlement (Bride 1898: 40, 219; Dawson 1881: 94). Kenyon (1912) described such a trap near L. Condah which requires further investigation. The most complex and unique aboriginal construction was a series of earth ditches seen in 1841 by Robinson, who was crossing swampy country somewhere between Mt Sturgeon and Mt William (Kenyon 1928: 156). 'One continuous treble line measured 500 yards in length, 2 feet in width, and from 18 inches to 2 feet in depth. These treble dikes led to extensive ramified watercourses. The whole covered an area of at least 10 acres . . .'

Apparently the most obvious evidence of aboriginal occupation was provided by inland middens known as 'ovens' or 'mirrnyongs'. Near Mortlake there was a group of 5 of them, up to 100 ft in diameter and 8 ft thick (Smyth 1878, 11: 233).

There were at least 40 mounds in the area near Meredith (McPherson 1884: 59); Dawson (1881: 103), familiar with the Camperdown area, commented on 'native mounds, so common all over the country'. These observers were too intrigued to leave the mounds without investigation and many of them were 'dug'; in any case, numbers had been destroyed by 1876 for the fertile soil which they contained (Smyth 1878, 11: 234). 'As many as 5 or 6 skeletons have been found in one mound', one of them noted (Smyth, ibid.). McPherson's exertions at Mortlake portray their excavation technique (1884: 55).

'The first 6 or 8 inches were nearly as hard as brick, but under this dome the ashes were quite loose and easily tossed about. After prolonged work there was no sign of human remains. Another portion of the mound was pierced and searched, but still without success. Returning to the portion first tried, the spade was driven into the open side, when several bones fell down along with the loose dry ashes.' Dawson also dug enthusiastically; 'in every large mound, and in some of the smaller ones, human skeletons were found'. He did recognize, however, that the mounds were internally stratified and were therefore gradual accumulations due to human occupation (1881: 104).

Fossicking was not limited to 'ovens'. It extended to coastal middens and other sites where post-European erosion exposed 'blows'; sites where the surface covering was removed exposing stone or bone artefacts. As early as 1857, Bonwick (1858: 93) visited Bridgewater caves and found shells and stone implements. 'Stirring about the soil', he uncovered some animal bones. And so the plundering of the Bridgewater deposits began. Exactly a century later, a Melbourne University expedition visited the site, hoping to excavate it; this was a vain hope, for it had been churned over (Mulvaney 1957: 43). In this same report the writer described other frustrations for field workers in the W. District. Throughout this century the area has been the chief source for cabinet collections. Unfortunately, many collectors failed to record the precise locality from which their finds came, and others omitted to label them at all. Even material lodged in the National Museum is frequently catalogued imprecisely, so that the distribution of certain implement types cannot be plotted. Collectors were also subjective; they sought special implement types or finely worked specimens, and left the waste flakes or crude implements behind. The result is that existing collections cannot provide a comprehensive record of aboriginal culture, nor do they permit adequate statistical assessment of stone working techniques. What has been left lying on the ground is equally misleading as a guide to aboriginal material possessions in an area.

If any sites survived the 'grave-digging' phase, subsequent ploughing has possibly levelled them. However, they cannot be overlooked as valuable archaeological and carbon dating prospects. Some sites might be located by aerial photography. As long ago as 1869, McPherson (1884: 49) observed from a train window near Meredith that 'owing to the drought . . . the green mantle of grass had disappeared, leaving the black patches of the oven-mounds very easily distinguishable from the bare surface of the soil'. Elsewhere, he commented, crops grew green and tall on the fertile ashy mounds. Features such as these should still be recoverable by photography because, in Britain, ploughed out barrows produce crop marks even after the passage of 4,000 years.

McBryde (1962) and Webster (1962) have demonstrated the practicability of archaeological aerial photography in Australia. They provided a new perspective for the investigation of aboriginal stone quarries in N.S.W., particularly through the use of infra-red photography. Similar photographs of Victorian axe stone sources would be helpful. In regard to such stone quarries, scientists could contribute in another way towards an objective assessment of aboriginal trade and culture contacts.

A century ago, Blandowski (1855: 7) and Krefft (1865: 366) both claimed that edge ground axes used in the Lower Darling R. area had been quarried in C. Victoria. Since that time, Mt William, near Lancefield, has become notorious for its alleged far-flung contacts, the most distant of which is the Northern Territory (Gross 1955: 38). While Mt William has attracted some specialist attention, stone quarries in the W. District have been neglected. The most important sources were the epidiorite at Ceres and Dog Rocks, Batesford, in the Barrabool Hills, and diabase outcrops near Chatsworth, Mt Stavely, and Juluka, 15 miles from Ararat (Mitchell 1961). Tindale (1957: 31) has claimed that axes from Chatsworth were traded into South Australia as far W. as the Yorke Peninsula.

The validity of these distributional claims cannot be established merely by handling the specimens. The systematic petrological identification of sources of stone is essential for objective study. British archaeologists were faced with the same confusion before the last war, and a sub-committee of archaeologists, museum officials, and petrologists was appointed. Some hundreds of specimens were examined and the investigation revealed an unexpected complexity of culture contact in prehistoric Britain and the continent (Clark 1952: 248). The Royal Society could provide a valuable service by sponsoring a similar Australian committee.

Dawson (1881: 78) sketched the mechanics of the transfer of such raw materials in tribal society, although the essentially ceremonial and obligatory nature of the transactions escaped him. He described inter-tribal gatherings at Mt Noorat, although Mt William stone quarry performed a similar function in its area (Howitt 1904). A petrologist would have been an interested observer at Mt Noorat.

'At the periodical great meetings trading is carried on by the exchange of articles peculiar to distant parts of the country. A favourite place of meeting for the purpose of barter is a hill called Noorat, near Terang. In that locality the forest kangaroos are plentiful, and the skins of the young ones found there are considered superior to all others for making rugs. The aborigines from the Geelong district bring the best stones for making axes, and a kind of wattle gum celebrated for its adhesiveness. This Geelong gum is so useful in fixing the handles of stone axes and the splinters of flint in spears, and for cementing the joints of bark buckets, that it is carried in large lumps all over the Western District. Greenstone for axes is obtained also from a quarry on Spring Creek, near Goodwood; and sandstone for grinding them is got from the salt creek near Lake Boloke. Obsidian or volcanic glass, for scraping and polishing weapons, is found near Dunkeld. The Wimmera country supplies the maleen saplings, found in the mallee scrub, for making spears. The Cape Otway forest supplies the wood for the bundit spears, and the grass-tree stalk for forming the butt piece of the light spear, and for producing fire; also a red clay, found on the sea coast, which is used as a paint, being first burned and then mixed with water, and lain on with a brush formed of the cone of the banksia while in flower by cutting off its long stamens and pistils. Marine shells from the mouth of the Hopkins River, and freshwater mussel shells, are also articles of exchange.'

To unravel the antiquity and cultural succession of human occupation, close collaboration between archaeologists and scientists is essential. The extensive coastal dunes and former lake margins offer opportunities for correlating human occupation with changes on the face of the plains. Gill (1953, 1955a) has demonstrated that valuable evidence concerning the past few centuries can be obtained from coastal middens. Systematic work on these eroding dunes is a matter of urgency, for nature and the avid collector have destroyed considerable information. To realize the extent of lost opportunities, it is only necessary to mention the richness of the Koroit Beach middens at the time of the first descent by collectors (Mitchell 1958, Dawson 1881: 19).

In New Zealand, it has been possible to correlate prehistoric occupation with periods of vulcanism, and this aspect cannot be overlooked here. Indeed, Keble (1947) and Gill (1953) have presumptive evidence that, at Bushfield, a grooved axe was buried beneath 9 ft of Tower Hill tuff. The initial discovery was accidental, but there seems to be no reason for doubting the authenticity of the discovery. This eruption was possibly more recent than the latest ash shower from Mt Gambier, and there are fully authenticated instances of the discovery of aboriginal artefacts sealed beneath this deposit.

The age of these finds is around 5,000 years, and radiocarbon 14 has shown that man lived in South Australia at least 4,000 years before that time. The relative antiquity of the Bushfield specimen is interesting because no hafted **grooved** axe was ever collected from living aborigines, although surface specimens are distributed widely over the plains and none has been recovered through archaeological excavation. These artefacts are more massive than the common edge ground axe and it may be significant that many are deeply patinated or decomposed and a number has been unearthed at some depth (Archibald 1894, Gill 1953: 73).

Dawson (1881: 102) is cited frequently in support of the thesis that as aboriginal legends include volcanic eruptions, the aborigines must have been present at such times. No doubt they were. But this does not justify the use of this material as evidence. Dawson is virtually the only source for this belief and what he does recount might be European rationalization. Gregory (1904: 134) showed a healthy scepticism, and so did the squatter in 1854, who warned (Bride 1898: 184) that aborigines 'will at any time admit or say anything which they think will please their interlocutors . . . if leading questions are put to them, as is usually done by enthusiastic enquirers, who are following up their own ideas, they . . . may be made to say anything'.

Did man occupy the plains during Pleistocene times? While some claims have been fanciful, there is some intriguing evidence which merits further investigation. The Buninyong bone cannot be accepted. It neither looks nor reads like an authentic aboriginal tool (Gregory 1904, Mahony 1943). An evolutionary minded public hailed the discovery at Warrnambool in 1890 of imprints in dune limestone of alleged human feet and buttocks. The vogue for 'Pliocene' man coincided with the announcement of *Pithecanthropus* in Java. It cannot be denied that animal and bird imprints do occur in the soft rock, but it requires subjective rather than objective qualities to convert the celebrated marks into humans. While the literature is voluminous, the consensus of opinion (Gill 1953: 73) regards the evidence as dubious for, as Gregory (1904: 132) observed, if these were human feet, they 'wore a modern type of boot'. Perhaps the last word lies with the enthusiastic museum curator (Archibald 1894). The museum display card pronounced that the impressions were those of a man and woman sitting on some prehistoric river bank, and this Archibald remarked, was 'a consideration which, I regret to say, seems to have great weight with certain frivolous young visitors to our Museum, who profess to derive comfort from the reflection that "that sort of thing" has the sanction of remote antiquity'.

The evidence from Pejark Marsh is more worthy of investigation. The evidence has been exhaustively treated by Keble (1947: 47) and Gill (1953: 62). It is evident that bones of extinct giant mammals are present at certain levels in the marsh; this fact, together with the unique possibilities for pollen analysis, gives the site some priority for future research. The doubt concerns aboriginal involvement. In 1908, an aboriginal millstone or anvil stone was found. Subsequent excavations (Spencer and Walcott 1911, Keble 1947: 49) have failed to find additional traces of aborigines. Apart from a depression worn on one surface, the stone is featureless and cannot be assigned to any phase or culture upon typological considerations. It seems probable that the stone came from beneath the tuff and, on the word of the finder, it was associated with the fauna. Unfortunately, he washed away the 'yellow clay' adhering to it, otherwise pollen determinations might have assisted. Here then is the nub of the problem. If the finds are associated, it establishes the presence of Pleistocene man; but no matter how far subsequent discussion proceeds, it depends upon accepting the reliability of the finder's report. For such a crucial issue this is inadequate.

L. Colongulac presents similar problems. Bones of extinct mammalian fauna were collected on eroded surfaces by the lake around 1847. Gill (1955b) has presumptive evidence for dating these remains to 13,725 ± 350 years ago. Mixed with these bones were the remains of dingo (Gill 1953: 57). Subsequent fluorine analysis has demonstrated that the dingo bones are not as old as the fauna with which they were associated (Gill pers. comm.). Many of the mammalian bones have been considerably worn or chewed, but by what process cannot be ascertained. However, one of them is exceptional. It is the distal portion of the metatarsal of an extinct marsupial, which has a deep wedge-shaped cut. Expert opinion (Spencer and Walcott

1911: 116, Gill 1953: 58) rejects the possibility of a post-European cut and, in this instance, animal teeth seem precluded as the agent. Gill is convinced that aboriginal activity is the only alternative and, while this may be so, the question remains inconclusive. It is to be hoped that future fieldwork at L. Colangulac will produce more positive evidence for, together with that from Pejark and Keilor, there are tantalizing hints concerning man's presence in Pleistocene Victoria. It is appropriate to conclude with Gregory's admonition (1904: 125).

'In dealing with the fossil traces of man, the evidence of a single specimen, which was not collected *in situ* by a collector of known trustworthiness, must always be received with caution. The chance of genuine mistake and of practical joke must not be forgotten. The literature of the antiquity of man contains many warnings against founding important conclusions upon single specimens.'

References

ARCHIBALD, J., 1894. Notes on the antiquity of the Australian aboriginal race. *Trans. Roy. Geog. Soc. Aust'sia* 11: 22-25.

BLANDOWSKI, W. VON, 1855. Personal observations in Victoria. *Trans. Philos. Soc. Vict.* 1: 50-74.

BONWICK, J., 1858. *Western Victoria . . .* Geelong.

BRIDE, T. F., 1898. *Letters from Victorian Pioneers.* Melbourne.

CASEY, D. A., 1938. Aboriginal ceremonial ground . . . *Vict. Nat.* 54: 130.

CLARK, J. G. D., 1952. *Prehistoric Europe: the Economic Basis.* London.

DAWSON, J., 1881. *The Australian Aborigines.* Melbourne.

FOXCROFT, E. J., 1941. *Australian Native Policy.* Melbourne.

GILL, E. D., 1953. Geological evidence in Western Victoria relative to the antiquity of the Australian aborigines. *Mem. Nat. Mus. Melb.* 18: 25-92.

————, 1955a. Aboriginal midden sites in Western Victoria dated by radiocarbon analysis. *Mankind* 5: 51-55.

————, 1955b. Radiocarbon dates for Australian archaeological and geological samples. *Aust. J. Sci.* 18: 49-52.

GREGORY, J. W., 1904. The antiquity of man in Australia. *Proc. Roy. Soc. Vict.* 17: 120-144.

GROSS, A., 1955. Excursion to Mt William. *Vic. Hist. Mag.* 27: 37-40.

HOWITT, A. W., 1904. *The Native Tribes of South-East Australia.* London.

KEBLE, R. A., 1947. Notes on Australian Quaternary climates and migration. *Mem. Nat. Mus. Melb.* 15: 28-81.

KENYON, A. S., 1912. Camping places of the aborigines of south-east Australia. *Vic. Hist. Mag.* 2: 97-110.

————, 1928. The aboriginal Protectorate of Port Phillip. *Vic. Hist. Mag.* 12: 134-172.

KIDDLE, M., 1961. *Men of Yesterday.* Melbourne.

KREFFT, G., 1865. On the manners and customs of the aborigines . . *Trans. Phil. Soc. N.S.W.*: 357-74.

KRZYWICKI, L., 1934. *Primitive Society and its Vital Statistics.* London.

MCBRYDE, I., 1962. Archaeological field survey work in northern N.S.W. *Oceania* 33: 12-17.

MACPHERSON, P., 1884. The oven-mounds of the aborigines in Victoria. *Journ. Proc. Roy. Soc. N.S.W.* 18: 49-59.

MAHONY, D. J., 1943. The problem of the antiquity of man in Australia. *Mem. Nat. Mus. Melb.* 13: 7-56.

MEGGITT, M. J., 1962. *Desert People.* Sydney.

MITCHELL, S. R., 1949. *Stone-Age Craftsmen.* Melbourne.

————, 1958. An aboriginal bone industry. *Mankind* 5: 194-199.

————, 1961. Victorian aboriginal axe stone. *Vict. Nat.* 78: 71-78.

MULVANEY, D. J., 1957. Research into the prehistory of Victoria. *Historical Studies* 8: 32-43.

————, 1962. Archaeological excavations on the Aire River. *Proc. Roy. Soc. Vict.* 75: 1-15.

SMYTH, R. B., 1878. *The Aborigines of Victoria.* 2 vol. Melbourne.

SPENCER, W. B., and WALCOTT, R. H., 1911. The origin of cuts on bones of Australian extinct marsupials. *Proc. Roy. Soc. Vict.* 24: 92-123.

TINDALE, N. B., 1957. Culture succession in SE. Australia. *Rec. Sth. Aust. Mus.* 13: 1-49.

WEBSTER, W. J. E., 1962. Techniques of field photography for archaeological purposes. *Oceania* 33: 139-142.

19

THE TERTIARY ECHINOIDS OF SOUTH-EASTERN AUSTRALIA

II CIDARIDAE (2)

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Abstract

The following Australian Tertiary cidarids are described and figured: *Stereocidaris australiae* (Duncan), *S. cudmorei* sp. nov., *S. fosteri* sp. nov., *S. inermis* sp. nov., *S.* (?) *hispida* sp. nov., *S.* (?) *intricata* sp. nov., *S.* sp. A, *S.* sp. B, *S.* sp. C, *Goniocidaris murrayensis* C. & C., *G. praecipua* sp. nov., *G. tubaria hallettensis* subsp. nom. nov., *G.* (?) *pentaspinosa* C. & C., *Austrocidaris operta* sp. nov., *Delocidaris prunispinosa* (C. & C.) gen. nov., *Menocidaris compta* gen. et sp. nov. Fragmentary cidarid remains consisting of 3 different types of test and 7 different types of radiole are also listed and figured. The possible origins of the Ctenocidarina and Goniocidarina are reviewed, and it is concluded that both these groups were derived from the Stereocidarina in the Palaeogene. The *G. murrayensis-G. tubaria* lineage is discussed in detail.

Introduction

This paper concludes the description of the cidarids of the Tertiary of SE. Australia, the first section of which was given in Part I (Philip 1963b). Part III will deal with the Stirodonta, Aulodonta and the first section of the Camarodonta. The continued assistance of the individuals mentioned in Part I is gratefully acknowledged, in particular that of Mr Edmund D. Gill. A University of New England research grant has made continuation of the work possible.

Systematics

Genus **Stereocidaris** Pomel

Eucidaris Pomel 1883, p. 109.
Stereocidaris Pomel 1883, p. 110.
? *Typocidaris* Pomel 1883, p. 111.
Phalacrocidaris Lambert 1902, p. 27.
Anomocidaris Agassiz and H. L. Clark 1907, p. 30.
Sinaecidaris Fourtaw 1921, p. 9.
Stereocidaris Pomel, Mortensen 1928, p. 225 *et seq.* (*cum synon.*).
? *Compsocidaris* Ikeda 1939b, p. 160.
Stereocidaris Pomel, Fell 1954, p. 32-33.
(*Non*) *Eucidaris* Pomel *auctt.* (*fide* Philip, 1963).

TYPE SPECIES: The type species of *Stereocidaris* is *Cidaris crestosa* Mantell, by subsequent designation of Lambert and Thiéry 1909, p. 31 (*fide* Mortensen 1928, p. 226). The type species of *Typocidaris* is *Cidaris malum* Gras, by monotypy. The type species of *Phalacrocidaris* is *Dorocidaris japonica* Döderlein, by original designation. The type species of *Anomocidaris* is *Cidaris* (*Stereocidaris*) *tenuispinus* Yoshiwara (= *Dorocidaris japonica* Döderlein), by original designation.

DIAGNOSIS: Moderately large, often thick tested forms, typically with comparatively few, relatively high interambulacral plates. Scrobicules of uppermost one or more interambulacral plates rudimentary; primary tubercles usually smooth but may show traces of crenulation. Scrobicules generally incised. Often one or more of upper horizontal interambulacral sutures naked or depressed, ambital horizontal sutures often grooved admedianly. Apical system usually dicyclic, with widely exsert oculars, and madreporite not obviously enlarged. Pores non-conjugate with separating wall forming a low, rounded projection.

Radioles variably ornamented, with shafts covered by longitudinally arranged spicules or granules, or sometimes ridges or laminae, between which is usually a spongy coat of cortical hairs. Distal termination often flared; collar usually very short; neck long and conspicuous.

REMARKS: One peculiarity of the genus is that the apical system is apparently less caducous than in other cidarids so that it is not uncommonly preserved in fossil tests. The only cidarid test with the apical system intact known so far from the Tertiary of Australia is of *Stereocidaris inermis* sp. nov. described below.

There can be little doubt that both *Phalacrocidaris* and *Anomocidaris*—both based on *Stereocidaris japonica* (Döderlein)—should be regarded as synonyms of *Stereocidaris*. The distinguishing feature would be the degree of atrophy of the upper scrobicules of the interambulacra, but in fossil forms there is a whole gradation from species with only a single rudimentary scrobicule through to species comparable with *S. japonica*. Mortensen (1928) maintained *Phalacrocidaris* as a subgenus of *Stereocidaris* for this latter species in dealing with the living species of the genus, for then *S. japonica* stood well apart from the other living forms in its extremely rudimentary upper scrobicules. However, subsequently Mortensen (1939, p. 7-8, Pl. 2, fig. 1-4) described *S. reducta* which, in common with *S. japonica*, possesses considerably reduced upper scrobicules. Mortensen also noted that his new form in other respects showed close affinities with *S. microtuberculata* (Yoshiwara) (and, indeed, may be regarded as a subspecies of this form) so it would appear that even in living species the feature, although striking, is of no major taxonomic importance.

Compsocidaris Ikeda, based on *Compsocidaris pyrsacantha* (Ikeda 1939b, p. 160-4, Pl. 7-10) from the Bonin Is., is distinguished from the genus *Stereocidaris* only by its 'sparse tuberculation', so that its value is doubtful.

Whether or not *Typocidaris* should be regarded as a direct synonym of *Stereocidaris* is another matter. From the Mesozoic, particularly from the Cretaceous of Europe, there have been described a great number of *Stereocidaris*-like species which are typified by high interambulacral plates, rudimentary upper scrobicules, often bare or grooved horizontal sutures and, in general, non-conjugate pores. In the eventual grouping of these species, *Typocidaris* may well be retained for a group characterized by marked enlargement of the peristome, as is seen in the type species *Cidaris malum* Gras. In fact, a fairly obvious grouping of the great number of species of *Stereocidaris* can be achieved by utilizing test characters which, although apparently trivial, have been found to be of some taxonomic significance in dealing with living cidarids. In the absence of a detailed examination of specimens of these many species, one can do no more than point to the existence of these species groups, but it would seem that at least two groups (IV and V) should be accorded full generic status. The species groups are:

GROUP I—*Stereocidaris* S.S.

This group includes forms as diagnosed above; the peristome is smaller than the apical system, or, at the most, approximately the same diameter.

The group would seem to have its origin in the Jurassic; such species as *Cidarites moniliferus* Goldfuss and *Cidarites marginatus* Goldfuss (1824, p. 118-9, Pl. 39, fig. 7) belong here. The group is perhaps best known from the Cretaceous of Europe. Cotteau (1861-7) gives descriptions of the following forms which are all species of *Stereocidaris* S.S.: *Cidaris Loryi* Cotteau, *Cidaris insignis* Gras, *Cidaris vesiculosa* Goldfuss, *Cidaris Rhothomagensis* Cotteau, *Cidaris Ligeriensis* Cotteau, *Cidaris sceptifera* Mantell, *Cidaris subvesiculosa* d'Orbigny, *Cidaris perlata* Sorignet, *Cidaris Vendocinensis* Cotteau, *Cidaris cretosa* Mantell, *Cidaris Merceyi* Cotteau, *Cidaris serrifera* Forbes.

As Cidaridae are poorly represented in the Cainozoic of Europe, only 3 species of *Stereocidaris* S.S. are known, 2 from the Eocene (*Phalacrocidaris Gautheri* Lambert 1902, Pl. 19, fig. 23-7, and *Stereocidaris destefanni* d'Innocenti, *fide* Mortensen 1928, p. 230) and probably *Cidaris* (*Leiocidaris*) *Balestrai* Oppenheim (1902, p. 173, Pl. 9, fig. 1a-c) from the Oligocene. The genus is abundantly represented in the present day Indo-Pacific fauna, but it is known in the Atlantic only from a single form.

Although the upper Eocene species described below are the earliest occurrences of this group in the Australasian region, the genus was apparently established in the Indo-Pacific toward the end of the Cretaceous. Stoliczka (1873, Pl. 7) has described and illustrated a number of fragmentary forms (identified as European Cretaceous species of *Stereocidaris*) from rocks of Cenomanian to Santonian age in S. India. Farther W., from Persia, the Senonian *Cidaris persica* Cotteau, Gauthier and Douville (1895, Pl. 13, fig. 1-5) is undoubtedly a species of *Stereocidaris*. Lambert (1936) has described a cidarid as *Dorocidaris besairiei* (p. 23, Pl. 3, fig. 6) from sediments of reputed Campanian age in Madagascar. This appears to be a species of *Stereocidaris*, although Lambert describes the pores as subconjugate.

There appears to be little record of the genus throughout the Cainozoic of the Indo-Pacific region. Mortensen (1928, p. 300) suggested that a radiole from the Miocene of Java may belong to *Stereocidaris*; further, some fragmentary cidarids from the Miocene of Kachh, figured by Duncan and Sladen, are probably best included in the genus *Stereocidaris*. Gerth (1927, Fig. 1) has illustrated a cidarid from the Pliocene of Timor which appears to be a species of *Stereocidaris*. Considering its abundance in the Recent Indo-Pacific fauna, however, the genus is surprisingly rare.

Mortensen (1928) recognized 16 living species and 6 varieties all of which belong to *Stereocidaris* S.S. Subsequently (1932, 1934) he added 2 more species. These fall into 7 species groups which are:

1. *S. grandis* Döderlein from Japanese waters with the morphological variant *hyatorina* Mortensen. Allopatric forms of this are *S. hawaiiensis* Mortensen from Hawaii, *S. granularis* Mortensen from the Philippines (with its morphological variant *rubra* Mortensen), and *S. squamosa* Mortensen from the Indian Ocean.
2. *S. microtuberculata* (Yoshiwara) from the Sagami Sea. Its allopatric forms are *S. purpurescens* Mortensen from the Kei Is., *S. tubifera* Mortensen from the Philippines, *S. reducta* Mortensen from Indian waters, and *S. excavata* Mortensen from S. African waters.
3. *S. indica* Döderlein, an extremely variable species widely distributed through the Indian Ocean. Mortensen recognizes a morphological varient *philippinensis*. It seems very likely that *S. capensis* Döderlein, and *S. alcocki* (Anderson) are also varieties of *S. indica*. An allopatric form is *S. ingolfia* Mortensen from the West Indies and the N. Atlantic.
4. *S. leucacantha* Agassiz and Clark, from Hawaii, although resembling *S. grandis* to some extent, is apparently a good species.

5. *S. sceptiferoides* Döderlein, with its morphological variants *lanceolata* Mortensen and *lamellata* Mortensen, is a well-marked species from Japan.
6. *S. japonica* (Döderlein) is again a well circumscribed Japanese species.
7. *S. sulcatispinis* Mortensen, from the Kei Is. and Borneo.

GROUP II—*Typocidaris*

This group differs from Group I in that the peristome is markedly enlarged relative to the apical system, a feature seen in only two other cidaroid genera. Species, known only from the Cretaceous of Europe, include:

Cidaris malum Gras, Cotteau 1861-7, p. 198, Pl. 1045, fig. 1-12.
Cidaris pretiosa Desor, Cotteau 1861-7, p. 185, Pl. 1041.
Cidaris Lardyi Desor, Cotteau 1861-7, p. 190, Pl. 1043, 1049, fig. 1-4.
Cidaris Cenomanensis Cotteau 1861-7, p. 229, Pl. 1052.
Goniocidaris farringdonensis (Wright), Lambert 1892, p. 39, Pl. 2, fig. 3-5 [(*Non*) *Cidaris farringdonensis* Wright = *Stereocidaris* S.S.] = *Cidaris testiplana* Hawkins 1912, p. 531.

Most of the species referred by Lambert and Thiéry (1909, p. 151) to *Typocidaris* belong rather to Group I if they are allied to *Stereocidaris* at all (e.g. *Goniocidaris arduennensis* Lambert, *Typocidaris corbaricus* Lambert, *Cidaris farringdonensis* Wright).

GROUP III

Scrobicular tubercles with a definite raised ridge inside the mamelon, as in *Phyllacanthus*. Species of this group are known from the Cretaceous of Europe and probably N. America, and from the Paleocene of N. America.

Europe—
Cidaris Pyrenaica Cotteau 1861-7, p. 201, Pl. 1047-8, fig. 1-10.
Cidaris Forchammeri Desor, Cotteau 1861-7, p. 324, Pl. 1078-9, fig. 1-3.
North America—
Cidaris texanus Clark, Cooke 1953, Pl. 1, fig. 14, Cretaceous of Texas, probably belongs here.
Cidaris splendens (Morton), Cooke 1959, Pl. 1, fig. 10, Paleocene of New Jersey.
Cidaris sp. affin. *C. splendens* (Morton), Cooke 1959, Pl. 1, fig. 11, Paleocene of Alabama.

GROUP IV

Two N. American species with ridged scrobicular tubercles differ markedly from *Stereocidaris* S.S. in the conjugation of the pores and the apical system, which, at least in *S. hudspathensis*, possesses an enlarged madreporite. In *S. hudspathensis* the peristome is wider than the apical system, but in *Leiocidaris hemigranosus* they are approximately the same size. The species are:

Leiocidaris hemigranosus (Shumard), W. B. Clark and Twitchell 1915, p. 84, Pl. 10, fig. 1a-e; Pl. 11, fig. 1a-b, Cretaceous of the Gulf States, U.S.A.
Stereocidaris hudspathensis Cooke 1955, p. 89, Pl. 18, fig. 1-4, Cretaceous of Texas.

GROUP V

A single species appears to stand well apart from the other groups. This is *Cidaris foveata* Jackson (1922, p. 17-18, Pl. 1, fig. 6-7) from the probable Eocene of Jamaica. This imperfectly known species is described as possessing bare and grooved horizontal interambulacral sutures (*Goniocidaris-Stereocidaris* feature), conjugate pores (cf. Group IV) and strongly crenulate tubercles.

The known geographic and stratigraphic distribution of the Stereocidarina is given in Fig. 3 appended to a discussion of the relationships and origin of the genus *Goniocidaris*.

DISTRIBUTION: The genus *Stereocidaris* (limited to Group I above) is very well represented in the Mesozoic of Europe, particularly the Cretaceous, but thereafter is rare, and is only represented by a single form in the living Atlantic fauna (which probably represents a recent re-invasion of the Atlantic by the genus). Although some Upper Cretaceous forms are known from the Indo-Pacific region, it is very poorly represented throughout the Cainozoic, but here the genus flourishes in Recent times. In the Australasian region the genus is very well represented in the Palaeogene. The occurrence in the Cretaceous of N. America (suggested by Mortensen 1928, p. 230, and recorded by Cooke 1955, p. 88-9) is based on forms which cannot be placed in *Stereocidaris* in a strict interpretation of the genus (i.e. Groups III and IV above).

Stereocidaris australiae (Duncan)

(Pl. LVIII, fig. 1-5; Fig. 2a, d, g-h)

Leiocidaris Australiae Duncan 1877, p. 45, Pl. 3, fig. 1-2.
Cidaris (*Stereocidaris*) *Australiae* (Duncan), Tate 1898, p. 411 (*partim*).
Cidaris (*Leiocidaris*) *australiae* Duncan, Chapman 1914, p. 145, Fig. 80a.
Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), Pl. 12, fig. 5-6, (*non*) fig. 1-4, (*non*) Pl. 15; H. L. Clark 1946, p. 290 (*partim*); Fell 1954, p. 10-11 (*partim*).
(*Non*) *Leiocidaris Australiae* Duncan, Hutton 1887, p. 406.
(*Nec*) *Cidaris* (*Leiocidaris*) *australiae* Duncan, Tate 1894, p. 126.
= *Stereocidaris striata* (Hutton), Fell 1954, p. 33.

DIAGNOSIS: A species of *Stereocidaris* with up to 7 interambulacral plates in each vertical column, the upper one or 2 with rudimentary scrobicules. Scrobicules of the lower plates strongly sunken, and secondary tubercles very coarse. Interporiferous tracts ornamented with a regular series of marginal tubercles, usually with 2 smaller internal tubercles on larger plates.

Radioles cylindrical, often with trumpet-shaped distal terminations. Shaft ornamented by coarse longitudinal ridges bearing flattened, spur-like projections.

TYPE SPECIMEN: Holotype BM E42395 (the interambulacral zone originally figured by Duncan, *loc. cit.*). All available test fragments of this species, including the holotype, are labelled in the collection 'AW.5' or 'lower beds, AW.5'. They possess an adhering matrix of an impure limestone with rounded quartz and limonite fragments. It may reasonably be inferred that all specimens come from the Castle Cove Limestone, of 'Pre-Janjukian' age.

DESCRIPTION: The slightly sinuate ambulacra are about ⅓ the width of the interambulacra and are distinctly incised (Fig. 2a). The poriferous tracts are slightly wider than the interporiferous tracts. The marginal tubercles are well separated and form a regular vertical series, with a further vertical series of smaller internal tubercles. There are 2 internal tubercles on each of the larger plates (Fig. 2g), but the smaller plates away from the ambitus generally possess only one (Fig. 2d). The rounded pores are non-conjugate, and distinctly oblique, particularly in the smaller plates. The wall between the pores rises to a poorly defined crest, whereas the transverse ridge above the pores is sharp and well defined, and is at the level of the interporiferous tract.

Up to 7 interambulacral plates are present in each vertical column, with the scrobicules of the upper one or two plates rudimentary. The fully developed scrobicules are mounted toward the centre of each column and are deeply incised, so that the small, smooth, perforate tubercles only just rise above the level of the interambulacral plates. The scrobicules are in general well rounded and become only slightly ovate adorally. The scrobicular tubercles are not prominent as they are comparable in size to the secondary tubercles which cover the interambulacral plates. All the sutures are somewhat incised, and small pits may be present at the admedian ends of the horizontal ambital sutures.

MEASUREMENTS: Inferred measurements of the test from which P18913, an interambulacral zone, was derived are: h.d. *c.* 60 mm; v.d. *c.* 35 mm; width of apical system *c.* 23 mm; width of peristome *c.* 17 mm.

ASSOCIATION OF TEST AND RADIOLES: The reasons for associating the radioles described below with *S. australiae* were given under the description of *Stylocidaris* (?) *chapmani* (Part I, p. 199).

DESCRIPTION OF RADIOLES: The shafts are cylindrical and possess up to 12 coarse longitudinal ridges which periodically bear flattened, spur-like projections. The distal termination is often sharply expanded to give a trumpet-shaped termination. The proximal portion is missing in all the available radioles.

SYNOPSIS OF MATERIAL:

Aire Coast:

AW.5 (probably Castle Cove Limestone, 'Pre-Janjukian'), P18900-2 (test fragments and radiole); 'lower beds', P18903-7, 9, 12-13 (test fragments); P18937-9 (radioles).

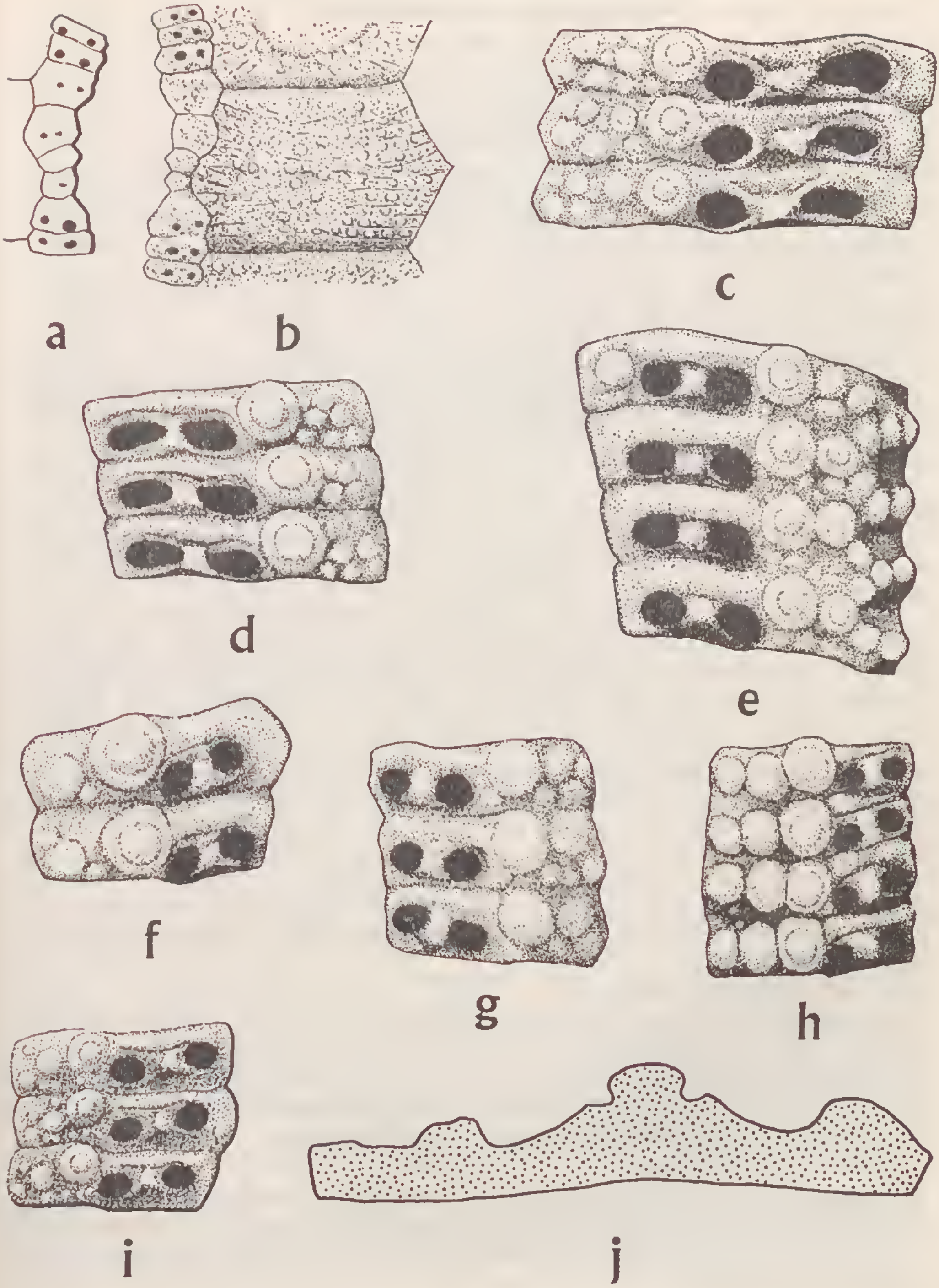
'Johanna R., hard limestones with occasional softer beds, dipping northerly' (? Castle Cove Limestone), P19006-12 (radioles).

'Point Flinders', P19751 (radiole), Lower Glen Aire Clays, 'Pre-Janjukian'.

REMARKS: Duncan (*loc. cit.*) originally described this species as possessing conjugate pores, which has undoubtedly contributed much to the past uncertainty as to its identity. Chapman and Cudmore (loc. cit.), on the basis of topotype material, correctly pointed out that Duncan was in error; however, their own exceedingly liberal interpretation of the species has not assisted its subsequent discrimination. As interpreted here, the species is known only from the Aire Coastal section.

The widely-flared, cup-shaped terminations of the radioles are somewhat atypical for a species of *Stereocidaris*. However, they are known in the living form *S. tubifera* Mortensen, and appear to have been common in the Australian Palaeogene species of *Stereocidaris*, for they are seen in *Stereocidaris* sp. A. and other radioles which apparently belong to *Stereocidaris*-like forms.

FIG. 1—*Stereocidaris* spp. a-d, i-j, *Stereocidaris cudmorei* sp. nov. a, Internal. b, External view of abnormal ambulacrum of AUGD F15738. Note small podial pores do not extend to outside of test, × 3. c, Ambital ambulacrum of large specimen AUGD F15737, × 12. d, Ambital ambulacrum of AUGD F15731, × 12. i, Ambital ambulacrum of holotype P19365, × 10. j, Profile of ambulacrum and interambulacrum of holotype, × 6. e, *Stereocidaris* (?) *intricata* sp. nov. Ambital ambulacrum of holotype P22319, × 12. f-g, *Stereocidaris fosteri* sp. nov. f, Ambital ambulacrum of AUGD F15741, × 12. g, Ambital ambulacrum of holotype AUGD F15739, × 12. h, *Stereocidaris* (?) *hispida* sp. nov. Ambital abulacrum of holotype AUGD F15745, × 12.


a
b
c
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e
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j

Stereocidaris cudmorei sp. nov.

(Pl. LX; Fig. 1a-d, i-j)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), Pl. 12, fig. 4, (*non*) fig. 1-3, 5-6, (*non*) Pl. 15.
? *Stylocidaris* sp. H. L. Clark 1946, p. 290.

Diagnosis: A large species of *Stereocidaris* with up to 9 interambulacral plates in each vertical column, the scrobicule of the upper one of which is reduced or rudimentary. Tubercles large and smooth, rising well above the level of the test. Interporiferous tracts complexly ornamented. Median and horizontal ambulacral sutures incised and naked to varying degrees or bearing pits at the admedian ends of the horizontal sutures.

Type Specimen: Holotype P19365, 'Aldinga, lower beds', Tortachilla Limestone, Upper Eocene.

Description: The ambulacra are about ¼ of the width of the interambulacra and are only slightly sinuate. The poriferous tracts (Fig. 1c-d) are approximately the same width as the interporiferous tracts and are not incised. The marginal tubercles are relatively small, although they form a regular vertical series. Up to 6 irregularly placed internal tubercles are present on each of the ambital ambulacral plates, and are surrounded by closely spaced granules, which also occur between the marginal tubercles. The pores are non-conjugate and elongate (particularly the outer of each pair) with the separating wall rising to a prominent crest. Below the crest and the pores the plate is deeply sunken. The transverse ridge above the pores is sharply delimited below by a deep furrow.

Up to 9 interambulacral plates are present in each vertical series, with a rudimentary scrobicule on the uppermost. The other scrobicules are incised although the large smooth primary tubercles rise well above the level of the test (Fig. 1j). The perforations of the primary tubercles, particularly those above the ambitus, tend to be somewhat elongate in the direction of the vertical axis. The scrobicules are rounded above the ambitus, but become transversely oval toward the peristome, where they are confluent. The scrobicular tubercles are not prominent and are only slightly larger than the surrounding secondary tubercles. The interambulacral midzone is variable in width, and may be marked by a naked zig-zag groove, which contains the median suture. In some specimens this is reduced to pits at the admedian ends of the horizontal sutures. Pits are usually present at the adradial ends of the same sutures. Apart from naked grooves and pits the midzones are covered by closely spaced secondary tubercles and numerous granules which tend to be arranged on horizontal ridges.

The radioles are unknown.

Measurements: The holotype was derived from a test with the following inferred measurements: h.d. *c.* 50 mm, v.d. *c.* 30 mm, diameter of peristome *c.* 17 mm, diameter of apical system *c.* 23 mm, 10 ambulacral plates opposite highest interambulacral plate. Largest test fragments derived from tests with h.d. *c.* 70 mm; 14 ambulacral plates opposite highest interambulacral plate.

Synopsis of Material:

St Vincent Basin, Tortachilla Limestone, Upper Eocene: 'Maslin Bay', P19365-6, P20486, P20491, AUGD 15731-2, 6-7 and 20 other specimens *ex* R. J. Foster Coll., AUGD 15738 and 2 specimens AUGD Coll., 'Christies Beach', 1 specimen AUGD Coll.

Blanche Point Marls, 'Pre-Janjukian', 'Witton's Bluff, Christies Beach', 1 specimen AUGD Coll.

ABNORMALITY: One specimen (AUGD F15738; Fig. 1a-b; Pl. LX, fig. 5) shows an interesting abnormality. The specimen is an interambulacral zone in which one of the interambulacral plates, apparently the second from the apical system, completely lacks a scrobicule and tubercle. The secondary tubercles which cover the plates are arranged in sub-horizontal rows between the grooves which apparently represent the courses of the superficial nerve plexi. The adjacent ambulacral plates in general are not pierced, and are covered with secondary tubercles and grooves identical with those of the interambulacral plates. These ambulacral plates are irregular, both in size and shape, but are arranged in one vertical column, abutting against normal ambulacral plates above and below. Inside the test most of the test plates possess rudimentary depressions for the podia (Fig. 1a). The whole interambulacral zone is twisted in a fashion which would be consistent with the torsion resultant upon a relative decrease in the growth rate of the damaged ambulacrum. The interambulacral zone apparently came from a highly distorted test.

This abnormality is probably best explained as the result of severe damage and loss of plates (and podia) at an early growth stage, perhaps just after metamorphosis.

REMARKS: H. L. Clark (1946) has suggested that the specimen of this species illustrated by Chapman and Cudmore as *Stereocidaris australiae* 'is much more like *Stylocidaris* and probably represents an undescribed species of that or a related genus'. Although the generalized character of the test and radioles of *Stylocidaris* afford no satisfactory basis for its recognition in incomplete fossil material (Part I, p. 194), *Stylocidaris* lacks bare and pitted sutures (*Stereocidaris-Goniocidaris* characters). The rudimentary upper scrobicules are also suggestive of *Stereocidaris*, although they do occur in some species of *Stylocidaris*. On the other hand, the large number of interambulacral plates, a feature which characterizes the species, is not typical of *Stereocidaris*.

S. cudmorei shows considerable variation, particularly in the width of the interambulacral midzones and the development of naked interambulacral sutures. It is the most abundant cidarid of the Tortachilla Limestone and ranges up into the Blanche Point Marls.

Stereocidaris fosteri sp. nov.

(Pl. LIX, fig. 6; Pl. LXV, fig. 3; Fig. 1 f-g)

DIAGNOSIS: A moderately large species of *Stereocidaris* with up to 7 interambulacral plates in each vertical column, the scrobicule of the upper one of which is usually rudimentary. Tubercles comparatively large and smooth, with the scrobicules moderately incised so that the mamelons rise above the level of the test. Interporiferous tract ornamented by a regular series of large marginal tubercles with up to 2 smaller internal tubercles in each plate. Pores rounded, non-conjugate and slightly oblique. Upper horizontal interambulacral sutures bare and incised, and pits are developed at their admedian ends.

TYPE SPECIMEN: Holotype AUGD F15739, 'Maslin Bay', Tortachilla Limestone, Upper Eocene (*ex* R. J. Foster Coll.).

DESCRIPTION: The slightly sinuate ambulacra are about ⅕ the width of the interambulacra. The incised poriferous tract is similar in width to the interporiferous tract, which is ornamented with a regular series of marginal tubercles, with up to 2 small internal tubercles present on each plate, although smaller tubercles and granules may be present (Fig. 1g). The somewhat oblique pores are non-conjugate and rounded with the separating wall rising to a well-marked protuberance. The transverse ridge is low and rounded.

Up to 7 interambulacral plates are present in each vertical column, the scrobicule of the uppermost of which is usually rudimentary. The other scrobicules are moderately incised, relatively large and rounded, with smooth tubercles with comparatively small mamelons which rise just above the level of the test. The scrobicular tubercles are rather prominent in comparison with the small secondary tubercles and granules which lie outside them. The interambulacral midzone is narrow and the interambulacral sutures tend to be incised, particularly the upper horizontal ones which are grooved. Small pits are usually present at the adradial and admedian ends of the horizontal sutures.

The radioles are unknown.

Measurements: The holotype was derived from a test with the following inferred measurements: h.d. *c.* 35 mm, v.d. *c.* 20 mm, width of peristome *c.* 12 mm, width of apical system *c.* 20 mm; 15 ambulacral plates opposite the highest interambulacral plate.

Synopsis of Material:

'Maslin Bay', Tortachilla Limestone, Upper Eocene: AUGD 15739-41, and 3 other specimens *ex* R. J. Foster Coll., P20487.

Remarks: *Stereocidaris striata* (Hutton) (Fell 1954, p. 33-4), from the Oligocene of New Zealand, apparently is a species very close to *S. fosteri*. From Fell's description it appears that *S. striata* has wider interporiferous tracts, less ambulacral plates opposite the interambulacral plates, and more rounded lower scrobicules. Although existing information suggests that the forms are closely related, they cannot be considered as subspecies until they become better known.

S. fosteri differs from its associate *S. cudmorei* in its small size, fewer interambulacral plates, rounded pores and less complexly ornamented interporiferous tracts, and generally narrow interambulacral midzones. It resembles more closely *S. australiae* but differs from this species in the scrobicules, which are less incised, and fewer of them are rudimentary. The secondary ornament is also coarser in *S. australiae*.

P19779, a small interambulacral zone with no locality differs from the available specimens of *S. fosteri* only in the partial crenulation of the tubercles, and so is provisionally identified as *S. fosteri*.

The species is named after Mr R. J. Foster whose extensive collection of echinoids has permitted satisfactory recognition of a number of the rarer cidarid species.

Stereocidaris inermis sp. nov.

(Pl. LIX, fig. 1-3, 7-8; Fig. 2 b-c, e-f)

Goniocidaris inermis MS. Tate 1898, p. 411 (*fide* Chapman and Cudmore 1934, p. 129).
Cidaris (*Stereocidaris*) *Australiae* Duncan, Tate 1898, p. 411 (*partim*).
Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), Pl. 12, fig. 1-3, (*non*) fig. 4-6; (*non*) Pl. 15; H. L. Clark 1946, p. 290 (*partim*); Fell 1954, p. 10-11 (*partim*).
(*Non*) *Leiocidaris Australiae* Duncan 1877, p. 45, Pl. 3, fig. 1-2.

Diagnosis: A species of *Stereocidaris* with 8 or 9 interambulacral plates in each vertical column, the scrobicules of the upper 3 to 5 of which are rudimentary. Interambulacral sutures bare and deeply incised, with the admedian ends of the horizontal sutures often deeply grooved at ambitus. Poriferous tracts markedly sunken; interporiferous tract with each plate ornamented by a regular series of marginal tubercles augmented by up to 3 irregularly placed internal tubercles.

TYPE SPECIMEN: Holotype AUGD T363 (a test bearing R. Tate's MS label '*Goniocidaris inermis*' and illustrated by Chapman and Cudmore 1934, Pl. 12, fig. 1-2 as '*Stereocidaris australiae*'), 'Aldinga', Tortachilla Limestone, Upper Eocene.

DESCRIPTION: The deeply incised ambulacra are about ⅕ the width of the interambulacra and are distinctly sinuate. The poriferous tracts of the ambulacra are approximately the same width as the interporiferous tracts and are markedly incised. The relatively small marginal tubercles of each plate form a regular vertical series. Two or even 3 irregularly placed internal tubercles are also present on each of the ambital ambulacral plates (Fig. 2b, f). The pores are non-conjugate and distant, with the separating wall rising to a definite elevation. They are round and slightly oblique. The transverse ridge above the pores is low.

8 or 9 interambulacral plates are present in each vertical series. The scrobicules, mounted toward the centre of each column, are rudimentary or absent on the upper 3, 4 or 5 interambulacral plates. Below the ambitus the scrobicules are deeply incised and ovate, and almost confluent adorally. Because of the deepness of the scrobicules the relatively small, smooth primary tubercles rise only slightly above the level of the test (Fig. 2c). The scrobicular tubercles are small and closely spaced so that only rarely are secondary tubercles interposed between them. The uppermost interambulacral plates are covered by very regularly spaced, comparatively large secondary tubercles which show a tendency to be arranged in horizontal series. Similar secondary tubercles cover the midzone and the adradial zone of the lower plates. The sutures are bare and incised while at the ambitus the admedian ends of the horizontal sutures may form pits (Pl. LIX, fig. 8).

The apical system is regularly dicyclic, with the oculars widely exsert. One genital plate, apparently the madreporite, is very slightly enlarged (Fig. 2c; Pl. LIX, fig. 7). All the plates of the apical system are covered by secondary tubercles similar in size and spacing to those of the upper coronal plates.

Both the ambulacral and interambulacral plates are remarkably thick (Fig. 2c). No radioles can be associated with this species.

MEASUREMENTS: The holotype (a small test which has been slightly crushed increasing the original h.d. at the expense of the v.d.) has the following dimensions: v.d. 18·5 mm, h.d. 35·0 mm, width of apical system 15 mm (43% of h.d.), width of peristome 11·5 mm (33% of h.d.); 10-12 ambulacral plates opposite an ambital interambulacral plate.

SYNOPSIS OF MATERIAL:

Tortachilla Limestone, Upper Eocene: 'Glauconitic limestone of the Aldinga Cliffs' (Tate 1898, p. 411), AUGD T362 (a test fragment derived from a test of h.d. approximately 50 mm—the specimen compared by Tate (1898) with the type specimen of *S. australiae* (Duncan) and identified as that species, and subsequently illustrated as such by Chapman and Cudmore 1934, Pl. 12, fig. 3); 'Aldinga', P20493 (a test fragment, undoubtely from the Tortachilla Limestone, labelled '*Goniocidaris inermis* Tate'); AUGD T363, AUGD 15744 and 5 other specimens *ex* R. J. Foster Coll.

REMARKS: This species is readily separable from the other Australian Tertiary species of *Stereocidaris* by the striking atrophy of the scrobicules of the interambulacral plates above the ambitus. In this feature it is comparable with the Recent species *S. japonica* (Döderlein) and the Cretaceous species *S. merceyi* (Cotteau).

A certain variation obtains in the available specimens, not only in the number of upper interambulacral plates which bear rudimentary scrobicules, but also in their degree of atrophy. The holotype possesses rudimentary tubercles on the 3 uppermost interambulacral plates, whereas one specimen (Chapman and Cudmore 1934, Pl. 12, fig. 3) shows all trace of the scrobicules to be lost on the 4 uppermost plates. That all specimens are conspecific is beyond doubt, although Tate (1898) identified one as *Stereocidaris australiae* (Duncan) and another as his *Goniocidaris inermis*. Chapman and Cudmore identified all as *S. australiae*.

The test of *S. inermis* closely resembles that of the living species *S. japonica* (Döderlein). This is most striking in comparing the holotype (a small specimen) of *S. inermis* with Mortensen's (1928) description and figures of *S. japonica*. The most obvious difference lies in the fact that only the upper 2 or 3 scrobicules are rudimentary in *S. japonica*. Furthermore, in *S. inermis*, both the apical system and peristome are relatively wider, and the interporiferous tracts possess slightly more complex ornament. Other differences which may be noted are that *S. inermis* may possess pits at the admedian ends of the horizontal sutures (a feature apparently absent in *S. japonica*), the remarkably thick test of *S. inermis* has not been reported in *S. japonica*, and apparently *S. inermis* grew to a larger size.

Chapman and Cudmore (p. 129), in discussing the apical system of the holotype of this species, state that 'all the plates are present, even the anal plate, which is depressed into the underlying matrix'. At present, however, the specimen is without trace of periproctal plates.

Stereocidaris (?) hispida sp. nov.

(Pl. LXI, fig. 8-9; Fig. 1h)

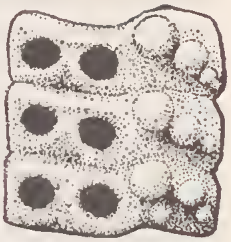
DIAGNOSIS: A small *Stereocidaris*-like form with up to 6 interambulacral plates in each vertical column, and with the uppermost scrobicule in each zone rudimentary. Tubercles comparatively small and smooth, with small scrobicules. Secondary tubercles coarse and closely spaced. Interporiferous tracts with regular series of marginal tubercles and with two series of large internal tubercles. Interambulacral sutures slightly sunken and pits may be developed at the admedian ends of the horizontal sutures.

TYPE SPECIMEN: Holotype AUGD 15745, 'Maslin Bay', Tortachilla Limestone, Upper Eocene.

DESCRIPTION: The slightly sinuate ambulacra are about ¼ of the width of the interambulacra. The sunken poriferous tracts (Fig. 1h) are approximately ⅗ of the width of the interporiferous tracts. The large marginal tubercles are almost contiguous and form a regular vertical series. On each plate up to two enlarged internal tubercles may be present, and these may also form regular vertical series. The pores are rounded and non-conjugate. The transverse ridge above the pores is wedge-shaped and bounded below by a deep furrow.

FIG. 2—*Stereocidaris* spp. a, d, g-h, *Stereocidaris australiae* (Duncan). a, Profile of ambulacrum and interambulacrum of P18905, × 6. d, Sixth and seventh ambulacral plates from peristome of P18904, × 15. g, Ambital ambulacrum of P18905, × 15. h, Ambital interambulacral plate and adjacent ambulacrum of holotype BM E42395, × 5. b-c, e-f, *Stereocidaris inermis* sp. nov. b, Ambital ambulacrum of holotype AUGD T363, × 5. c, Profile of ambulacrum and interambulacrum of P20493, × 6. e, Apical system of holotype. The madreporite is apparently the slightly enlarged genital lacking surface detail, × 4. f, Ambital ambulacrum of P20493, × 15.

a



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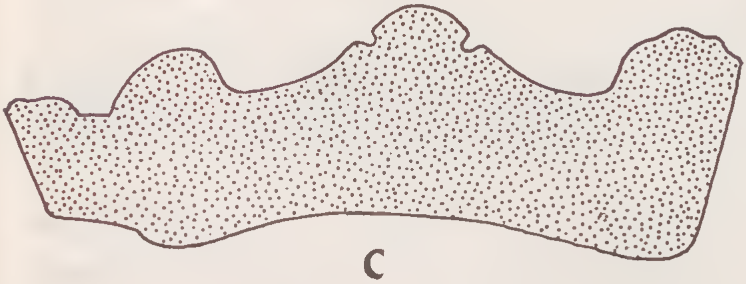

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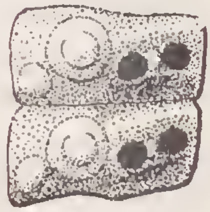

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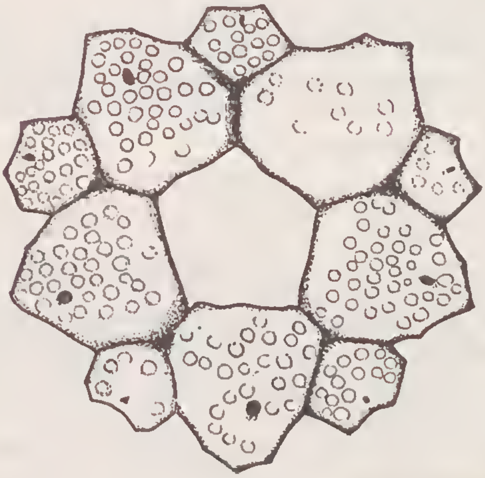

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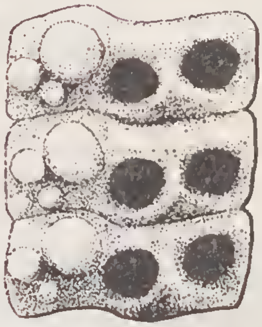
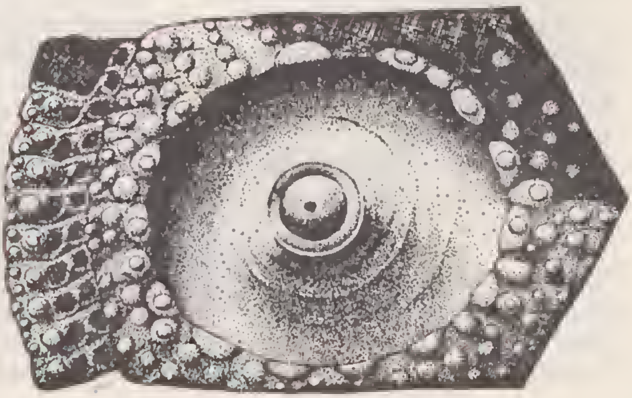


f

g



h

Up to 6 interambulacral plates are present in each vertical series, with a reduced or rudimentary scrobicule on the uppermost of each zone. The other scrobicules are rounded and small, and are mounted adradially so that the interambulacral midzone is wide. The scrobicular tubercles are enlarged and closely spaced and possess elongated mamelons. The relatively large mamelons of the smooth primary tubercles rise well above the level of the test. The secondary tubercles are relatively large and closely spaced. The interambulacral sutures are slightly sunken, and pits may be developed at the admedian ends of the horizontal sutures. The upper horizontal sutures tend to be bare.

The radioles are unknown.

MEASUREMENTS: AUGD F15746 was derived from a test with the following inferred measurements: h.d. *c.* 20 mm, v.d. *c.* 12 mm, diameter of peristome *c.* 11 mm, diameter of apical system *c.* 14 mm; 10 ambulacral plates opposite highest interambulacral plate. AUGD 15745 was derived from a test with h.d. *c.* 27 mm.

SYNOPSIS OF MATERIAL:

'Maslin Bay', AUGD F15745 and 3 other specimens *ex* R. J. Foster Coll., Tortachilla Limestone, Upper Eocene.

'Seaford', AUGD F15746 and 2 other specimens *ex* R. J. Foster coll., Port Willunga Beds, Janjukian to Batesfordian; one specimen *ex* AUGD Coll.

REMARKS: This species is best included in *Stereocidaris* although its small size and coarse tuberculation are not typical of the genus. Knowledge of the radioles would provide additional evidence of its generic position. To some extent it resembles *Delocidaris prunispinosa*, but is much more coarsely ornamented. No other comparisons can be suggested.

Stereocidaris (?) intricata sp. nov.

(Pl. LIX, fig. 4; Fig. 1e)

DIAGNOSIS: A species of *Stereocidaris* with 6 or 7 interambulacral plates in each vertical column, and with the uppermost scrobicule rudimentary. Median interambulacral and upper horizontal sutures bare and incised. Poriferous tracts slightly sunken; interporiferous tracts ornamented by a regular series of marginal tubercles augmented by a complex grouping of up to 6 internal tubercles. Admedian ends of horizontal ambulacral sutures with conspicuous pits.

TYPE SPECIMEN: Holotype and only known specimen P22319, 'Aldinga, lower beds', Tortachilla Limestone, Upper Eocene.

DESCRIPTION: The ambulacra are slightly sinuate and about ½ the width of the interambulacra. The sunken poriferous tract is slightly narrower than the interporiferous tract. The marginal tubercles form a regular vertical series. The remainder of the interporiferous tract bears a complex arrangement of up to 6 internal tubercles on each plate (Fig. 1e). Conspicuous pits are developed at the admedian ends of the horizontal ambulacral sutures. The rounded pores are horizontal and non-conjugate with the separating wall rising to a protuberance. The horizontal ridge above the pores is low.

Up to 7 interambulacral plates in each vertical column, with the scrobicule of the uppermost rudimentary. On the other plates the scrobicules are comparatively small and rounded and deeply incised, so that the small smooth primary tubercles rise just above the level of the test. The scrobicular tubercles are small and closely spaced, and the secondary interambulacral ornament consists of dense secondary tubercles and granules. The upper horizontal sutures are bare and incised, as in the median interambulacral suture, so that a prominent median zig-zag furrow is present. Pits are developed at the adradial ends of the horizontal ambital sutures.

The radioles of this species are not known.

MEASUREMENTS: P22319 was derived from a test with the following inferred measurements: h.d. *c.* 40 mm, v.d. *c.* 22 mm, width of peristome *c.* 15 mm, width of apical system *c.* 20 mm.

REMARKS: This species, in its rudimentary upper scrobicules and general characters, is suggestive of the genus *Stereocidaris,* and, indeed, it resembles *S. australiae* in its general appearance. The bare median interambulacral suture, and the pits developed at the admedian ends of the horizontal ambulacral sutures, however, are atypical of this genus, and rather indicate affinities with *Goniocidaris. S.* (?) *intricata* thus belongs to the group of Eocene and Oligocene forms which are transitional ambulacral sutures (some varieties of *S. cudmorei, Stereocidaris* sp. C) and forms with pits developed along the median ambulacral sutures in addition (Corona sp. 2, *S.* (?) *intricata*).

When more complete material of these intermediate forms becomes available (particularly when the nature of the radioles becomes known) it may prove desirable to erect a genus to accommodate some of these species. The present material suggests, however, that in dealing with this plexus of Palaeogene forms, characters which may be accorded generic merit in living cidarids lack the stability to enable worthwhile subdivisions.

No similar forms are known outside the Australian Tertiary.

Stereocidaris sp. A

(Pl. LXI, fig. 2-3; Pl. LXII, fig. 4-5; Pl. LXV, fig. 2)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-130 (*partim*), Pl. 15, fig. 32a-b (6 radioles), (*non*) fig. 34-6; (*non*) Pl. 12; H. L. Clark 1946, p. 290 (*partim*); Fell 1954, p. 10-11 (*partim*).

(*Non*) *Leiocidaris Australiae* Duncan 1877, p. 45, Pl. 3, fig. 1-2.

DESCRIPTION: Radioles cylindrical or slightly tapered, with the shaft ornamented by small, sharp denticles usually arranged in longitudinal series or mounted on longitudinal ridges. There are usually between 12 and 20 such series or ridges on each radiole. The distal termination may be slightly flattened and is flared and trumpet-shaped in all the available specimens. The cortex between the denticles on well preserved specimens is covered by a thick anastomosing mass of strong cortical hairs, which may almost envelop the denticles (Pl. LXII, fig. 5). The neck is prominent and is usually between 0·5 to 1·5 times the diameter of the shaft. The collar is of comparable height and expands slightly to the milled ring. The acetabulum may show traces of crenulation (Pl. LXI, fig. 2). In transverse section the cortex layer is relatively thick.

Isolated interambulacral plates from the same locality as the radioles (apparently derived from a small test with h.d. *c.* 30 mm) includes one plate on which the scrobicule is rudimentary (Pl. LXII, fig. 4). On the other plates the scrobicules are usually deeply incised, with the small perforate tubercle rising just above the level of the plate. The tubercle of one of the plates shows traces of crenulation. The secondary tubercles are usually of similar size to that of the rounded scrobicular tubercles. Facets of 14 ambulacral plates are present along the adradial edge of the highest interambulacral plate.

MEASUREMENTS: P15978 has the following measurements: length 31 mm;

maximum diameter of the shaft 3·3 mm; maximum diameter of the neck 3 mm; maximum diameter of the milled ring 4·2 mm.

Synopsis of Material:

'Aire Coast, Point Flinders, AW.1', Lower Glen Aire Clays, Pre-Janjukian:
P19343-53 (test fragments); P19578-96 (radioles); P19730-50 (radioles); P19699-704 (radioles).

Remarks: One of the isolated interambulacral plates (P19344, Pl. LXII, fig. 4, top left) differs from the others in possessing a shallow scrobicule, a somewhat larger tubercle and more prominent scrobicular tubercles. Conceivably it could belong to a different species.

The collars of the radioles are notably long for a species of *Stereocidaris*. Although this form is apparently distinct from the other Australian species of *Stereocidaris*, the incomplete nature of the available material prevents positive identification.

Stereocidaris sp. B

(Pl. LXIV, fig. 7, 9-11)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-130 (*partim*), (*non*) figs; H. L. Clark 1946, p. 290 (*partim*); Fell 1954, p. 10-11 (*partim*).
Chondrocidaris clarkii Chapman and Cudmore 1934, p. 141-2 (*partim*), (*non*) figs; H. L. Clark 1946, p. 248 (*partim*); Fell 1954, p. 11 (*partim*).
(*Non*) *Leiocidaris Australiae* Duncan 1877. p. 45, Pl. 3, fig. 1-2.
(*Nec*) *Phyllacanthus clarkii* (Chapman and Cudmore).
(*Nec*) *Menocidaris compta* gen. et sp. nov.

Description: Radioles cylindrical or fusiform, and thick and stout. The shaft shows extreme variation in ornament from forms which merely possess longitudinally aligned denticles, through to others in which the denticles are augmented by spur-like projections, which in turn may coalesce into high, irregular lamellae running most of the length of the shaft. The radioles usually show a tendency for the ornament to be less developed along one (adoral?) side; immediately above the neck the ornament is also more rudimentary. The surface of the shaft possesses a sparse coat of simple cortical hairs, which apparently extended about half way up the flanks of the lamellae, but was absent from the denticles. The distal termination, known in only one radiole, is slightly expanded and cupped. The neck is short, usually less than the diameter of the shaft, while the collar is often only half this diameter. As a consequence the milled ring is only slightly expanded. In a number of radioles (Pl. LXIV, fig. 7) the acetabulum is partly crenulate. In transverse section the cortex layer is thin.

Isolated interambulacral plates (derived from a test with h.d. *c.* 50 mm) associated with the radioles in the collection show that the rounded scrobicules may be small in relation to the size of the plate. The scrobicules are well incised, so that the large primary tubercle hardly rises above the level of the plates; in no case is the scrobicule rudimentary. The secondary tubercles outside the scrobicular circle are comparable in size to the rounded, closely spaced scrobicular tubercles, and may be distinctly mamillate. They are widely and irregularly spaced. The surface of the plates between the secondary tubercles is marked by a well developed system of grooves radiating from the scrobicule. Facets of 19 ambulacral plates are present along the adradial edge of the highest interambulacral plate.

Measurements: P18959 has the following measurements: length, 40 mm; maximum diameter of the shaft, 4·7 mm; diameter of neck, 2·8 mm; diameter of milled ring, 3·4 mm.

SYNOPSIS OF MATERIAL:

Aire Coast, Browns Ck Clays, Pre-Janjukian:
'Hamilton Ck', Horden Vale, P18940-6 (test fragments); P18947-86 (radioles); 'Browns Ck, right side of valley ½ mile from mouth', P19910-11 (radioles); 'Browns Ck', P20147-50, 52 (radioles).

REMARKS: The highly ornate radioles in particular distinguish this large and well-marked species of *Stereocidaris*. Again, however, the incomplete material prevents naming of the form.

Stereocidaris sp. C

(Pl. LXVI, fig. 3, 8)

DESCRIPTION: Ambulacra slightly sinuate with the poriferous and interporiferous tracts equal in width. The moderately large marginal tubercles form a regular vertical series. A small internal tubercle is also present diagonally below the marginal tubercle on each plate. The pores are slightly oblique and non-conjugate, with the separating wall rising to a distinct elevation. The horizontal ridge above the pores is well defined.

Up to 7 interambulacral plates are present in each vertical column. The interambulacral midzone is narrow and is marked by a prominent zig-zag furrow, and the upper horizontal sutures are also incised. Secondary interambulacral ornament is confined to a narrow circlet of small tubercles immediately adjacent to the scrobicular circle. The scrobicules of the uppermost interambulacral plates are rudimentary; the lower scrobicules are shallow and the primary tubercles rise well above the level of the test. The upper tubercles are partially crenulate with the crenulation confined to the adapical portions of the platforms.

MEASUREMENTS: AUGD F15742 was derived from a test with the following inferred measurements: h.d. *c.* 27 mm, v.d. *c.* 15 mm, width of peristome *c.* 10 mm, width of apical system *c.* 12 mm; 11 ambulacral plates opposite the highest interambulacral plate.

SYNOPSIS OF MATERIAL:

AUGD F15742, the only known specimen, is from the Tortachilla Limestone (Upper Eocene) at Aldinga (*ex* R. J. Foster Coll.).

REMARKS: This species is characterized by the prominent median interambulacral furrow, which is suggestive of *Goniocidaris*. In other respects, however, the species is typical of *Stereocidaris*, so that the form is to some extent intermediate between the two genera. Although readily separable from other described species, the available specimen does not warrant formal naming.

Genus **Goniocidaris** Agassiz & Desor

Goniocidaris L. Agassiz and Desor 1846, p. 33.
Stephanocidaris A. Agassiz 1863, p. 18.
Discocidaris Döderlein 1885, p. 10.
Petalocidaris Mortensen 1903, p. 25.
Cyrtocidaris Mortensen 1927, p. 67.
Aspidocidaris Mortensen 1928a, p. 67.
Goniocidaris Agassiz and Desor, Mortensen 1928, p. 149 *et. seq.* (*cum synon.*).
Adelcidaris Cotton and Godfrey 1942, p. 217.
Goniocidaris Agassiz and Desor, Fell 1954, p. 37.

TYPE SPECIES: Some confusion exists as to the identity of the type species of *Goniocidaris*. The type species given by L. Agassiz and Desor is *Cidarites gera-*

noides Lamarck, which as Mortensen (1928, p. 161) points out, is not recognizable as a species of *Goniocidaris*. However, Agassiz and Desor's figure of *Goniocidaris geranoides* is indistinguishable from *Cidarites tubaria* of Lamarck, so that most subsequent authors have taken *C. tubaria* as the type species of the genus. Strict application of the laws of priority would mean that *Stephanocidaris* Agassiz (based on *Cidarites tubaria* Lamarck) should replace *Goniocidaris* but, as there is a clear case for action by the International Commission of Zoological Nomenclature to stabilize the widely used name *Goniocidaris* under Article 70, it is retained for the group of *Cidarites tubaria*.

Because of the uncertainty as to the nature of *Cidarites geranoides*, more recently Cotton and Godfrey (*loc. cit.*) proposed the genus *Adelcidaris*, based on *Cidarites tubaria*.

DIAGNOSIS: Small, often rather fragile forms, usually with depressed tests. Ambulacra normally wide, with narrow poriferous tracts in which the pores are close together and separated by a distinct wall. Both ambulacral and interambulacral horizontal sutures grooved medianly and often connect with a vertical furrow containing the median suture. Primary tubercles smooth. Radioles extremely variable and usually highly ornamented, often with an expanded disc at the base and/or a trumpet-shaped distal termination. The cortical hairs in general fine, rarely anastomosing, and often very long with free terminations. Collar usually short.

REMARKS: Mortensen (1928) recognized 5 subgenera (*Goniocidaris* S.S., *Discocidaris*, *Petalocidaris*, *Cyrtocidaris* and *Aspidocidaris*) through which were distributed the 14 species which he then recognized. 3 more living species have been described subsequently. The subgenera, based largely on the character of the radioles, are of very little value, as was admitted by Mortensen and, indeed, they were subsequently abandoned by him (e.g. 1939). If polytypic species are recognized within the genus there are but 5 well marked living species of the genus. These may be listed as:

G. tubaria (Lamarck) from SE. Australia, with the morphological variant *impensa*, and the allopatric subspecies *umbraculum* from New Zealand.

G. florigera Agassiz, known only from the Kei Is. The allopatric forms of this species are *spinosa* from Ambon Bay and *biserialis* from the Sagami Sea and the Suruga Gulf. *Goniocidaris belinensis* Mortensen (1932, p. 148), from the Beli Sea, may also be regarded as an allopatric subspecies of *florigera*.

G. mikado (Döderlein) from the Sagami Sea, with the allopatric form *peltata* from the Kei Is. and Termate (2 specimens). Mortensen's identification of hybrids (*mikado* × *rosea*) with *Rhophalocidaris rosea* suggests very close genetic relationship between *Rhophalocidaris* and *Goniocidaris*.

G. tenuispinosa Mortensen, from the Philippines, with its 2 morphological variants *tuberculata* and *major*.

G. clypeata (Döderlein) from the Sagami Sea and N. Japan, with the allopatric forms *fimbriata* from the Malaya Archipelago and the Kei Is., and the closely related *crassa* (based on 4 specimens) from Mindinao, *sigobae* (based on 3 specimens) dredged from 5° 3′ S. 119° E., *australiae* from the SE. Australian coast, the more recently described *G. indica* Mortensen (1939, p. 3) from Indian waters, and *G.* (*Aspidocidaris*) *parasol* Fell (1958, p. 32, 34, Pl. 3, fig. B; Pl. 5, fig. b) from New Zealand. Also in this group belongs *alba* from Satsuma, Japan, based on one specimen.

The relations and distributions within this large group are imperfectly known. From the present knowledge it seems *alba* and *clypeata* are sympatric. Thus it would appear that *G. alba* has become sufficiently differentiated from *clypeata* (by geographic isolation through such forms as *fimbriata* and *crassa*) as to be able to re-invade the range of *clypeata* in Japanese waters where the two forms may coexist as good species. The morphological separation of *australiae* suggests that perhaps this should also be accorded the rank of a full species.

These species groups are very well differentiated and sympatric for most of their ranges. Hybrids have been reported between some of the species groups (e.g. *mikado* × *clypeata*).

DISTRIBUTION: The genus thus is strictly Indo-Pacific and Australasian in its present day distribution, and is particularly well represented in the Malayan and Japanese seas.

Apart from the Australian species, a number of fossil forms have been described which have been placed in *Goniocidaris*. Mortensen (1928, p. 145-6) reviewed these and concluded that *Goniocidaris affinis* Duncan and Sladen and *Cidaris hallaensis* d'Archiac and Haime (Duncan and Sladen 1883, p. 51-53, pl. 8, fig. 7-9), from the Miocene of Kachh, are the oldest goniocidarinids. Mortensen also considered that radioles figured from the same locality suggest a species of *Goniocidaris*. Duncan and Sladen's fig. 8-11, 13-14 (all probably of the one species), rather than a true species of *Goniocidaris*, recall the Eocene and Oligocene Australian species which are here included in *Stereocidaris*, in particular *S. cudmorei*. The radioles are also similar to the Australian Palaeogene forms. The test, as described and figured, lacks naked or pitted sutures along the median zone of the ambulacra, and the pores are widely separated (both *Stereocidaris*-like features). From the present knowledge the Indian Miocene form is best regarded as a species of *Stereocidaris*.

The radioles illustrated by Duncan and Sladen (1888, Pl. 57, fig. 1-14) from the Pliocene Makran Series (similar radioles have been recorded by Currie 1924, from the Aru Is.), also considered by Mortensen to be suggestive of the genus *Goniocidaris*, appear to be far too massive for a member of this genus, even considering *G. tubaria*. Some possess verticellate ornament, so that a relationship with *'Plococidaris'* is suggested, but, at present, the affinities of these radioles are obscure.

Subsequent to Mortensen's review, Grant and Hertlein (1938, p. 6) have noted that H. L. Clark, who examined specimens of the Oligocene Californian species *Cidaris branneri* Arnold (*non* White), 'considered its characters resembling those of the genus *Goniocidaris*'. This comparison is not apparent in any published description or figure of the species.

Fell (1954) appears to have accepted the forms illustrated by Duncan and Sladen as true species of *Goniocidaris* although he writes (p. 17)—'By the Miocene the genus (i.e. *Goniocidaris*) was represented by two species in northern India (Gaj)'. As none of the Gáj cidarids resembles *Goniocidaris*, this is seemingly an error for the Kattywar forms mentioned by Mortensen. From the data available from Australia, Fell gave a map which showed the genus *Goniocidaris* arising in the Eocene of southern Australia, extending to New Zealand in the Oligocene, thence across Australia to India in the Miocene, in the Pliocene extending farther to the Persian Gulf, and finally to Japan and E. Africa in Recent times.

Of the data on which this figure is based it may be observed:

1. The Eocene record of the genus in Australia is based on Chapman and Cudmore's (1934) listing of their *G. prunispinosa* and *G. pentaspinosa* from the 'lower

beds, Aldinga'. Reynolds (1953) had previously shown these to have a considerable stratigraphic range—from Upper Eocene to Middle Miocene. Most of Chapman and Cudmore's cidarids were derived from the upper part of the sequence. The oldest species of *Goniocidaris* in the present collection are of Janjukian age.

2. No extra-Australasian fossil occurrences can be regarded confidently as species of *Goniocidaris*. If the Miocene Indian form(s) be admitted, then, by the same criteria, so must *Goniocidaris jorgensis* de Loriol (1902, p. 8, Pl. 1, fig. 14-15) from the reputed Eocene of Patagonia. This form is based on isolated interambulacral plates, with bare median sutures.

It does seem likely, however, from the present available evidence that the Goniocidarina (and the Ctenocidarina) did arise in the Palaeogene of the Australasian region. In the Indo-Pacific region, where knowledge of the early Tertiary and Mesozoic faunas is so incomplete, it would be extremely hazardous to argue the time and place of origin of a group from its first known occurrence. But, in this instance, an obvious ancestral group can be distinguished, namely the Stereocidarina. Indeed, in the Palaeogene of Australia, there exists a whole spectrum of forms the gross morphology of which connect the genera *Stereocidaris* and *Goniocidaris*.

The Upper Eocene *Stereocidaris cudmorei* possesses incised and bare median interambulacral sutures, a feature unknown in any other species of *Stereocidaris* but typical of *Goniocidaris*. Furthermore, *Stereocidaris australiae* has radioles with strongly cup-shaped terminations, as has also *Stereocidaris* sp. A. Such radioles are very rare in the living species of *Stereocidaris* (partially developed in *S. tubifera* Mortensen) and are atypical for the genus; however, they characterize *Goniocidaris*. The tests of the early species here included in *Goniocidaris* reflect their heritage, for here the *Stereocidaris*-like features of the rudimentary upper areoles of the upper interambulacral plates (a character lost in the *Goniocidaris murrayensis-G. tubaria* lineage) and the bare upper horizontal interambulacral sutures are present.

In this context, mention should be made of *Goniocidaris prunispinosa* Chapman & Cudmore. This small form lacks the incised sutural grooves which characterize the Goniocidarina and, to a lesser extent, the Stereocidarina and, thus, the test recalls the general morphology of the Ctenocidarina, although the pores are not oblique. Stereocidarine characters are seen in the rudimentary scrobicules of the upper interambulacral plates and the partial crenulation of the tubercles (a feature seen in the Ctenocidarina but not in the Goniocidarina). On the other hand, the highly ornate radioles with cup-shaped terminations strongly suggest *Goniocidaris*. Below the species is set apart as a new genus, *Delocidaris*, which combines stereocidarine, goniocidarine, and ctenocidarine features.

More obvious affinities with the Ctenocidarina are indicated by the species described below in the genus *Austrocidaris*. Here the pores are so oblique that an affinity with the Ctenocidarina is beyond reasonable doubt.

Thus, this record suggests that, although no direct ancestral species can be indicated, in the Oligocene some contribution was made by the Stereocidarina to the Goniocidarina. In this plexus of species the origins of the largely Antarctic group, the Ctenocidarina, can also be seen.

Mayr (1954) in discussing speciation in echinoids, and examining the Neogene records of some N. American living species, concluded 'that most lines have existed since the Lower Pliocene (12 million years ago) . . .' and 'a period of 20-25 million years might be in many cases a more precise estimate of the length of time required for the development of a new species'.

These figures would seem to speak against the late Palaeogene origin of such diverse cidarid groups as the Goniocidarina and the Ctenocidarina as is suggested by the Australian species. However, it must be remembered that Mayr's figure is based on stable lineages which, because of ecological equilibrium and active competition, have reached a conservative rate of speciation. There can be no doubt, during the time when a group was actively exploring new ecological habitats (i.e. during diversification), the rate of speciation was much greater. The present day wealth of clypeasteroid echinoids (which arose at the end of the Cretaceous) establishes this.

Fig. 3 summarizes the phylogeny and distribution suggested by the Australian Tertiary species and records from elsewhere in the world. The Roman numerals refer to the species groups discussed under *Stereocidaris*.

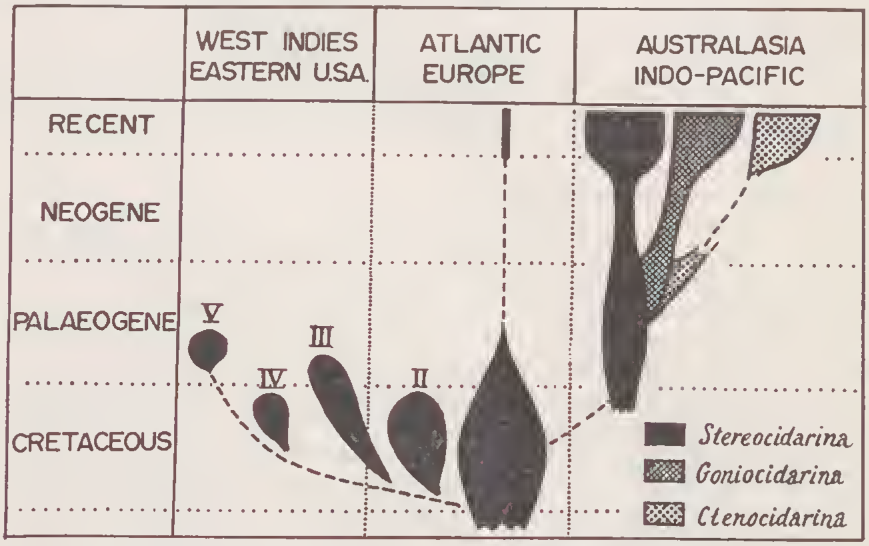


FIG. 3—Suggested phylogeny and distribution of the Stereocidarina, Goniocidarina and Ctenocidarina. Living members of the Ctenocidarina are confined largely to Antarctic waters. The Roman numerals refer to species of groups used in discussion of *Stereocidaris*.

Goniocidaris murrayensis Chapman & Cudmore

(Pl. LXII, fig. 2-3, 6-12; Pl. LXIV, fig. 5-6; Pl. LXVI, fig. 4, 6-7, 9-12; Fig. 4 a-f)

Goniocidaris pentaspinosa Chapman and Cudmore 1928 *in* Chapman 1928, p. 91-2 (*partim*), Pl. 11, fig. 74g, (*non*) fig. 74 a-f.
Goniocidaris murrayensis Chapman and Cudmore 1934, p. 138-9, Pl. 14, fig. 20-2.
Goniocidaris prunispinosa Chapman and Cudmore 1934, p. 135-7, (*partim*), (*non*) figs.
Goniocidaris pentaspinosa Chapman and Cudmore 1934, p. 137-8, (*partim*), Pl. 14, fig. 18, (*non*) fig. 19.
Goniocidaris murrayensis Chapman and Cudmore, H. L. Clark 1946, p. 292-3; Fell 1954, p. 11.

DIAGNOSIS: A moderately large species of *Goniocidaris* usually with median ambulacral and interambulacral furrows of variable width but which may be reduced to median pits, particularly below the ambitus. Upper horizontal interambulacral sutures usually bare and uppermost scrobicule rudimentary. Interporiferous tract ornamented by a regular series of small, marginal tubercles, with up to 5 closely spaced internal tubercles on each plate. 7 ambulacral plates opposite the highest interambulacral plates; up to 7 interambulacral plates in each vertical column.

Radioles comparatively long and somewhat fusiform with short collars and poorly defined necks. Shafts ornamented by irregularly placed, distally directed denticles.

TYPE SPECIMEN: Holotype, P4674, a small test originally designated by Chapman and Cudmore (1934, p. 18) and illustrated (op. cit.) Pl. 14, fig. 21-2, 'Lower Murray Cliffs', ? Morgan Limestone.

DESCRIPTION: The test is depressed with slightly incised ambulacral tracts.

The ambulacra are distinctly sinuate and up to ⅓ the width of the interambulacra. The ambulacral plates (Fig. 4b, d) are low, with the interporiferous tract slightly wider than the poriferous tract. The poriferous tract is sunken although the ridge above the pores on each plate is well defined. The slightly oblique pores are rounded and well separated with the wall between each pair rising to a poorly defined elevation. The median suture is deeply incised and furrows extend outward from this along the horizontal ambulacral sutures, imparting to the furrow a zig-zag appearance. The interporiferous tract is ornamented by a regular series of small marginal tubercles mounted toward the top of each plate. These are joined by up to 5 small internal tubercles on each plate.

The interambulacral plates are comparatively high, particularly above the ambitus. The scrobicules are rounded although those of the lower plates tend to be transversely elliptical and the lowermost may be confluent; that of the uppermost plate of each interambulacral zone is rudimentary. The scrobicules are not deeply incised and the bosses are conspicuous and rise well above the level of the test. The scrobicular tubercles are conspicuous and may tend to overhang the scrobicules. The secondary tubercles outside the scrobicular circle are small and densely spaced and form subhorizontal series across the wide median zones of the larger plates. The median interambulacral suture is deeply grooved in most specimens, but in some this groove does not continue below the ambitus, and rarely the groove may be completely replaced by a series of pits at the admedian ends of the horizontal sutures (Pl. LXII, fig. 12). The upper horizontal sutures are furrowed but toward and below the ambitus this furrow is closed so that only 'V'-shaped pits are present at both ends of the horizontal sutures.

MEASUREMENTS: Holotype test: h.d. 13 mm, v.d. 6 mm, diameter of apical system 6·5 mm, diameter of peristome 5 mm. Largest test fragments were derived from tests with h.d. *c.* 25 mm. In larger specimens up to 7 interambulacral plates in each vertical column; 7 ambulacral plates opposite the highest interambulacral plate. Longest radiole (incomplete) 28 mm long.

RADIOLES: Chapman and Cudmore did not recognize the radioles of this species. The radioles here associated with the test in this species were identified by them as either *G.* (?) *pentaspinosa* or *Delocidaris prunispinosa*.

However, there is little doubt that the present association is correct. The radioles are readily separated from those of the above species, and are co-extensive with the test fragments.

DESCRIPTION OF RADIOLES: The radioles are cylindrical or slightly fusiform and tapering. The collar is usually short, so that the milled ring is only slightly expanded. The neck, when visible, is long, almost equal to the diameter of the shaft. The shaft is usually ornamented by small, numerous, irregularly placed distally directed denticles, the interspaces between which are covered by apparently simple, serially arranged cortical hairs. The distal termination of the shaft may be slightly flared or cup-shaped, although it is lost on most of the available specimens. Some radioles appear to have possessed flattened distal terminations. In transverse section the cortex layer is thin.

Synopsis of Material:

'½ mile S. of Lethbridge', Maude Beds, P18531, ? Janjukian.

'Longford', ? Longford Limestone, P19979 (test fragment). 'Holdings old quarry, Torresdale, near Mt Gambier', Gambier Limestone, P19462-4, Janjukian or Longfordian.

'Le Grand's Quarry, Glencoe', GSV 58924-6 (15 test fragments); 'Marl pit 250 yds W. Brocks Quarry', GSV 58927-8, Gippsland Limestone, Batesfordian.

From localities along the Murray R. Cliffs, S.A.:

Mannum Formation, Longfordian.

'Wongulla', P19309-26, P19286-9 (test fragments); 'Lower Murray Cliffs', (? Morgan Limestone), holotype.

Morgan Limestone, Batesfordian and Balcombian.

'Morgan', P13719 (paratype test fragment), P19810 (test fragment), P19865-80 (radioles), P19915-7 (test fragments); '4 miles below Morgan', P19385 (radiole), P19883 (radiole), P19978 (test fragment).

'Murgheboluc, Sec. 4A', P19884 (radiole), P19926-7, P19918 (test fragments), Balcombian.

'Seaford', Port Willunga Beds, AUGD F15728-9, 33-5 and 30 specimens *ex* R. J. Foster Coll., Janjukian to Batesfordian.

'Tramway cutting (Geol. Surv. Loc. 6), Mississippi Ck', P18419-26 (radioles), Cheltenhamian.

'Roadside cutting, left bank Tambo R., downstream from Swan Reach bridge', i.e. Tambo R. Formation, P19076-120 (radioles), Cheltenhamian.

Remarks: Chapman and Cudmore (1934) identified specimens with narrow interambulacral midzones and with few secondary tubercles as belonging to their *G. pentaspinosa.* Examination of all available material, particularly that from the Port Willunga Beds, established that only one variable species is represented in the material. The wide variation exhibited by species, coupled with the incomplete nature of the material from all but a few horizons, serves to obscure the changes which may be present in this long ranging form. The tests from the Batesfordian and older horizons are usually small and often worn.

The radioles attributed to this species are from localities along the Murray R. cliffs, and the younger Bairnsdalian-Cheltenhamian limestones of Gippsland. The Gippsland examples possess noticeably longer collars, and the ornament is much more subdued (cf. Pl. LXVI, fig. 10, 11).

These observations suggest that probably a number of subspecies may, at a later stage, be found to be present in this species, but their recognition is not justified at present.

The species is closely related to *G. tubaria hallettensis* and the lineage is discussed under that subspecies.

Goniocidaris praecipua sp. nov.

(Pl. LXI, fig. 10-12; Fig. 4i, k, m)

Diagnosis: A species of *Goniocidaris* with wide interambulacral midzone and small, closely spaced secondary tubercles. Scrobicules of upper interambulacral plates either reduced in size or rudimentary. Poriferous tract sunken; interporiferous tract complexly ornamented with up to 10 small internal tubercles.

TYPE SPECIMEN: Holotype, P22316, a crushed test from the 'Polyzoal limestone, beach N. of Bird Rock, Torquay', i.e. '*Cellepora* Limestone', Puebla Formation, Longfordian. P18607, a test fragment from the same locality, is the only other known specimen.

DESCRIPTION: The ambulacra (Fig. 4m) are only slightly sinuate and about ⅕ the width of the interambulacra. The poriferous tracts are sunken so that they appear as grooves in the test. The interporiferous tract is almost twice as wide as the poriferous tract. On each plate the ridge above the pores is discernible, although not well developed, so that the lower portion of each plate in the poriferous tract is further sunken. The pores are comparatively small and round and are slightly oblique with the wall between them rising to a low protuberance. On each plate the ornament of the interporiferous tract consists of a small marginal tubercle mounted toward the upper margin of the plate and augmented by up to ten small, closely mounted internal tubercles which lack serial arrangement. 'V'-shaped pits are developed at the median ends of the horizontal ambulacral sutures, although the median suture is not itself sunken or naked.

The interambulacral plates (Fig. 4k) possess relatively small, well rounded scrobicules. On the uppermost plates the scrobicules are rudimentary, whereas those of the lower plates are moderately incised, and mounted toward the adradial side of each column. The bosses rise just above the level of the test to the small smooth mamelons. The scrobicular tubercles are small and insignificant as are also the closely spaced secondary tubercles. A prominent zig-zag groove is developed along the median interambulacral suture. The margins of this are irregular and scalloped, imparting a ragged appearance, accentuated by the varying depth of the floor of the groove. The upper horizontal sutures are incised for their entire length, but toward and below the ambitus the incised portions are confined to the adradial and admedian ends of the sutures, where they appear as lateral extensions of the median furrow.

Radioles are unknown.

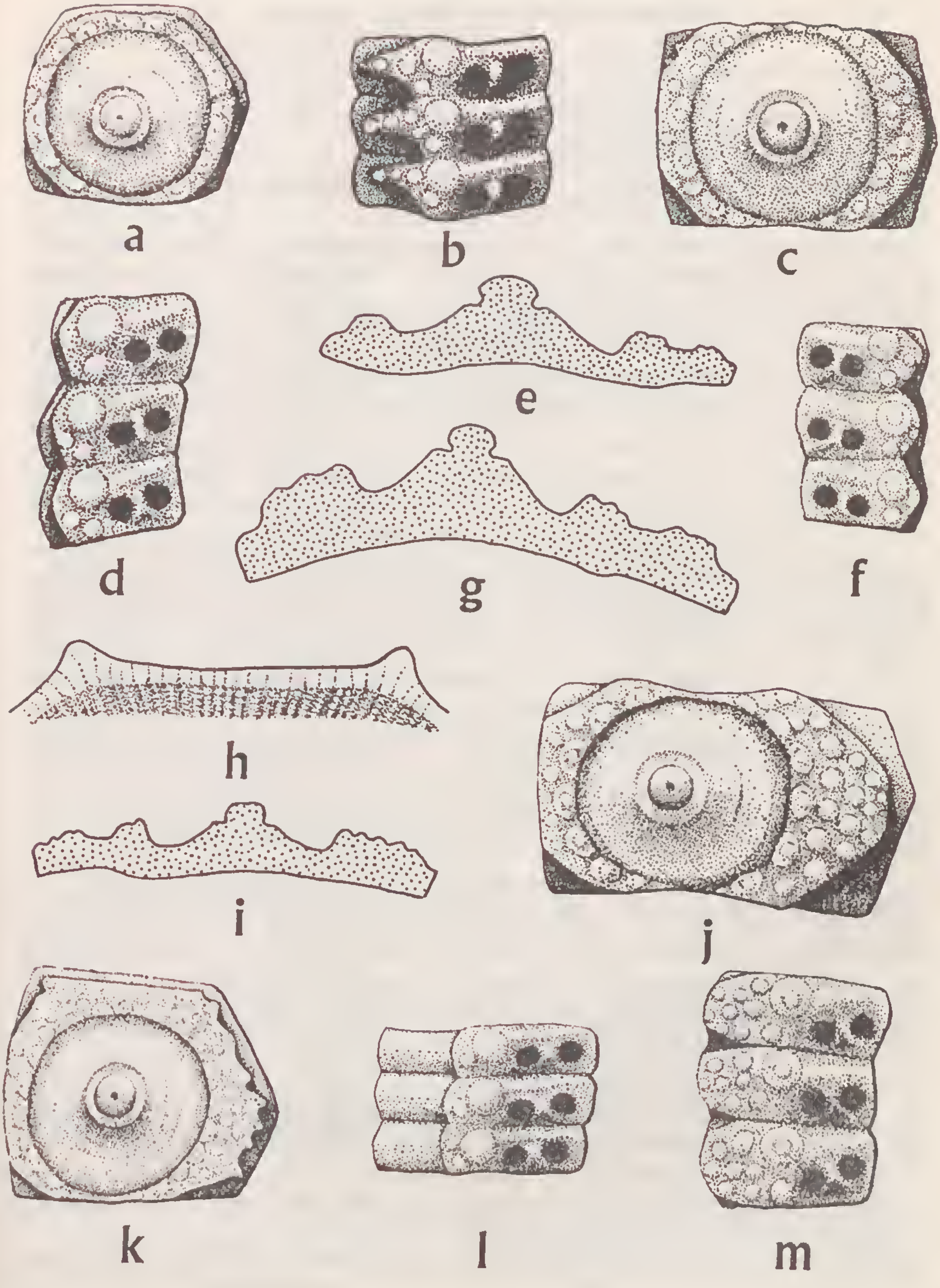
MEASUREMENTS: The holotype, a crushed test, has the following maximum dimensions: h.d. 18·5 mm; v.d. 8 mm; diameter of apical system 9·5 mm; diameter of peristome 8 mm; 6-7 interambulacral plates in each vertical column; 6 ambulacral plates opposite the highest interambulacral plate.

REMARKS: This species stands well apart from the other species of *Goniocidaris*, particularly in the very complexly ornamented interporiferous tracts of the ambulacra. The oblique pores suggest some relationship with *Austrocidaris* but this feature is much less marked than in *A. operta* sp. nov.

Goniocidaris tubaria (Lamarck)

Cidarites tubaria Lamarck 1816, p. 57.
Goniocidaris tubaria (Lamarck), Mortensen 1928, p. 156-163, Pl. 12, fig. 1-7; Pl. 13, fig. 10-11; Pl. 69, fig. 4; Pl. 78, fig. 1-6 (*cum synon.*).

FIG. 4—*Goniocidaris* spp. a-f, *Goniocidaris murrayensis* Chapman & Cudmore. a, Ambital interambulacral plate of P19288, × 6. b, Ambital ambulacrum of P19810, × 15. c, Ambital interambulacral plate of P19810, × 10. d, Ambital ambulacrum of P19288, × 12. e, Profile of ambulacrum and interambulacrum of P19288, × 10. f, Ambulacrum of GSV 58908, × 12. g, j, l, *Goniocidaris tubaria hallettensis* subsp. nom. nov. g, Profile of ambulacrum and interambulacrum of P19449. × 6. j, Interambulacral plate P19449. × 6. l, Ambulacrum of P19451, × 10, h, *Goniocidaris* (?) *petaspinosa* Chapman & Cudmore. Cortical layer in transverse section, × 40. i, k, m, *Goniocidaris praecipua* sp. nov. i, Profile of ambulacrum and interambulacrum of P18607, × 6. k, Interambulacral plate of P18607, × 6. m, Ambital ambulacrum of P18607, × 15.


a
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Goniocidaris tubaria hallettensis nom. nov.

(Pl. LXVI, fig. 1-2, 12; Pl. LXVII, fig. 4-6; Fig. 4g, j, l)

Goniocidaris mortenseni Chapman and Cudmore 1934, p. 139-140, Pl. 14, fig. 23, 27; H. L. Clark 1946, p. 291; Fell 1954, p. 11.

(*Non*) *Goniocidaris mortenseni* Koehler 1900, p. 816, *fide* Koehler 1901, p. 5, Pl. 1, fig. 1; Pl. 2, fig. 2; Pl. 3, fig. 17; Pl. 4, fig. 29; Pl. 5, fig. 30.

= *Notocidaris mortenseni* (Koehler), Mortensen 1909, p. 27.

DIAGNOSIS: A subspecies of *G. tubaria* with high ambulacral plates, so that 7 or 8 are opposite the highest interambulacral plates.

TYPE SPECIMEN: P13720, the test fragment originally selected and figured (Chapman and Cudmore 1934, Pl. 14, fig. 23) as holotype of *G. mortenseni*, from the Hallett Cove Sandstone, Middle Pliocene.

DESCRIPTION: The ambulacra (Fig. 4l) are straight, and up to ⅓ of the width of the interambulacra. The poriferous tract is about ½ of the width of the interporiferous tract. The rounded pores are well spaced, slightly oblique, and non-conjugate with the wall between rising to a distinct elevation. The transverse ridge above the pores is prominent. The median ambulacral zone is marked by a deep furrow, usually about ⅓ of the width of the abulacra. In this furrow the horizontal sutures are incised, imparting a ladder-like appearance. The ornament of the interporiferous tract consists of a regular series of almost contiguous marginal tubercles, joined on each plate by a few small and irregularly placed internal tubercles.

The interambulacral plates (Fig. 4j) are low, usually with rounded scrobicules, which may be transversely oval, with a tendency toward confluence. The scrobicules are shallow, and are mounted adradially so that the interambulacral midzone is wide. The bosses are conspicuous, and rise well above the level of the test to the small smooth tubercles. The scrobicular circles are conspicuous, with several rows of smaller tubercles outside them in the midzones of the larger plates. A very deep zig-zag furrow marks the interambulacral midzone. This may be as wide as the width of the scrobicules, and extends outwards as grooves along the horizontal sutures. The adradial ends of the horizontal sutures are also depressed and bare.

RADIOLES: The radioles originally associated with this test undoubtedly belong here. They are the only goniocidarinids known from the type formation, and both the test and radioles are closely similar to the living species of *G. tubaria*.

DESCRIPTION OF RADIOLES: The radioles are comparatively massive and cylindrical or slightly tapered. Both the neck and collar are short and the milled ring is but slightly expanded. The shaft is usually ornamented by fairly small, distally directed thorns, which are larger and more numerous distally. The distal termination may be slightly flared or even cup-shaped. The cortical hairs appear to be simple (or have simple terminations) and are serially arranged. In transverse section the cortical layer is very thin. Many of the radioles from the type horizon are of a purplish colour, which could be their original colouration.

MEASUREMENTS: Largest test fragments (e.g. P19451) derived from tests with h.d. *c.* 35 mm. 7 or 8 ambulacral plates opposite highest interambulacral plates; *c.* 9 or 10 interambulacral plates present in each vertical column.

SYNOPSIS OF MATERIAL:

'Tramway cutting, Mississippi Ck (Geol. Surv. Loc. 6)', P18417-8 (radioles), Tambo R. Formation, Cheltenhamian.

From the Middle Pliocene rocks of the St Vincent Basin: Hallett Cove Sandstone, 'Aldinga', P19400-10 (radioles), P19447-54 (test fragments), P19354-64 (radioles), 'Maslin Bay', 1 test fragment AUGD Coll. Dry Ck Sands, 'Dry Ck bore at the abattoirs', P19334-5 (radioles).

REMARKS: This form is very similar to the living SE. Australian species *G. tubaria*. Because of the great variation which obtains in this latter species, it seems that none of the distinctions originally seen by Chapman and Cudmore in their species is valid. Thus H. L. Clark (loc. cit.) concluded that 'For stratigraphical purposes, it may be as well to accept the species, but sufficient well preserved material would probably show that the specific characters are hardly sufficient to warrant separation from *tubaria*'. However, the test of *G. tubaria hallettensis* is readily distinguished by the very much larger ambulacral plates, of which usually 7 are present opposite the highest interambulacral plates. From Mortensen's (1928, p. 157) table of measurements, it can seen that the number in adult specimens of *G. tubaria tubaria* is 10-12, while only in specimens of h.d. 14 mm or less are there as few as 7. The radioles of *G. tubaria hallettensis* also appear to lack the extreme ornamentation of those of *G. tubaria tubaria*, but this feature is extremely variable in the living form. Because of the close similarity, *hallettensis* is here regarded as a subspecies of *G. tubaria*.

G. mortenseni Chapman and Cudmore is a junior primary homonym of *G. mortenseni* Koehler. The name here substituted is derived from the type formation, the Hallett Cove Sandstone.

THE *G. murrayensis*-*G. tubaria* LINEAGE:

The similarity in morphology of *G. murrayensis, G. tubaria hallettensis* and *G. tubaria tubaria* suggests that these are a closely knit species group, and, from the stratigraphical occurrence of the forms, there is little doubt that they represent a phyletic series. This appears to be the first reasonably documented cidarid lineage noted. The trends exhibited by the lineage are:

1. Increase in size of the test. The older Longfordian specimens of *G. murrayensis* usually are no more than 12 mm in h.d., although some of the tests from the Port Willunga Beds are larger. From the Batesfordian and Balcombian Morgan Limestone the tests are up to 25 mm in h.d., although usually they are smaller. The fragments of *G. tubaria hallettensis* indicate that the test grew to a maximum h.d. of *c.* 35 mm, while *G. tubaria tubaria* grows to a size of over 60 mm, although normally adults are about 40 mm in h.d.
2. Increase in number of interambulacral plates. *G. murrayensis* has up to 6 or 7 plates in each vertical column. The fragments of *G. tubaria hallettensis* suggest 9 or 10 were present. *G. tubaria tubaria* has up to 13 but normally a few less than this.
3. Increase in number of ambulacral plates. 7 ambulacral plates are opposite the highest interambulacral plate in *G. murrayensis* (5 in the smaller varieties). Up to 8 are seen in *G. tubaria hallettensis*, and in *G. tubaria tubaria* there are as many as 13, although 10 may be present in some large specimens.
4. Ambulacral ornament. There is a slight decrease in the complexity of the secondary ambulacral ornament through the lineage.
5. Radioles. The radioles become more strongly ornamented through the lineage, although there is some reversal of this trend in *G. murrayensis*. They remain almost constant in size, and so become relatively shorter in relation to the test size.
6. Interambulacra. Accompanying the increase in the number of interambulacral plates, the lowermost scrobicules become confluent in the youngest members of the lineage. The *Stereocidaris*-like character of bare and incised upper horizontal

sutures persists through the lineage (*G. tubaria* alone of the living species of *Goniocidaris* possesses this feature), although the rudimentary upper scrobicules are apparently lost in *G. tubaria hallettensis*, and certainly are absent in *G. tubaria tubaria*.

Of these trends, phyletic increase in size is perhaps the most widely acknowledged evolutionary trend in invertebrates (cf. Newell 1948), and similarly trends 1-3 may be considered as allomorphic. Apart from size increase, the trends in the lineage are not obviously adaptive, although the increase in the number of ambulacral podia may well have been necessary for the respiratory efficiency of the larger urchins.

Although *G. murrayensis* undergoes a certain increase in size during its history, it is apparently replaced by (or perhaps overlaps the range of) the closely related *G. tubaria hallettensis* in the Cheltenhamian and this form persisted until at least Middle Pliocene times. *G. tubaria tubaria* is known only as the living form. The lineage thus appears to have progressed by a marked 'saltation' in the Cheltenhamian.

The interpretation of this seems clear. Mayr (1954), after discussing speciation in echinoids, concluded that (p. 16) 'geographic speciation is the principal, if not the exclusive speciation mechanism in most marine animals'. It would seem, therefore, that the replacement of a particular species by a very closely related form in the geological record should be interpreted as the invasion of the particular area by an allopatric population which replaces the earlier form (cf. Fleming 1957).

There is some evidence to support this interpretation here. The radioles of the youngest form of *G. murrayensis* from the Cheltenhamian differ from the older form in that the ornament is more subdued and the collars are long. On the other hand, the radioles of *G. tubaria hallettensis* recall those of the older forms of *G. murrayensis* both in their ornament and collars.

The present collection suggests that *G. murrayensis* and *G. tubaria hallettensis* were sympatric rather than allopatric. Both are known from 'Tramway cutting, Mississippi Ck', a locality of Cheltenhamian age.

Goniocidaris (?) pentaspinosa Chapman & Cudmore

(Pl. LXV, fig. 1, 4-16; Fig. 4h)

Goniocidaris pentaspinosa Chapman and Cudmore *in* Chapman 1928, p. 91-2 (*partim*), Pl. 11, fig. 74 a-f, (*non*) fig. 74g; Chapman and Cudmore 1934, p. 137-8 (*partim*), Pl. 14, fig. 19, (*non*) fig. 18; H. L. Clark 1946, p. 293 (*partim*); Fell 1954, p. 11 (*partim*).

DIAGNOSIS: Moderately large, tapering and somewhat fusiform radioles, with simple terminations, and usually polygonal in cross-sections, with ridges formed by thickening of the cortex at the angles. Thorn-like projections sometimes developed along these ridges which are poorly developed in the more fusiform varieties.

TYPE SPECIMEN: Chapman and Cudmore (1928) originally figured as syntypes of this form 6 radioles from Griccs Ck and an interambulacral zone from Neumerella. This latter was subsequently (1934) identified as belonging to *G. murrayensis*, and Chapman and Cudmore then figured 5 radioles from Griccs Ck as paratypes, and substituted what was termed a 'neotype' (a test fragment from Wongulla) for the wrongly identified specimen from Neumerella.

It is nowhere stated whether the radioles originally illustrated were the group subsequently figured (1934, fig. 19) from the same locality as paratypes. Despite the crudeness of the original illustrations, it does seem that most of the radioles are the same. However, in the original figures, the radioles shown in fig. 74d-e cannot be matched with radioles in the subsequent figure, and it would seem that the largest radiole in (1934) fig. 19 has been substituted for these two radioles. Fig 74d, however, corresponds with the proximal portion of the later illustrated spine, and fig. 74e appears to represent a fragment rather than a small radiole. As the combined length of radiole in 74d-e corresponds with the length of the subsequently illustrated radiole, it is suggested that the groups of radioles are, in fact, the same.

As lectotype of *G. pentaspinosa* the radiole illustrated by Chapman and Cudmore (1928, Pl. 11, fig. 74b) is here chosen. This presumably was re-illustrated as the right-hand radiole of their (1934) Pl. 14, fig. 19 and the group is catalogued as P13718.

DESCRIPTION OF TOPOTYPE RADIOLES: The radioles are long, slender and tapering, although some may be slightly fusiform. The neck is not apparent while the length of the collar is usually about ⅔ of the diameter of the proximal portion of the shaft. The milled ring is slightly expanded and fairly prominent. The shafts have a polygonal cross-section, which is often accentuated by the ridges along the angles bearing small, distally directed denticles. The shafts taper uniformly to a distal point. The outer surface of the shaft is remarkably smooth and glossy, but has a distinctly striate appearance, due to the transparency of the cortical layer through which the lamellar zone is clearly visible. Cortical hairs apparently absent.

In transverse section the medullary zone is narrow (*c.* ⅕ of the diameter of the shaft), whereas the cortex layer (Fig 4h) is relatively thick, and thickens markedly to form the longitudinal ridges at the angles.

VARIATION: Radioles from different horizons and localities fall into three well-marked groups. These are:

VAR. A. Long and slender forms which often possess well-marked denticulations along the longitudinal ridges. Radioles of this group often show what is apparently traces of original colour banding. Radioles from the type locality belong here.

VAR. B. These radioles are more robust and more fusiform than Var. A, although they are comparable in length. They lack denticles at the base of the shaft.

VAR. C. From usually older horizons the radioles are much shorter and distinctly fusiform, with the lower part of the shaft expanded. The well-defined polygonal cross-section is absent, and the shaft may be serrated for most of its length. Radioles of this type occur with Var. B along the Murray R. Cliffs (Pl. LXV, fig. 16).

SYNOPSIS OF MATERIAL:

VAR. A.

'Grices Ck', P19376-7, P19429-46, Balcombian; 'Balcombe Bay', P19386-94, Balcombian; 'Murgheboluc Sec. 4A', P19918-25, ? Balcombian; 'Orphanage Hill', Fyansford Clay, P19955, Balcombian; '2½ miles W. of Gellibrand', Gellibrand Clay, P18378-9, ? Balcombian; 'Gellibrand', Gellibrand Clay, P19904-5, ? Balcombian; 'Altona Coal Shaft', P19948, Balcombian.

VAR. B.

'Neumerella railway cutting', P18381-3, Bairnsdalian.
From localities along the Murray R. Cliffs, S.A.:
Mannum Formation, Longfordian.
    'Murray R. Cliffs from Wongulla to Mannum', P19705-24.
Morgan Limestone, Batesfordian and Balcombian.
    'Lower Beds, Morgan', P19830-40; 'Base of cliffs at Pelican Point, 4 miles below Morgan', P19882.

VAR. C.

'Aire Coast, AW.3', Calder R. Limestone, P19005, Janjukian; '1¾ miles NW. Mt Gambier (D.31)', Gambier Limestone, AUGD F15730, ? Janjukian; 'Torresdale, Holding's Old Quarry, Gambier Limestone', P19459-61, ? Janjukian; 'Lower beds, Muddy Ck', P14638, Balcombian.

From the Gippsland Limestone and probable equivalents of Batesfordian age:

'Skinner's, Mitchell R.', GSV 58909-10 (8 specimens), GSV 58911 (7 specimens), GSV 53240 (16 specimens); 'Mitchell R., P20120; 'Le Grand's Quarry', GSV 58912 (6 specimens); 'Marl pit 250 yds. W. Brock's Quarry, GSV 58913 (15 radioles); GSV 58914 (20 radioles).

REMARKS: The test-fragments with which Chapman and Cudmore associated these radioles, both in 1928 and 1934, are here identified as *G. murrayensis*. Like its descendant *G. tubaria*, the width of the interambulacral midzone is particularly variable in *G. murrayensis*. Specimens with narrow interambulacral midzones and with few secondary tubercles were identified as belonging to *G. pentaspinosa* by Chapman and Cudmore.

At present, no tests can be associated with *G.* (?) *pentaspinosa*, nor can these radioles be ascribed to any other species. It is possible that they belong to *Delocidaris prunispinosa* because they apparently lack cortical hairs, and because the two 'species' are usually found in association and show similar modifications in different localities. However, no radioles of the *pentaspinosa* type are associated with P13174, a test of *D. prunispinosa* which shows some radioles in position.

The radioles show no resemblance to those of *Goniocidaris* (particularly in their simple terminations) nor to any other described genus. However, the form must be retained in *Goniocidaris* provisionally.

Genus **Austrocidaris** H. L. Clark

Temnocidaris Agassiz 1863, p. 18.
Austrocidaris H. L. Clark 1907, p. 212.
? *Ogmocidaris* Mortensen 1921, p. 143.
Austrocidaris H. L. Clark, Mortensen 1928, p. 140. (*cum synon.*)
(*Non*) *Temnocidaris* Cotteau 1863, p. 355.

TYPE SPECIES: *Temnocidaris canaliculata* A. Agassiz by original designation (H. L. Clark 1907).

DIAGNOSIS: Small, *Goniocidaris*-like forms, with closely spaced, oblique pores. The wall between the pores is narrow, and apparently never perforate.

REMARKS: In dealing with the fossil material, the only attribute which distinguishes *Austrocidaris* from *Goniocidaris* is the obliquity of the pores. This is a general feature of the Ctenocidarina, but in most genera of this group the narrow wall between the pores is perforate, giving rise to a condition approaching conjugation. *Austrocidaris* and *Ogmocidaris* stand apart from the other genera of the Ctenocidarina, not only in lacking such a feature, but also in possessing sunken furrows along the median ambulacral and interambulacral sutures. Both the genera *Austrocidaris* and *Ogmocidaris* are to date apparently monotypic (see below) and are to be distinguished principally by the number of peristomial plates. It is thus doubtful whether *Ogmocidaris* should be maintained as a full genus.

The Ctenocidarina are a specialized group of living cidarids which, with the exception of *Ogmocidaris* and some species of *Aporocidaris*, inhabit Antarctic and sub-Antarctic seas to the apparent exclusion of other cidarids. The occurrence of this group in the early Miocene of Australia in an environment which was undoubtedly as warm as, if not warmer than, the present is noteworthy. It suggests that the migration of the Ctenocidarina into the Antarctic could be a relatively recent occurrence, and also tends to negate palaeoclimatological arguments which could be based on the geological occurrence of the group (cf. Fell 1954, p. 45).

The only convincing fossil ctenocidarine which has been described previously is *Notocidaris vellai* Fell from the Pliocene of New Zealand. In this case even pedicellariae were obtained which clearly defined the affinities of the species.

Mortensen (1928) considered it 'highly probable' that *Goniocidaris jorgensis* de Loriol, from the reputed Eocene of Patagonia, belongs to the genus *Austrocidaris* and represents the ancestor of *A. canaliculata*. However, there is nothing in the original description which allies the form with the Ctenocidarina rather than the Stereocidarina.

Distribution: The common living species *Austrocidaris canaliculata* (Agassiz) is widely distributed through the sub-Antarctic Seas. Mortensen (1928) recognized a further species *A. spinosa* Mortensen, from S. of the Falkland Is., which is to be distinguished from *A. canaliculata* by the radioles 'the coarse thorns at the base of the upper primaries being the main distinguishing feature . . .'. There is little doubt that this form is an allopatric subspecies of *A. canaliculata*. The genus *Ogmocidaris* is more clearly monotypic, with the type species *O. benhami* Mortensen known only from New Zealand.

Austrocidaris operta sp. nov.

(Pl. LXI, fig. 5-6; Pl. LXIV, fig. 1-4, 8; Fig. 5 d-e)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-130 (*partim*), (*non*) figs.
Goniocidaris prunispinosa Chapman and Cudmore 1934, p. 135-137 (*partim*), (*non*) figs.
Stereocidaris australiae (Duncan), H. L. Clark 1946, p. 290 (*partim*); Fell 1954, p. 10-11 (*partim*).
Goniocidaris prunispinosa Chapman and Cudmore, H. L. Clark 1946, p. 292 (*partim*); Fell 1954, p. 11 (*partim*).

Diagnosis: A small *Goniocidaris*-like form with pits at the ends of the horizontal ambulacral and interambulacral sutures. Upper horizontal interambulacral suture bare, and the uppermost scrobicule of each zone rudimentary. Ambulacral plates very high; interporiferous tracts complexly ornamented. Pores non-conjugate, very strongly oblique and mounted toward the top of the plates so that the horizontal ridge is poorly defined.

Radioles short (approximately the h.d. of the test), and comparatively thick. Collar and neck short, with the shaft ornamented by a few irregularly placed thorns.

Type Specimen: Holotype P18608, an interambulacral zone with ambulacral columns, from the 'Polyzoal limestone, Beach N. of Bird Rock, Torquay', i.e. Zeally Limestone, Longfordian.

Description: The ambulacra are slightly sinuate and up to 35% the width of the interambulacra. The poriferous tract is about ½ the width of the interporiferous tract, but, unlike other cidarids, is poorly defined, with a secondary tubercle of the interporiferous tract almost alternating with the innermost pores (Fig. 5d). The pores themselves are small, very strongly oblique and closely spaced, with the wall between rising to a well-marked elevation. There is no horizontal ridge above the pores, but the lower outer corner of each plate is slightly depressed. Toward the ambitus the interporiferous tract is ornamented by up to 5 secondary tubercles with a slightly enlarged marginal tubercle. 'V'-shaped pits, which widen medianly, mark the horizontal sutures. These pits apparently extend on to the plates of the neighbouring ambulacral column, for the median angle of each plate is notched, imparting a scalloped appearance to the margin of the median ambulacral fracture.

In the interambulacra (Fig. 5e) the scrobicules are rounded and fairly deeply incised, although that of the uppermost interambulacral plate is rudimentary. The lowermost scrobicules tend to be ovate and confluent. The tubercles are small, smooth and perforate, and are mounted on high bosses which rise well above the level of the test. The scrobicular circles are prominent, with only a few secondary tubercles, more or less confined to the mid-zone, outside these. The uppermost horizontal sutures are bare and sunken while, elsewhere, deep 'V'-shaped pits are developed at the adradial and admedian ends of the horizontal sutures. As with those of the ambulacra, these tend to encroach on the plates of the adjacent column.

ASSOCIATION OF TEST AND RADIOLES: A number of radioles were included in a batch of specimens containing test fragments of the species. As similar radioles occur with the test fragments in Gippsland, these are associated in the species.

DESCRIPTION OF RADIOLES: The radioles are short and thick, with slightly tapered cylindrical shafts. The milled ring is well expanded and the collar is short, usually about ½ of the diameter of the shaft. The neck is not apparent. The shaft is ornamented by a few irregularly placed thorn-like projections.

MEASUREMENTS: The holotype was derived from a test with h.d. *c.* 12 mm, v.d. *c.* 7 mm, diameter of apical system *c.* 9 mm, diameter of peristome *c.* 6 mm; 5-6 interambulacral plates in each vertical column. 4 ambulacral plates opposite an ambital interambulacral plate, but as many as 7 opposite the high uppermost interambulacral plate; 6 interambulacral plates are present in each vertical column.

SYNOPSIS OF MATERIAL:

Zeally Limestone, Torquay, Longfordian:

'Polyzoal Limestone, beach N. of Bird Rock', P18608 (holotype), P18606 (test fragment); 'Mouth of Spring Ck, Torquay, (i.e. '*Scutellina*' Limestone) P18639-42 (test fragments), P18643-60 (radioles).

From the Gippsland Limestone and its probable equivalents of Batesfordian age:

'Le Grand's Quarry, Glencoe', GSV 58929-31 (8 test fragments); 'Skinner's, Mitchell R', P20121-3, GSV 58932.

Radioles from various localities of probable Balcombian age:

'Murgheboluc Sec. 2B, P19894-902; 'Murgheboluc Sec. 4A, P19885-91; 'Altona Bay Coal Shaft', P19954; '2½ miles W. of Gellibrand R.', Gellibrand Clay, P19380; 'Grice's Ck', P19811-3.

REMARKS: The species is largely characterized by the character of the ambulacra, and in particular the striking obliquity of the pores. This is variable, although normally it is developed to a degree such that the typical pattern of the cidarid ambulacra is interfered with (Fig. 5d). No comparisons with previously described species can be suggested.

Genus **Delocidaris** gen. nov.

Goniocidaris L. Agassiz and Desor, Chapman and Cudmore 1933, p. 135 *et seq.* (*partim*).

TYPE SPECIES: *Goniocidaris prunispinosa* Chapman and Cudmore.

DIAGNOSIS: Test moderately large, without pitted or incised sutures, and with sparse secondary interambulacral ornament. Primary tubercles small, and often partially crenulate. Scrobicules of uppermost interambulacral plates rudimentary.

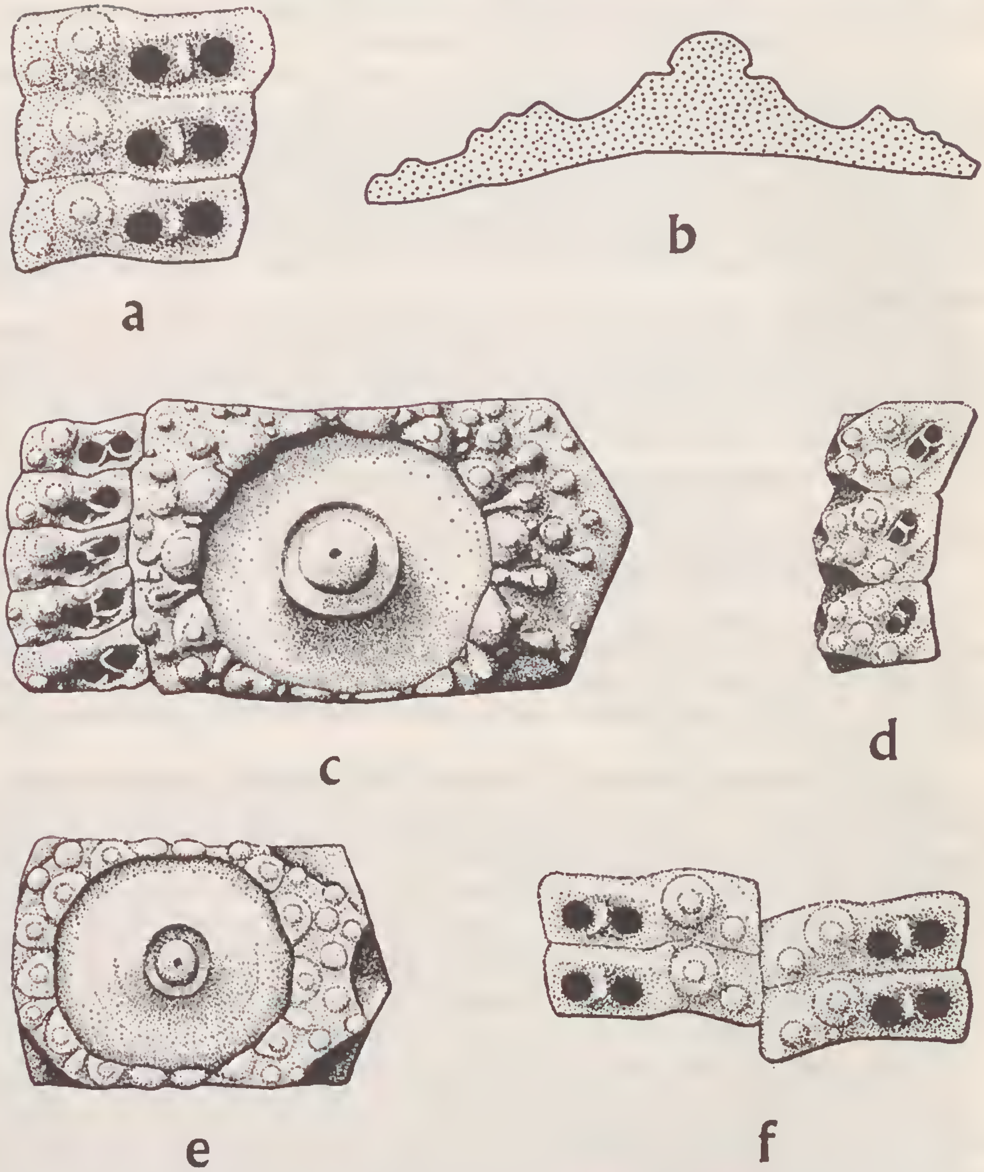

FIG. 5—*Delocidaris* and *Austrocidaris*. a-c, f, *Delocidaris prunispinosa* (Chapman & Cudmore). a, Ambital ambulacrum of P19411, × 15. b, Profile of GSV 58918, × 10. c, Isolated interambulacral plate and adjacent ambulacrum GSV 58918, × 10. f, Ambulacral plates of P13174, × 15. d-e, *Austrocidaris operta* sp. nov. d, Ambulacral plates of GSV 58930, × 15. e, Interambulacral plate of GSV 58930, × 15.

Pores non-conjugate. Radioles variably ornamented, often with prominent thorn-like projections, and flared, cup-shaped terminations. Collars long; cortex layer thick and glossy, apparently without cortical hairs.

REMARKS: The highly ornate radioles of *D. prunispinosa* provide the only basis for the original reference of the species to *Goniocidaris*. Even so, they are not typical of *Goniocidaris*, for they possess long collars and lack cortical hairs. The test lacks the grooved sutures of *Goniocidaris* and, indeed, is more closely akin to *Stereocidaris* in its upper rudimentary scrobicules and the partial crenulation of the tubercles. From *Stereocidaris*, however, the test of *Delocidaris* differs in the very sparse secondary tuberculation and the absence of depressed horizontal sutures. The radioles are unlike those of *Stereocidaris* in their ornate nature and apparent absence of cortical hairs.

No worthwhile comparisons can be made with other genera, nor have any other species been noted which could be referred to the genus. *Goniocidaris hebe* Fell (1954, p. 37), from the Oligocene of New Zealand, was considered by Fell to be closely comparable with *D. prunispinosa*. However, this species is described as possessing sutural grooves and so is apparently a species of *Goniocidaris*.

Delocidaris prunispinosa (Chapman & Cudmore)

(Pl. LVIII, fig. 6-9; Pl. LXIII; Fig. 5 a-c, f)

Goniocidaris prunispinosa Chapman and Cudmore *in* Chapman 1928, p. 90-1 (*partim*), Pl. 11, fig. 73 a-e; Chapman and Cudmore 1934, p. 135-7 (*partim*), Pl. 13, fig. 12 (16 radioles), 13-14; H. L. Clark 1946, p. 292; Fell 1954, p. 11 (*partim*).

DIAGNOSIS: A species of *Delocidaris* with interporiferous tract similar in width to the poriferous tract and ornamented by a regular vertical series of marginal tubercles, usually with two smaller internal tubercles on each plate. Up to 8 interambulacral plates in each vertical column and 7 ambulacral plates opposite the highest interambulacral plate.

TYPE SPECIMEN: Chapman and Cudmore (1928) originally figured as syntypes of their *Goniocidaris prunispinosa* 7 radioles from Grices Ck, 4 radioles from Balcombe Bay, and an isolated interambulacral plate from the Gellibrand R. Subsequently, they figured a test with some attached radioles from Morgan as the holotype, and 17 radioles from Balcombe Bay as paratypes. 3 of the original syntypes (radioles) of *G. prunispinosa* from Grices Ck were included in the second batch of type specimens. One of these, that figured in their (1928) Fig. 73k, is here selected as lectotype of *G. prunispinosa*. This radiole was re-illustrated as the lower right-hand figure of Chapman and Cudmore's (1934) Pl. 13, fig. 12. With the remainder of the radioles in their Fig. 12, it is catalogued as P13715.

DESCRIPTION OF TOPOTYPE RADIOLES: The radioles are long and slender (probably greater in length than the h.d. of the test). The neck is not apparent, and the collar is comparatively long, usually equal to the diameter of the shaft. The milled ring is moderately expanded, prominent and strongly striate, and the acetabulum is often partly crenulate. The shaft is variably ornamented with distally directed thorns which often tend to be closely developed at each side of the shaft, where they may even coalesce to give irregular platey lateral wings which can be developed for most of the length of the shaft. Radioles with such wings tend to possess a prominent series of enlarged thorns toward the middle of what was apparently the adoral surface of the shaft. Other radioles may show no tendency to develop lateral wings. Where known, the distal termination is flared, occasionally very strongly, giving a wide, cup-shaped apical disc.

The cortical hairs are apparently absent, and the outer surface of the cortex is extremely glossy. The cortical layer is moderately thick and is transparent, giving the surface of the shaft a definite striate appearance as the underlying radial zone is usually visible.

VARIATION: The radioles of this species, as here interpreted, form a fairly closely knit series. However, a certain variation is seen when comparing the radioles of this species from the different localities. Those from the Murray R. Cliffs tend to be larger, more robust and generally more sparsely ornamented than do those from Grices Ck and Balcombe Bay. The distinctions, however, are so slight, that they may well have arisen as the result of the unrepresentative nature of available collections.

Far more obvious are the distinctions of the radioles from the Batesfordian horizons in Gippsland. These are very much shorter and more robust than the typical forms, and also tend to be more uniformly ornamented with thorns. The association with test fragments indentical with the typical *D. prunispinosa* is supported by often partially crenulate acetabula. Provisionally this older form is recognized as *D. prunispinosa* var. B.

Several radioles from the Lower Maude Beds apparently also belong to this species, although the shafts, which possess longitudinal ridges of thickened cortex, suggest to some extent those of *G.* (?) *pentaspinosa*. For the present, these are identified as *D. prunispinosa* var. C. Test fragments of the species are unknown from this locality.

ASSOCIATION OF TEST AND RADIOLES: One specimen (P13174) from the Morgan Limestone shows the association of test and radioles. This is the only known cidarid from the Australian Tertiary showing the radioles largely preserved in position. The partial crenulation of the tubercles also allows confident association of test and radioles.

DESCRIPTION OF TEST: The test is small and somewhat depressed. The ambulacra (Fig. 5 a, f) are slightly sinuate, and up to ¼ the width of the interambulacra. The poriferous tract is similar in width to, or slightly wider than, the interporiferous tract and is not sunken below its level. The non-conjugate pores are rounded and very slightly oblique, with the wall between rising to a very prominent elevation. The interporiferous tract is ornamented by a very regular series of large marginal tubercles, with a single internal tubercle at the lower corner of each plate. Occasional granules are also present. The median zone of the ambulacra tends to be unornamented, with the median suture slightly sunken; however, no groove is present, nor are pits developed.

In the interambulacra (Fig. 5c) the scrobicules are comparatively small and rounded, with a tendency for those of the most adoral plates to be confluent. They are mounted adradially so that the interambulacral midzone is wide. The scrobicule of the uppermost plate of each column is usually rudimentary. They are not incised and thus the bosses rise well above the level of the test. The parapets are wide, and may show traces of crenulation particularly on those plates above the ambitus. The scrobicular tubercles are fairly prominent and closely spaced, while the secondary tubercles outside of the scrobicular circle are distant, so that the median zone is virtually unornamented. The median interambulacral suture tends to be depressed.

MEASUREMENTS: P13174, a slightly crushed test from Wongulla, has the following measurements: h.d. 29 mm, v.d. 15 mm, diameter of peristome *c.* 12·5 mm, diameter of apical system *c.* 14 mm; largest test fragment (Morgan Limestone) from a test with h.d. *c.* 32 mm; longest radiole from same horizon 37 mm long; up to 8 interambulacral plates in each vertical column, 7 ambulacral plates opposite the highest interambulacral plate.

SYNOPSIS OF MATERIAL:

VAR. A.

'Balcombe Bay', P19790-809 (radioles), P19395-9 (radioles), P19412-6 (radioles), Balcombian; 'Red Hill, Shelford', P19131-41 (radioles), P19906-9 (radioles), Balcombian; 'Clifton Bank, Muddy Ck', P19966-9 (radioles), Balcombian; 'Orphanage Hill', P19956-7 (radioles), Balcombian; Altona Coal Shaft, P19949-53 (radioles), Balcombian.

From localities along the Murray R. cliffs, S.A.:

Mannum Formation, Longfordian.

'Lower beds, Mannum to Wongulla', P19815-29 (radioles); 'Wongulla', P19327-42 (test fragments).

Morgan Limestone, Batesfordian and Balcombian.

'Lower beds, Morgan', P19411 (test fragment), P13174 (test), P19855-64 (radioles); '4 miles below Morgan', P19976-7 (radioles), P19382-4 (radioles).

VAR. B.

From the Gippsland Limestone and its probable equivalents of Batesfordian age:

'Le Grand's Quarry, Glencoe', GSV 58915-7 (43 radioles), GSV 52531 (3 test fragments; 4 radioles), GSV 57429 (12 test fragments), GSV 58918-9 (41 test fragments); 'Marl Pit, 250 yds W. Brocks Quarry', GSV 58920 (24 test fragments), GSV 58921 (20 test fragments); 'Skinners, Mitchell R.', GSV 58922 (13 radioles), GSV 58923 (4 test fragments).

VAR. C.

'½ mile S. Lethbridge', (? TM 3, Singleton 1941, p. 71, fig. 12); 'Lower Maude Beds', Janjukian or Longfordian, P18532-9 (radioles).

No specimens of *D. prunispinosa* have been located from the following localities whence Chapman and Cudmore list their species; Sorrento Bore, Fischer Point, Native Hut Ck, Waurn Ponds, Ocean Grove, Neumerella, Grange Burn, Dartmoor, Millicent, Aldinga.

Genus **Menocidaris** gen. nov.

TYPE SPECIES: *Menocidaris compta* gen. et sp. nov.

DIAGNOSIS: Moderately large forms with prominent smooth tubercles and non-conjugate pores; scrobicular tubercles with internal ridges similar to *Phyllacanthus*. Peristome with width similar to apical system. Pores non-conjugate. Radioles long and slender, ornamented with distally directed flanges, which distally give way to low serrated ridges; collars long; cortical hairs forming a spongy coat.

REMARKS: *Menocidaris compta* includes the radioles which were identified by Chapman and Cudmore as belonging to their *Chondrocidaris clarkii*. As noted previously (Part I, p. 214) the tests of *'C.' clarkii*, on which the species was based, belong to the genus *Phyllacanthus*.

Although the ornament of these radioles is suggestive of the living genus *Chondrocidaris*, H. L. Clark (1946) has pointed out that they are very much more slender, and so questioned their assignment to *Chondrocidaris*. They also differ from those of *Chondrocidaris* in their shorter collars and their coat of cortical hairs. The real distinctions of the genera, however, lie in their test characters, for *Chondro-*

cidaris has conjugate pores and highly specialized secondary tubercles. Indeed, the test of *Menocidaris* resembles *Stylocidaris*, particularly *S.* (?) *scoparia* which also has ridged scrobicular tubercles. No worthwhile comparison with other cidarid genera can be made.

Radioles which may be assigned confidently to *Menocidaris* have been recorded from Miocene strata elsewhere. Together with *'Chondrocidaris' clarkii* these afford the basis for the record of the fossil occurrence of the rare living Indo-Pacific genus *Chondrocidaris*. They include those figured by Cottreau (1907, Pl. 5, fig. 7-7a) from the Miocene of Madagascar and those described by K. Martin (1885, p. 287, Pl. 15, fig. 293 a-c) as *Phyllacanthus sundaica* from the Miocene of Java. Mortensen (1928, p. 492) drew attention to the resemblance of these radioles with *Chondrocidaris* and subsequently Jeannet and R. Martin (1937, p. 221-2) referred *P. sundaica* to *Chondrocidaris* with the Madagascar radioles placed in synonymy. Fell (1954, p. 14) also lists these occurrences as representing *Chondrocidaris*. *'P.' sundaica* is here referred to *Menocidaris* which it resembles much more closely than *Chondrocidaris*. *Chondrocidaris problepteryx* H. L. Clark (1945, p. 314), based on fragmentary radioles from the Miocene of Lau, probably should also be included in *Menocidaris*. No fossil representatives of *Chondrocidaris* are known.

'Dorocidaris' henjamnensis Clegg (1933, p. 17-8, Pl. 2, fig. 3 a-c) from the Miocene Mekran 'Series' of India, and from Henjam Is. in the Persian Gulf, is based on a test fragment, which, as illustrated, appears to agree closely with the test characters of *Menocidaris*.

DISTRIBUTION: *Menocidaris* is confined to the Miocene of the Australasian and Indo-Pacific regions (Madagascar, Indonesia, Fiji, ? India, ? Persian Gulf).

Menocidaris compta sp. nov.

(Pl. LIX, fig. 5; Pl. LXI, fig. 1; Pl. LXVII, fig. 1; Fig. 6)

Chondrocidaris clarkii Chapman and Cudmore 1934, p. 141-2 (*partim*), Pl. 15, fig. 31 (radioles), (*non*) Pl. 13, fig. 15-17; H. L. Clark 1946, p. 248 (*partim*); Fell 1954, p. 11 (*partim*).

DIAGNOSIS: A species of *Menocidaris* with narrow interambulacral midzone, and with narrow interporiferous tracts ornamented by a regular series of large marginal tubercles with occasional small internal tubercles.

TYPE SPECIMEN: Holotype P22315, an interambulacral zone labelled as collected with the radioles of *Chondrocidaris clarkii*, 'Morgan', Morgan Limestone, Balcombian or Batesfordian.

DESCRIPTION: The ambulacra are sinuate and about ⅕ the width of the interambulacra. The interporiferous tract is slightly narrower than the poriferous tract. The large, almost contiguous marginal tubercles form a regular vertical series, and may be augmented by a single small internal tubercle on each plate (Fig. 6c). The rounded pores are slightly oblique and non-conjugate, with the wall between rising to a low crest, whereas the transverse ridge above the pores is low.

Up to 8 interambulacral plates in each vertical column. The large shallow scrobicules are subquadrate, and the ambulacral midzone is exceedingly narrow, so that secondary tubercles outside the scrobicular circle are few (Fig. 6b). The smooth primary tubercles are large and prominent, and the bosses rise well above the level of the test. Each of the prominent scrobicular tubercles possesses a well-defined ridge running from the mamelon across the boss to the edge of the scrobicule of its primary tubercle.

RADIOLES: The holotype is labelled in the National Museum collections as being originally associated with the group of radioles illustrated as *Chondrocidaris clarkii* by Chapman and Cudmore.

The radioles are long and slender, cylindrical or slightly tapered and somewhat flattened, and attain twice the h.d. of the test. The shaft is ornamented proximally

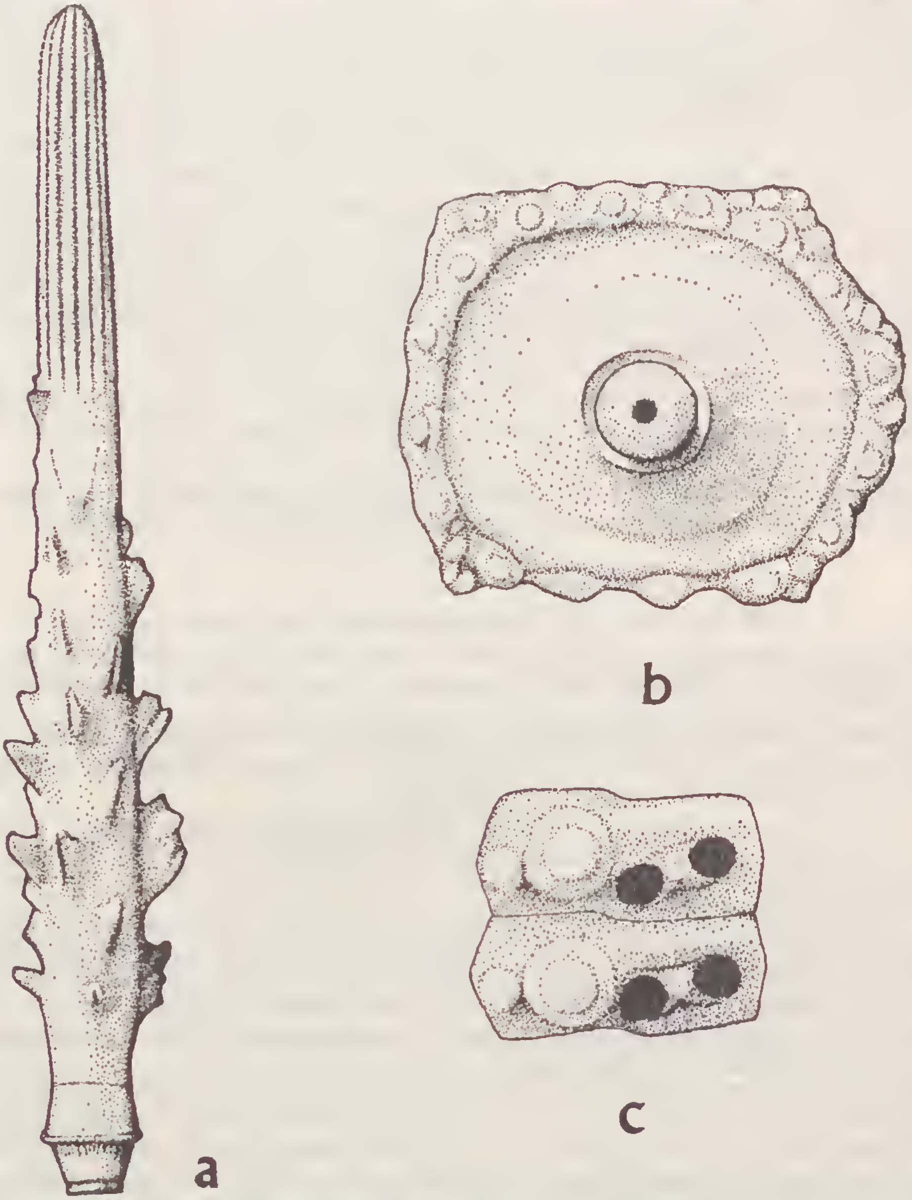

FIG. 6—*Menocidaris compta* gen. et sp. nov. a, Radiole based on P13713, × 4. b, Interambulacral plate and adjacent ambulacrum of holotype P22315, × 10. c, Ambulacrum of holotype, × 25.

by distally directed flattened thorns which tend to be aligned in longitudinal series on the adapical surface and along each side of the shaft where they coalesce to form lateral flanges. Distally this ornament usually gives way to fine serrated ridges which end in a blunted apex. The collar is up to 3 mm long, whereas the neck is short and is seldom apparent. Traces of a thick coat of spongy cortical hairs extending well up the flanks of the flanges are present in some specimens.

MEASUREMENTS: The holotype P22315 was derived from a test with the following inferred measurements: h.d. *c.* 28 mm; v.d. *c.* 15 mm; diameter of apical system *c.* 13 mm; diameter of peristome *c.* 13 mm; 10 ambulacral plates opposite highest interambulacral plate. P19789 was derived from a test with h.d. *c.* 35 mm.

SYNOPSIS OF MATERIAL:

Murray R. Cliffs, Wongulla to Mannum, ? Mannum Formation, Longfordian, P19928-33.

'Morgan', Morgan Limestone, Balcombian/Batesfordian, P19789, P22315 (test fragments); P13713 (6 radioles), P19943-7.

REMARKS: The test of *M. compta* resembles that of *Phyllacanthus duncani* in the large tubercles, well-defined and ridged scrobicular tubercles, narrow interambulacral midzones and narrow interporiferous tracts. The simpler ambulacral ornament, the non-conjugate pores and fewer ambulacral plates, however, distinguish *M. Compta.*

Cidarid Fragments

In this section a number of fragmentary species, either generically indeterminate or inadequately characterized, is listed. These are included for completeness, and further indicate the remarkable abundance and variety of cidarids in the SE. Australian Tertiary.

Corona sp. 1

(Pl. LXII, fig. 1)

Prionocidaris scoparia Chapman and Cudmore 1934, p. 134-5 (*partim*), (*non*) figs.

MATERIAL AND HORIZON: One interambulacral zone (P19788) and 6 interambulacral plates (P19272-7), 'Aldinga, lower beds', probably Port Willunga Beds.

DESCRIPTION AND REMARKS: A moderately large species (h.d. *c.* 40 mm) with up to 6 interambulacral plates in each vertical column. Scrobicules shallow and the primary tubercles are smooth and prominent. The interambulacral midzone is wide and is furrowed by closely spaced sub-horizontal grooves, between which are mounted small secondary tubercles. The interporiferous tract is narrow and the pores are non-conjugate, with a well-marked transverse ridge above the pores.

This distinctive species is probably best included in *Stylocidaris.* One of the groups of radioles described as Radiolus sp. 5-7 could belong to this test.

Corona sp. 2

(Pl. LXI, fig. 4, 7)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-130 (*partim*), (*non*) figs.

Goniocidaris murrayensis Chapman and Cudmore 1934, p. 138-9 (*partim*), (*non*) figs.

MATERIAL AND HORIZON: One interambulcral zone (P13857) and 4 test fragments (P19293-4; P19303-4), 'Aldinga, lower beds', probably Port Willunga Beds.

DESCRIPTION AND REMARKS: A moderate sized form (h.d. *c.* 30 mm) with up to 6 interambulacral plates in each vertical column. The poriferous tracts are depressed and the interporiferous tract is wide and complexly ornamented. Scrobicules small, very deeply incised, and are mounted toward the adradial sides of the columns leaving a wide interambulacral midzone. The primary tubercles are smooth and the bosses are small, just rising above the level of the test. The pores are non-conjugate with the upper transverse ridges very high and prominent. Pits are developed at the median ends of the horizontal interambulacral sutures and similar pits may be present in the ambulacra, although this feature appears to be variable.

This form belongs to the group of species here included in *Stereocidaris* and *Goniocidaris*. It shows closer affinity with *Goniocidaris* than do *Stereocidaris cudmorei* and *Stereocidaris* sp. C, for naked sutural pits may be developed in the ambulacra as well as in the interambulacra.

The extreme development of the horizontal ridges above the pores is a striking feature of the species. This character is also known in some living goniocidarinids, particularly in *Goniocidaris florigera*, where the pore arrangement simulates conjugation. Indeed, Lambert and Thiéry (1910, p. 153) took *Petalocidaris* Mortensen (based on *G. florigera*) to be a good genus characterized by conjugate pores. However true conjugation of the pores is not known in the Goniocidarina.

Corona sp. 3

(Pl. LXVI, fig. 5)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), (*non*) figs.

Material and Horizon: Isolated interambulacral plates (P19290-2, P19295-6, P19298-301, P19305-8, P19465-9), 'Aldinga, lower beds', probably Port Willunga Beds.

Remarks: These plates, obviously derived from a species of *Stereocidaris*, appear to represent a form close to *Stereocidaris* sp. B from the Browns Ck Clays. It would, however, be unwise to identify the present fragments with those from the Aire Coast for they are of a smaller form, which possesses more closely spaced secondary tubercles. More than one species may be represented in these fragments.

Radiolus sp. 1

(Pl. LXVII, fig. 7-8)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), (*non*) fig.

(?) *Prionocidaris marshalli* Fell 1954, p. 54, Pl. 8, fig. B-C, I; Pl. 9, fig. C.

Material and Horizon: 'Hamilton Ck, Hordern Vale', P18987-9; 'Browns Ck', P20151, Browns Ck Clays, 'Pre-Janjukian'.

Description and Remarks: The shaft is apparently very long and cylindrical with irregular, distally directed thorns. Although the base is missing in all specimens, traces of a very long collar (3 mm +) are seen in some radioles. The cortex layer is very thin and glossy, and imparts to the surface of the shaft an enamelled appearance, whereas the collar is dark and matt in texture.

Fell (loc. cit.) described a very similar group of fragmentary radioles from the Middle Eocene of New Zealand as *Prionocidaris marshalli*. The character of the very thin cortex layer, which apparently lacked cortical hairs, precludes the identification of this form as *Prionocidaris* and, indeed, most other genera. It does, however, suggest a general comparison with the Histocidarina in which this feature is typical. Some confirmation of this suggested relationship would be found in the character of the acetabulum—whether crenulate or not. To date, however, it appears that all specimens of this form are too imperfect to show this feature. Certainly these radioles cannot be taken as indicative of the occurrence of *Prionocidaris* in the Australasian Tertiary.

Radiolus sp. 2

(Pl. LXVII, fig. 2)

Smooth spines, *incertae sedis,* Chapman and Cudmore 1934, p. 142-3; Pl. 14, fig. 24 (3 radioles).

MATERIAL AND HORIZON: 'Aldinga', P19417-8, ? Port Willunga Beds; 'Lethbridge' (? TM3), P18543-5, Lower Maude Beds, Janjukian; 'Lower beds, Wongulla to Mannum', P19369-75, Mannum Formation, Longfordian.

DESCRIPTION AND REMARKS: Small cylindrical or tapering radioles which possess somewhat glossy shafts, short collars, and smooth acetabula.

While the smooth, thin, even cortex layer immediately suggests a relationship with such living genera as *Calcocidaris* or *Homalocidaris*, in the absence of knowledge of test characters, the true affinities of this form must remain obscure.

Radiolus sp. 3

(Pl. LXVII, fig. 3)

MATERIAL AND HORIZON: '*Turritella* Bed', Table Cape, Tasmania, P19881, Janjukian.

DESCRIPTION AND REMARKS: The single specimen is the proximal portion of a large radiole, with a comparatively long collar, an expanded milled ring and smooth acetabulum. The shaft is smooth and the cortex layer is regular in thickness.

This is obviously different from the smooth radioles of Radiolus sp. 2, and recalls more closely the radioles of the ctenocidarinid *Homalocidaris* in the expanded milled ring.

Radiolus sp. 4

(Pl. LXVII, fig. 10)

Goniocidaris prunispinosa Chapman and Cudmore 1934, p. 135-7 (*partim*), (*non*) figs.

MATERIAL AND HORIZON: 'Forsyth's, Hamilton', P19936-42, Grange Burn Formation, Kalimnan.

DESCRIPTION AND REMARKS: Comparatively small, somewhat fusiform radioles, with short collars, poorly defined milled rings and smooth acetabula. The shaft is ornamented by well-spaced tubercles and may possess lateral wings. Traces of a thick coat of cortical hairs usually present between the tubercles.

While resembling the radioles which have already been described as *Eucidaris strombilata felli* (Part I, p. 202), these are obviously different as they possess lateral wings and very irregular ornament. These features would seem to preclude their placement in *Eucidaris* and in some respects they recall rather the highly ornate radioles of the Australian Tertiary species of *Stereocidaris.* This group of radioles appears to resemble closely those described as *Cidaris mertoni* Döderlein (1911, p. 236, Pl. 9, fig. 3-8; Currie 1924, Fig. 18-30) from the Pliocene of the Aru Is.

Radiolus sp. 5

(Pl. LXVII, fig. 9)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), (*non*) Pl. 12, Pl. 15, fig. 34-5, (*non*) fig. 32, 36.

MATERIAL AND HORIZON: 'Aldinga, lower beds', P19761-73, P19548-62, ? Port Willunga Beds.

Description and Remarks: Long slender radioles with shafts ornamented by fine denticles arranged in longitudinal series in low ridges, between which are preserved traces of short simple cortical hairs. Rarely the denticles may be enlarged as small flange-like projections. The neck is relatively long, the collar short and the acetabulum smooth. The distal termination is simple.

These radioles probably belong to a species of *Stereocidaris*.

Radiolus sp. 6

(Pl. LXVII, fig. 12)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), (*non*) Pl. 12, Pl. 15, fig. 36 a-b, (*non*), fig. 32, 34-5, 36c.

Material and Horizon: 'Aldinga, lower beds', P19477-513, P19534-46, ? Port Willunga Beds.

Description and Remarks: Moderately large cylindrical or slightly fusiform radioles with short collars and smooth acetabula. The shaft is ornamented by denticles and coarse thorns and the distal termination is expanded or cup-shaped.

These radioles apparently belong to a species of the *Stereocidaris-Goniocidaris* group.

Radiolus sp. 7

(Pl. LXVII, fig. 11, 13)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), (*non*) Pl. 12, Pl. 15, fig. 36c, (*non*) fig. 32, 34-5, 36 a-b.

Material and Horizon: 'Aldinga, lower beds', P19254-61, P19465-76, ? Port Willunga Beds.

Description and Remarks: Comparatively short often flattened and fusiform radioles usually with long collars and smooth acetabula. The shaft is ornamented with coarse denticles and irregular tubercles and lateral wings may be developed. The distal termination is tapered or slightly flared.

The ornament of the shaft suggests comparison with Radiolus sp. 4.

References

(Additional to those listed in Part I)

Clark, W. B., and Twitchell, M. W., 1915. The Mesozoic and Cainozoic Echinodermata of the United States. *U.S. Geol. Surv. Mon.* 54: 1-341, 108 Pl.

Clegg, E. L. G., 1933. Echinoidea from the Persian Gulf. *Mem. Geol. Surv. India* 22 (1): 1-35, 3 Pl.

Cooke, C. W., 1955. Some Cretaceous echinoids from the Americas. *U.S. Geol. Surv. Prof. Pap.* 264E: 87-112, Pl. 18-29.

Cotteau, G. H., Gauthier, V., and Douvillé, H., 1895. *Mission scientifique en Perse par J. 'de Morgan; Pt. II Paléontologie.* 1-107, 16 Pl. Paris.

Döderlein, L., 1911. Uber Echinoidea von den Aru-Inseln. *Abh. Senkenberg. Natur. Gesell.* 34: 237-48, Pl. 9-10.

Fell, H. B., 1958. Deep-sea echinoderms of New Zealand. *Zool. Publ. Vict. Univ. Wellington* 24: 1-40, Pl. 1-5.

Gerth, H., 1927. Uber einige Pliozän-Quartäre Echiniden von Timor. *Pal. Timor* 15: 181-4, Pl. 218.

Goldfuss, A., 1826. *Petrefacta Germaniae.* I. 1-252. 71 Pl. Düsseldorf.

Hutton, F. W., 1873. Catalogue of the Tertiary Mollusca and Echinodermata of New Zealand in the collection of the Colonial Museum, Wellington. *Col. Mus. Geol. Surv. Dept.* 38-43.

Jackson, R. T., 1922. Fossil echini of the West Indies. *Carnegie Inst. Wash. Publ.* 306: 1-103, 18 Pl.

Koehler, R., 1901. *Echinides et Ophiures Resultats du voyage du S.Y. Belgica. Zoologie* 1-42, 8 Pl., Commission de la Belgica.

LAMARCK, J. B. P., 1816. *Historie naturelle des animaux sans vertèbres* ii, 522-68; iii, 1-59, 71-74.

LAMBERT, J., 1900. Etude sur quelques échinides de l'Infralias et du Lias. *Bull. Soc. Yonne* 53: 3-57, Pl. 1.

———, 1902. Description des échinides fossiles de la province de Barcelone (I). *Mem. Soc. Geol. France* 9 (3): 1-58, Pl. 9-12.

———, 1936. Nouveaux échinides fossiles de Madagascar. *Ann Géol. Ser. Min. Madagascar* 6: 11-32, 4 Pl.

———, and JEANNET, A., 1935. Contribution à l'étude des échinides tertiares des îles de la Sonde. I, Echinides réguliers. *Mém. Soc. Pal. Suisse* 56: 1-62, 4 Pl.

LORIOL, P. de, 1902. *Notes pour servir à l'étude des échinodermes* 1 (10), 1-32, Pl. 32-5, Bâle & Geneve, Georg & Co.

NEWELL, N. D., 1949. Phyletic size increase, an important trend illustrated by fossil invertebrates. *Evolution* 3 (2): 103-14.

PHILIP, G. M., 1963b. The Tertiary echinoids of south-eastern Australia. I. Introduction and Cidaridae (1). *Proc. Roy. Soc. Vict.* 76 (2): 181-226, Pl. 21-26.

STOLICZKA, F., 1873. Cretaceous fauna of southern India; Echinodermata. *Pal. Indica* 4 (3): 1-57, 7 Pl.

TATE, R., 1894. Critical list of the Tertiary Mollusca and Echinodermata of New Zealand in the collection of the Colonial Museum. *N.Z. Geol. Surv. Rept. Geol. Explor. 1892-1893* 121-7.

Explanation of Plates

Figures × 1 unless otherwise stated.

PLATE LVIII

Fig. 1-5– *Stereocidaris australiae* (Duncan). (1) Holotype BM E42395, 'AW.5', Castle Cove Limestone, 'Pre-Janjukian'; (2) Radiole P19751, 'Point Flinders', Lower Glen Aire Clays, 'Pre-Janjukian', × 2; (3) Test fragment P18913, 'AW.5', × 2; (4) Radioles P18937-9, 'AW.5', × 2; (5) Radiole P18902, 'AW.5', × 2.

Fig. 6-9—*Delocidaris prunispinosa* (Chapman & Cudmore). (6) Radioles P18532-4, var. C, 'Lethbridge', Janjukian or Longfordian, × 2; (7) Interambulacral plate P19334 showing partial crenulation of the tubercle, 'Wongulla', ? Longfordian, × 2; (8) 9 radioles GSV 58915, var. B, 'Le Grand's Quarry, Glencoe', Batesfordian, × 2; (9) Radiole GSV 58916, var. B, same locality, × 5.

PLATE LIX

Fig. 1-3, 7-8—*Stereocidaris inermis* sp. nov. (1) Adapical, (2) Lateral, (3) Adoral views of holotype AUGD T363, 'Aldinga', Upper Eocene (2, unconventionally oriented); (7) Apical system of holotype, × 3; (8) Test fragment AUGD F15744, 'Aldinga', Upper Eocene, × 2.

Fig. 4—*Stereocidaris* (?) *intricata* sp. nov. Holotype P22319, 'Aldinga', Upper Eocene, × 2.

Fig. 5—*Menocidaris compta* gen. et sp. nov. Holotype P22315, 'Morgan', Batesfordian or Balcombian, × 3.

Fig. 6—*Stereocidaris fosteri* sp. nov. Holotype AUGD F15739, 'Maslin Bay', Upper Eocene, × 2.

PLATE LX

Fig. 1-5—*Stereocidaris cudmorei* sp. nov. (1) Test fragment AUGD F15736, × 2; (2) Test fragment AUGD F15732, × 2; (3) Holotype P19365, × 2; (4) Test fragment of abnormal specimen AUGD F15738, × 2; (5) Test fragment AUGD F15731, × 2. All specimens from the Upper Eocene Tortachilla Limestone.

PLATE LXI

Fig. 1—*Menocidaris compta* gen. et sp. nov. Adoral view of test fragment P19789, 'Morgan', Balcombian or Batesfordian, × 2.

Fig. 2-3—*Stereocidaris* sp. A. (2) Radioles P19578-9, 82, 89, 'AW.1', 'Pre-Janjukian'; (3) Radioles P19731-2, 7-8, same locality.

Fig. 4, 7—Corona sp. 2. (4) Test fragment P19293, 'Aldinga', Janjukian-Batesfordian, × 2; (7) Test fragment P13857, same locality, × 2.

Fig. 5-6—*Austrocidaris operta* sp. nov. (5) Radioles P18644-7, 'Spring Ck', Longfordian, × 2; (6) Holotype P18608, 'Beach N. of Bird Rock, Torquay', Longfordian, × 2.

Fig. 8-9—*Stereocidaris* (?) *hispida* sp. nov. (8) Test fragment AUGD F15746, 'Seaford', Janjukian/Batesfordian, × 2; (9) Holotype AUGD F15745, 'Maslin Bay', Upper Eocene, × 3.

Fig. 10-12—*Goniocidaris praecipua* sp. nov. (10) Adapical, (11) Lateral, (12) Adoral views of holotype P22316, 'Beach N. of Bird Rock, Torquay', Longfordian, × 3.

PLATE LXII

Fig. 1—Corona sp. 1. P19788, 'Aldinga', Janjukian/Batesfordian, × 2.

Fig. 2-3, 6-12—*Goniocidaris murrayensis* (Chapman & Cudmore). (2) Test fragment P18531, 'Lethbridge', Janjukian or Longfordian, × 4; (3) Test fragment P19918, 'Murgheboluc', ? Balcombian, × 4; (6) Lateral; (7) Adapical; (8) Adoral views of AUGD 15728, 'Seaford', Janjukian/Batesfordian, × 3; (9) Test fragment AUGD 15734, same locality, × 3; (10) Test fragment AUGD 15733, same locality, × 3; (11) Test fragment AUGD 15735, same locality, × 3; (12) Test fragment AUGD 15729, same locality, × 3.

Fig. 4-5—*Stereocidaris* sp. A. (4) Isolated interambulacral plates P19343-6, 53, 'AW.1', Pre-Janjukian', × 2; (5) Shaft of radiole P19581, same locality, × 5.

PLATE LXIII

Fig. 1-9—*Delocidaris prunispinosa* (Chapman & Cudmore). (1) Radioles P19395-9, var. A, 'Balcombe Bay', Balcombian, × 2; (2) Test fragment P19411, 'Morgan', Balcombian or Batesfordian, × 2; (3) Lateral view of test P13174, 'Morgan'; (4) Radioles P19412-6, var. A, 'Balcombe Bay', Balcombian, (uncoated), × 2; (5) Radioles P19815-8, var. A, 'Lower beds, Mannum to Wongulla', Longfordian, (uncoated), × 2; (6) Radioles P19790-3, var. A, 'Balcombe Bay', Balcombian, × 2; (7) Radioles P19949-50, var. A, 'Altona Coal Shaft', Balcombian, × 2; (8) Radiole P19976, '4 miles below Morgan', Balcombian or Batesfordian, × 2; (9) Radioles P19131-4, var. A, 'Red Hill, Shelford', Balcombian, (uncoated), × 2.

PLATE LXIV

Fig. 1-4, 8—*Austrocidaris operta* sp. nov. (1) Radiole P18643, 'Spring Ck', Longfordian, × 2; (2) Radioles P19811-3, 'Grices Ck', Balcombian, × 2; (3) Radioles P19885-6, 'Murgheboluc 4A', ? Balcombian, × 2; (4) Test fragment GSV 58930, 'Le Grand's Quarry, Glencoe', Batesfordian, × 10; (8) Radioles P19894-6, 'Murgheboluc 2B', ? Balcombian, × 2.

Fig. 5-6—*Goniocidaris murrayensis* (Chapman & Cudmore). (5) Test fragment P19916, 'Morgan', Batesfordian or Balcombian, × 3; (6) Test fragment P19288, 'Wongulla', Longfordian, × 3.

Fig. 7, 9-11—*Stereocidaris* sp. B. (7) Radioles P18947, 50-51, 53, 59, 62, 71, 74, 76, 84, 'Hamilton Ck', 'Pre-Janjukian'; (9) Isolated interambulacral plates P18940-2, same locality, × 2; (10) Radioles P19910-11, 'Browns Ck', 'Pre-Janjukian'; (11) Shaft of radiole P18948, 'Hamilton Ck', × 5.

PLATE LXV

Fig. 1, 4-16—*Goniocidaris* (?) *pentaspinosa* Chapman & Cudmore. (1) Radioles P18381-3, var. B, 'Neumerella Railway Cutting', Bairnsdalian, × 2; (4) Radioles P19386-8, var. A, 'Balcombe Bay', Balcombian, × 2; (5) Radioles P19376-7, var. A, ? showing original colour banding, 'Grices Ck', Balcombian, (uncoated), × 2; (6) Radiole P19955, var. A, ? showing original colour banding, 'Orphanage Hill', Balcombian, (uncoated), × 2; (7) Radiole P19948, var. A, ? showing original colour banding, 'Altona Coal Shaft', Balcombian, (uncoated), × 2; (8) Radiole P20120, var. C, 'Mitchell R.', Batesfordian, × 2; (9) Radiole P19005, var. C, 'AW.3'. ? Janjukian, × 2; (10) Radioles GSV 58909, var. C, 'Skinner's, Mitchell R.', Batesfordian, × 2; (11) Radioles AUGD F15730, var. C, '1¾ miles NW. of Mt Gambier', ? Janjukian, × 2; (12) Radioles GSV 58912, var. C, 'Le Grand's Quarry, Glencoe', Batesfordain, × 2; (13) Radioles P19429-33, var. A, 'Grices Ck', Balcombian, × 2; (14) Radioles P19378-9, var. A, 'Gellibrand R.', ? Balcombian, × 2; (15) Radiole P14638, var. C, 'Muddy Ck', Balcombian, × 2; (16) Radioles P19705-9, var. B & C, 'Wongulla to Mannum', Longfordian, × 2.

Fig. 2—*Stereocidaris* sp. A. Distal ends of 2 radioles P19699-700, 'AW.1', 'Pre-Janjukian', × 2.

Fig. 3—*Stereocidaris fosteri* sp. nov. Test fragment AUGD F15740, 'Maslin Bay', Upper Eocene, × 2.

PLATE LXVI

Fig. 1-2, 12—*Goniocidaris tubaria hallettensis* subsp. nom. nov. (1) Test fragment P19449, × 2; (2) Test fragment P19451, × 4; (12) Radioles P19400-5, × 2. Specimens from the Middle Pliocene Hallett Cove Sandstone.

Fig. 3, 8—*Stereocidaris* sp. C. (3) Oblique adapical view; (8) Lateral view of AUGD F15742, 'Aldinga', Upper Eocene, × 2.

Fig. 4, 6-7, 9-12—*Goniocidaris murrayensis* Chapman & Cudmore. (4) Radiole P19884, 'Murghebolue', ? Balcombian, × 2; (6) Shaft of radiole of stratigraphically older form P19883, 'Morgan', Batesfordian or Balcombian, × 5; (7) Shaft of radiole of stratigraphically younger form P19073, 'Tambo R., downstream from Swan Reach', Cheltenhamian, × 5; (9) Radioles P18419-21, 'Tramway Cutting', Cheltenhamian, × 2; (10) Radioles P19067-72, 'Tambo R., downstream from Swan Reach', Cheltenhamian, × 2; (11) Radioles P19865-70, 'Morgan', Batesfordian or Balcombian, × 2.

Fig. 5—Corona sp. 3. Test fragment P19465, 'Aldinga', Janjukian/Batesfordian, × 2.

PLATE LXVII

Fig. 1—*Menocidaris compta* gen. et sp. nov. Radioles P19943-5, 'Morgan', Batesfordian or Balcombian, × 2.

Fig. 2—Radiolus sp. 2. Radioles P19417-8, 'Aldinga', Janjukian/Batesfordian, × 2.

Fig. 3—Radiolus sp. 3. Radiole P19881, '*Turritella* bed Table Cape', Janjukian, × 2.

Fig. 4-6—*Goniocidaris tubaria hallettensis* subsp. nom. nov. (4) Radioles P18417-8, 'Tramway Cutting', Cheltenhamian, × 2; (5) Termination of radiole P19401, 'Aldinga', Middle Pliocene, × 5; (6) Radioles P19334-5, 'Dry Creek Bore at Abattoirs', Middle Pliocene, × 2.

Fig. 7-8—Radiolus sp. 1. (7) Radiole P18989 (uncoated), 'Hamilton Ck', 'Pre-Janjukian', × 2; (8) Radiole P20151, 'Browns Ck', 'Pre-Janjukian', × 2.

Fig. 9—Radiolus sp. 5. Radioles P19771-3, 'Aldinga', Janjukian/Batesfordian, × 2.

Fig. 10—Radiolus sp. 4. Radioles P19936-7, 'Forsyth's Hamilton', Kalimnan, × 2.

Fig. 11, 13—Radiolus sp. 7 (11) Radioles P19258-61; (13) Radioles P19254-7, 'Aldinga', Janjukian/Batesfordian, × 2.

Fig. 12—Radiolus sp. 6. Radioles P19534-6, 'Aldinga', Janjukian/Batesfordian, × 2.

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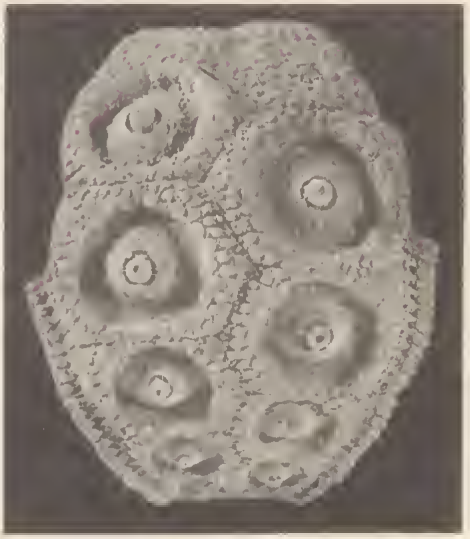

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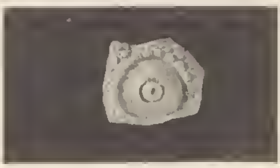

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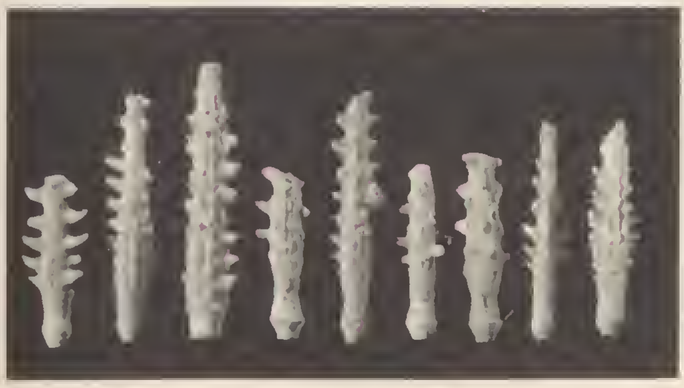

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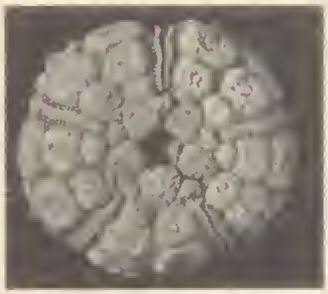

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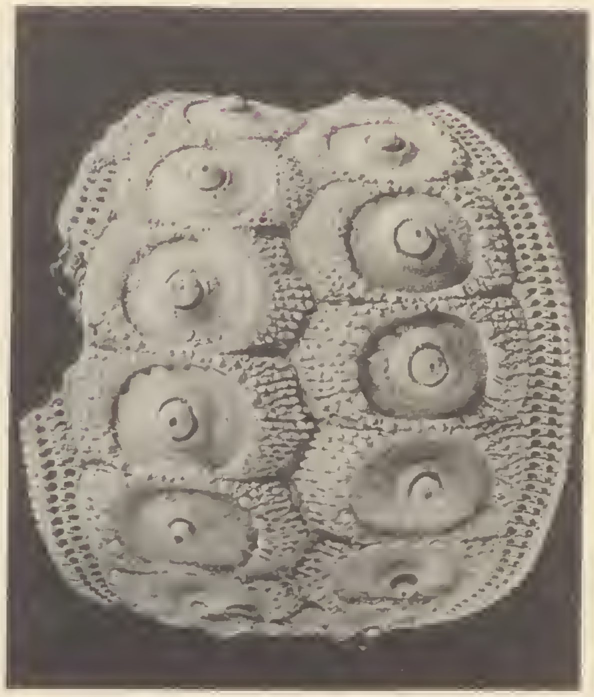

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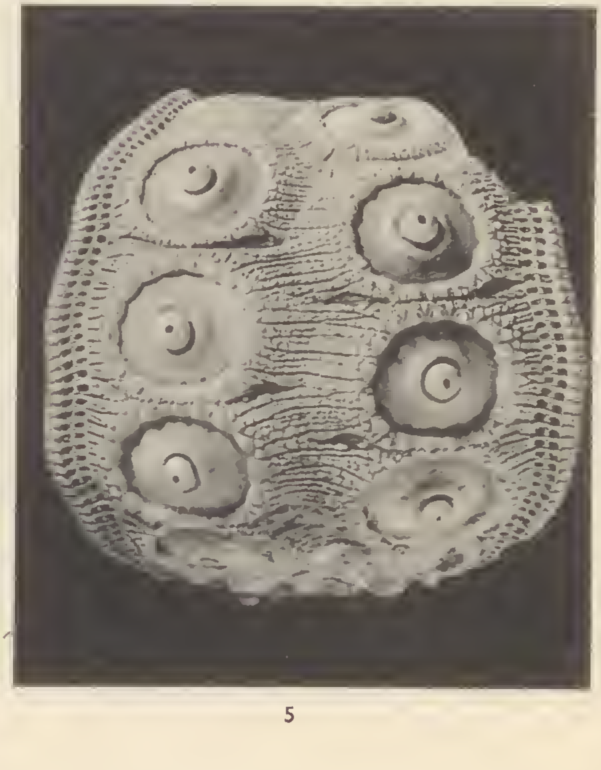

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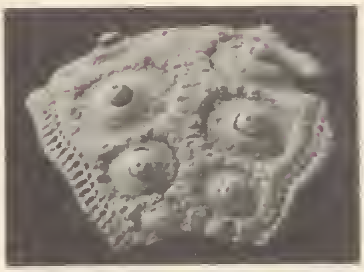
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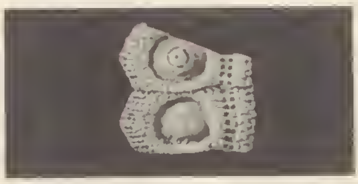
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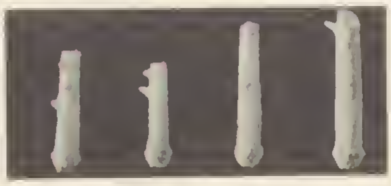
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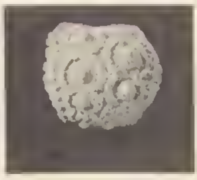
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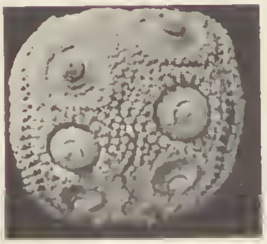
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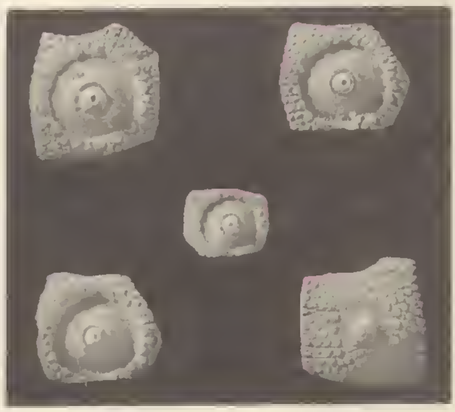

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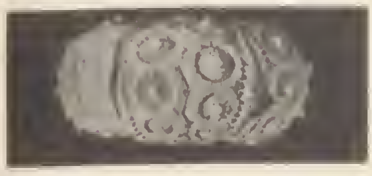

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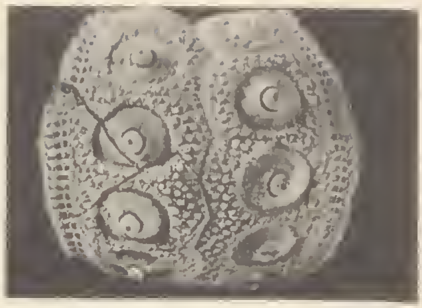
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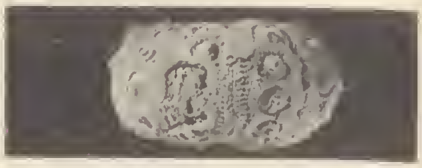
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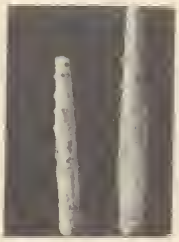
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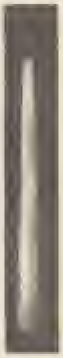

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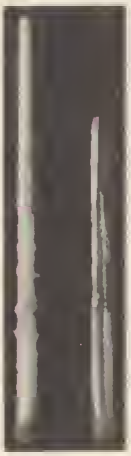

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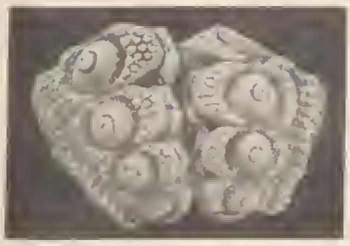
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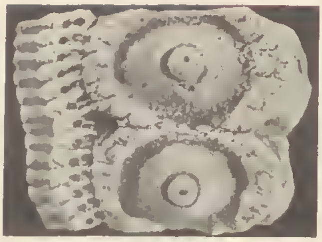
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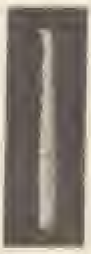
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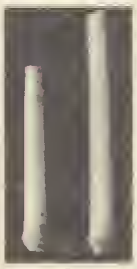

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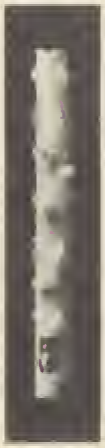

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ARCHAEOLOGICAL EXCAVATION OF ROCK SHELTER No. 6 FROMM'S LANDING, SOUTH AUSTRALIA

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Abstract

Although the cultural material recovered during this excavation was meagre, it supplements and supports conclusions reached in the report on Shelter 2. A variety of other important evidence was recovered and is discussed. Geomorphological features are outlined, particularly relating to the question of the causes of rock shelter formation. C14 dates 1000 ± 91 B.C. (NPL 28) and 1220 ± 94 B.C. (NPL 29) establish the antiquity of a Murray R. flood, which is the highest on record. The age of an almost complete dingo skeleton is intermediate between these dates, and is discussed in Appendix 2. All organic remains were identified, and the mammalian fauna was compared in detail with that recovered from Shelter 2, 400 yds away. In the course of this study, a thylacine tooth was identified from Shelter 2.

Introduction

Although Mr C. P. Mountford noted the aboriginal shelters at Fromm's Landing as long ago as 1926, it was not until 1952 that a party of students under the direction of Mountford and Dr (now Sir) A. Grenfell Price, surveyed the site and provided the numeration of the individual shelters, strung along 500 yds of the cliff, which is followed in this report (Price 1952). In 1956 and 1958, Mulvaney excavated Shelter No. 2 and was able to demonstrate that the aboriginals occupied the area some 5,000 years ago (Mulvaney 1960). The 1952 survey party had made a shallow excavation in No. 6 which had revealed occupational debris, and it was decided to extend this exploration of the floor sediments, partly in order to compare and check with the nearby No. 2, and partly to provide training in archaeological fieldwork. The direction of the excavation was undertaken by Mulvaney.

In this paper, several features arising from the excavation itself are first discussed, followed by an account of the artefacts and bones discovered during the excavation.

The Excavation and Related Features

General

The Fromm's Landing sites are located at the base of high precipitous cliffs that bound the narrow valley of the Murray R. which winds through Mallee plains. Within the narrow valley there is, of course, permanent water, but the surrounding plains underlain by Miocene marine sediments and with superficial developments of kunkar and sand dunes are arid to semi-arid (Mannum, the nearest official recording station to Fromm's has an average annual rainfall of 11½ in.).

Shelter No. 6 has a level sandy floor and a commanding view of the river to the E. (Fig. 1). The shelter which stands some 33 ft above the river is extensive and comparatively high and deep. The floor falls away outside the confines of the shelter

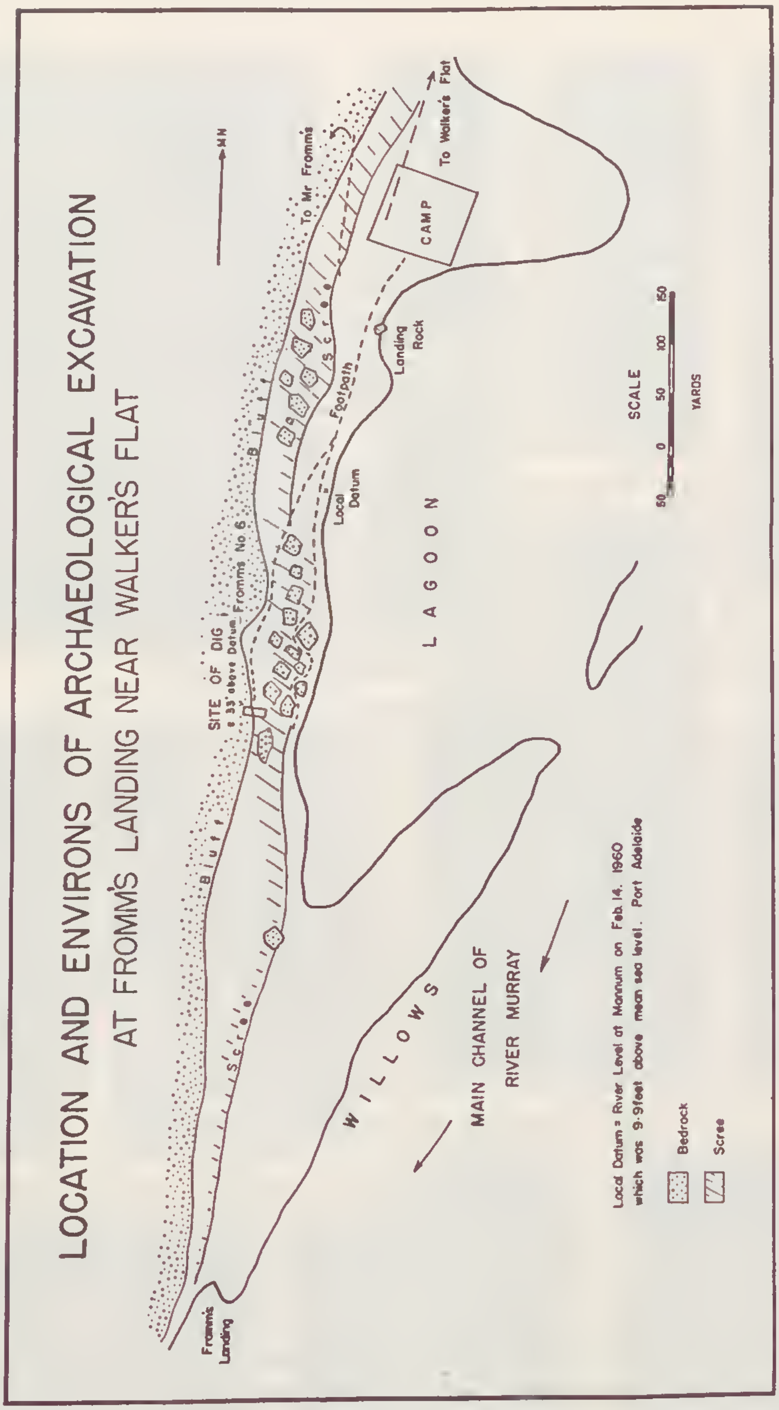

FIG. 1—Location and environs of Fromm's Landing.

and there is a steeply inclined slope down to the flats that border the present river channel. Above the shelter there are vertical cliffs about 75 ft high, eroded in richly fossiliferous Miocene calcarenite. Above the Miocene there are 20-25 ft of cross-bedded Pliocene sands with a massive oyster bed at the base. The shelter faces E. and is at present shaded by pepper trees, a function formerly performed by tall red gums. The initial excavation was made during a week in February 1960, and a further week in February 1963 sufficed to widen the trench to 10 ft and extend it for 28 ft down the slope from the backwall of the shelter. Work commenced by clearing out the rubble in the 1952 trench and extended out from both sides of that cutting. The excavation revealed a thick wedge of sediments, both natural and anthropogenic, resting upon an irregular bedrock surface (Fig. 2). As Pl. LXVIII testifies, the site provided a textbook demonstration of the reality of archaeological stratigraphy, with richly coloured bands of clean yellow sand, reddened sand, white ashy material, and concentrations of charcoal and mussel shells extending to a depth of 14 ft. All material was removed in layers by trowel, sieved and sorted. It was possible to break up all fallen boulders of Miocene calcarenite, thereby enabling the excavation to reach bedrock over the entire trench.

The number of artefacts recovered from the sediments was small, although the occurrence of a few type specimens enabled tentative correlations with other sites. However, there was some compensation for the paucity of the cultural record by other discoveries, including evidence for a high river level during prehistoric times and the fully articulated skeleton of a dingo from a depth of almost 6 ft in the excavation (see Appendix 2). Organic materials were preserved because of desiccation in the upper layers within the shelter.

SEDIMENTS

The unconsolidated sediments disclosed in the excavation fall naturally into two groups. The lower and earlier, consists overwhelmingly of fine to medium yellow* sands with large fragments of Miocene bedrock, and with only occasional hearths or their ashy bands and other occupational debris. The upper and younger sequence comprises for the most part occupational debris, mostly hearths and shells, with only thin bands of yellow sand.

[* All colour references are on the Munsell scale. While the following designations remain fairly consistent as regards Hue, Value and Chroma, the layers do vary in these qualities from place to place and the references may be taken as a guide only: Yellow 'clean' sand—2·5Y 7/6; grey-white 'ashy'—2·5Y 8/2; red sand, 'burnt'—2·5YR 5/8; brown (layers 3-4)—10YR 4/3; uniform grey, on weathered slope—10YR 5/2-3.]

Despite its vivid contrasts in colouration the composition of the deposit is basically similar throughout. It is medium to fine grained sand, derived from the disintegration of the Miocene parent rock. Mineralogically it consists principally of calcite. Variations in colour from one band to another are attributable in large measure to the vagaries of human activity.

The continuous bands of loose, clean yellow sand are a striking feature of the section (especially Layers 6, 10, 13, 16, 17, 18). While the presence of a few artefacts and bands of ash and shell testify that man was not wholly absent during their deposition, it is evident that the time of their deposition represented periods of virtual desertion by the aborigines.

It seems probable that the detritus of the yellow bands is derived essentially from weathering of the cliff and shelter roof. Ashy horizons occur within these layers. They are not stratified and do not in this respect compare with the one fluviatile sediment exposed in the section, nor are they related in any place with any sign of

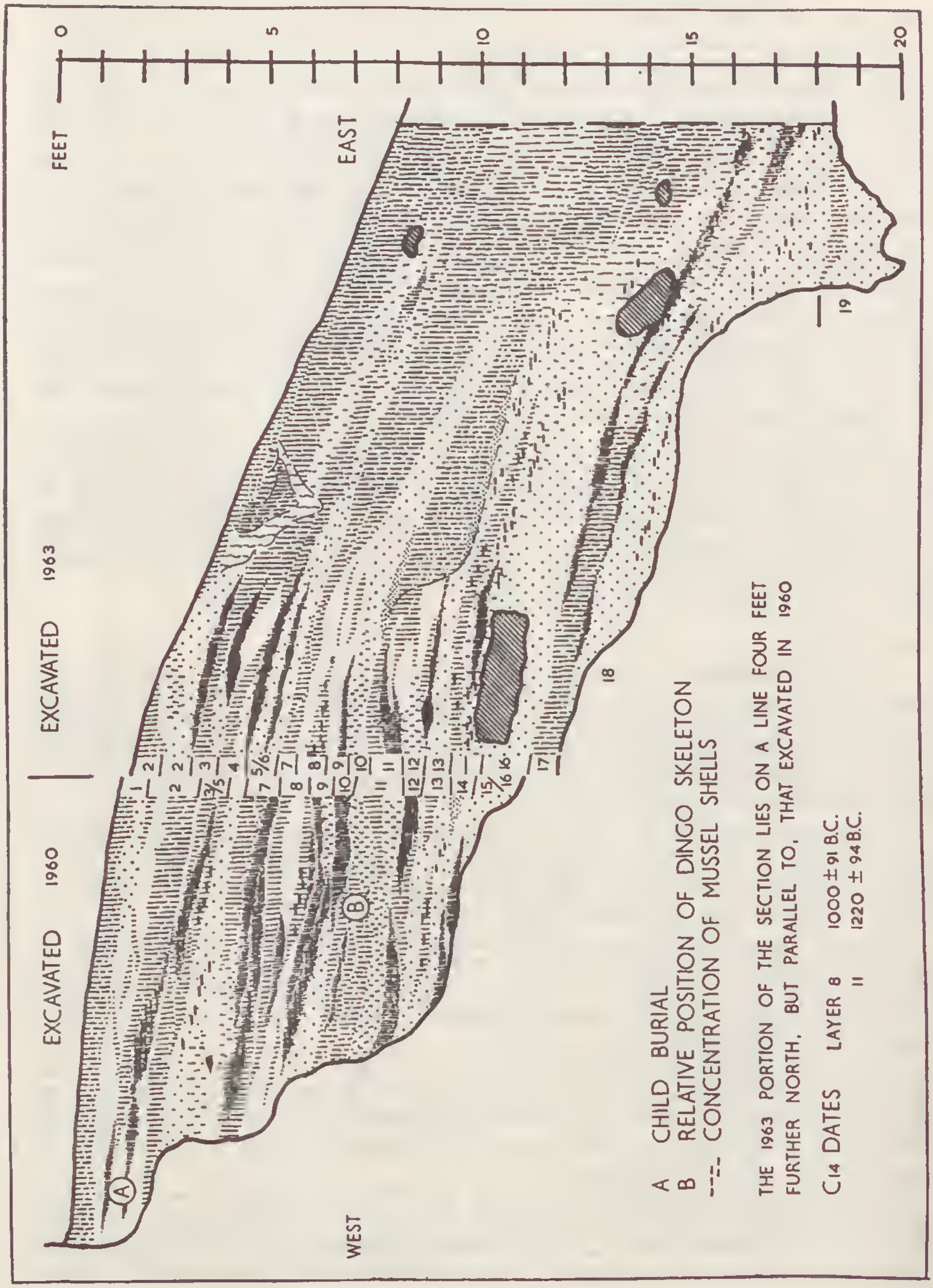

FIG. 2—Section of N. wall of trench.

river erosion. It is relevant that these layers contain numerous fossils derived from the local bedrock, especially *Lovenia forbesi* (from the Miocene) and *Ostrea sturtiana* (from the Pliocene).

But it is the analysis of the Miocene country rock, which occurs in the shelter roof and bluff, and its comparison with the material from the yellow layers which proves that the latter are formed directly as a result of the disintegration of the former. 20 gm samples of both materials were treated with dilute hydrochloric acid and then washed to remove colloidal material. Two other samples were washed with water alone in order to remove colloidal material but leave any calcium carbonate untouched. Results of the analyses are as follows:

Material	Wt left after acid on 20 gm sample	Wt left after water on 20 gm sample
Miocene calcarenite	2·91	16.06
Yellow layer	3·84	16·81

Thus the two samples are very similar. The rock consists of 65·7% $CaCo_3$ compared with the 64·9% of the yellow layer. Minor differences may be explained by the loss of some of the fine fraction of the weathered rock as a result of wind action.

It has been demonstrated that the yellow layers probably represent natural deposition during periods when aboriginal occupation was slight, while the high carbon content of the dark and grey horizons is chiefly the result of aboriginal camp fires. The reddened bands of sand are a problem. The visual evidence suggests that they were caused by intense baking beneath aboriginal fires; in places, the buried limestone cliff is reddened in contact with this sand. A similar phenomenon was noted in the upper layers at Shelter 2, inside the shelter and directly underlying hearths. But no matter how obvious the explanation to those who inspected the section, it was difficult to establish in the laboratory. Because the clay and fine silt fraction was so small, it was impossible to determine whether the heat produced brick aggregates. Microscopic examination was indecisive. The red stain was distributed fairly uniformly around the sand grains, and may be explained as precipitation of secondary iron hydroxide around them. If the reddening had been due to firing, it is probable that the colour would have been more intense on the side of the grain nearest the heat. It is questionable, in any case, whether the aboriginal fires would have been large and intensive enough to cause baking of the soil to a depth of some inches, or whether quartz grains could be reddened in this manner, but these are problems meriting further investigation.

It must be stressed that, except for the case of erosion due to the rise in river level discussed below, there was no interruption to the natural accumulation of layers on the site. Naturally, on the steep slope away from the shelter, tree roots, hillwash, and cliff fall complicated matters. The following strata could be traced over the entire trench, but even those which were discontinuous conformed to the pattern of these others: Layers 6, 10, 13, and the ash and shell bands in 16 and 17.

Layers 1 and 2 were loose and contained quantities of plant material, most of which must have been brought there by aborigines. The entire deposit was easy to trowel, except for Layers 8 to 10, where they were protected by the overhang. These were extremely consolidated and the deposit had to be removed in lumps and broken up with difficulty. The material consisted chiefly of the white 'ashy' sand. While this material included some charcoal, analysis failed to establish that the colour and apparent texture were due to a preponderance of ash. The flame photometer showed that it contained only about half the potassium present in the parent limestone of the cliff (2,500 p.p.m., compared with 5,400 p.p.m. in the crushed rock). However, this was greatly in excess of the water soluble potassium content of the reddened 'baked' sand (500 p.p.m.).

BEDROCK FLOOR

An important incidental discovery as a result of excavation calls for special comment, as it opens the question of the causes of rock shelter formation. The upper part of the subdebris bedrock surface does not descend evenly; a series of distinct steps were uncovered, the angularity and distinctness of which diminish progressively downslope. There are four steps (Fig. 2), and this higher stepped section is more precipitous than the slope below. The lower slope is gently concave, not smooth in detail and displaying nothing suggestive of steps. The lowermost part of this section is very rough and pitted in detail, below which it gives way abruptly to a near vertical cliff which is blanketed by many coarse blocks of calcarenite and which at its lowest exposed point is only 9 ft above the present river level. It is probably a remnant of an ancient river bluff.

In the wedge of debris that rests on this bedrock surface, the lower strata of essentially non-occupational debris are associated with the broadly regular concavity, the upper mainly occupational layers with the stepped section. In detail, too, there is a clear correlation between units of the debris sequence and elements of the stepped bedrock slope for, consistently, the treads of the slope are associated with the thin yellow layers, the steps with the thicker occupational debris.

The consistency of this relationship is such that it effectively disposes of the possibility that the development of the bedrock slope and the deposition of the strata within the shelter are separate unrelated events. The steps are not related to structures such as joints in the calcarenite but are etched out of the massive bedrock. The treads cannot be attributed to successive periods of river corrasion, for there is no sign of riverine sediments in association with them; on the contrary, as has been shown above, the yellow layers are of local derivation.

The presence of the remnants of small caverns on the buried bedrock, at least in the upper areas, shows that in the past, as at present, the shelter extended back into the bluff principally by the initiation and development of these small cavernous forms. These occur in overwhelming abundance at the junction of air, bedrock and debris, that is, at the contact of the upper limit of the debris with the bedrock of the backwall.

It seems plausible that the stepped bedrock surface is connected with variation in the rate of debris accumulation in the floor of the shelter. During periods of non-occupation, as at present, the yellow layers slowly accumulate; at the rear of the cavern, near the top of the debris, caverns form and extend because the accumulation is so relatively slow that there is time for the caverns to extend back some little distance, coalesce, and form a more-or-less planate bedrock bench resulting from weathering. However, during periods of occupation, natural aggradation was appreciably augmented by hearth and kitchen debris. The rate at which the floor was built up, therefore, increased. The rate of cavernous weathering, on the other hand, proceeded as before, but more slowly relative to the more rapid accretion of the floor. The critical upper limit of the debris rose before caverns could develop to any significant extent and, in place of the benches of the periods of non-occupation, there were steeply inclined bedrock slopes. Thus, with alternations of occupation and non-occupation, there were variations in the rate at which the floor of the shelter was built up and, in consequence, variations in the rate of upward movement of the upper limit of the debris where, at its contact with the backwall, cavernous forms are most profusely and extensively developed. Thus, there are variations in the time available for the development of the caverns and, as a result, a stepped surface has been formed.

That this interpretation is correct is suggested by:

1. The constant correlation of yellow layer with tread, and occupational debris with step.
2. The fact that the upper stepped slope is associated with intense occupation generally and is also more precipitous than the slope associated with non-occupation in the lower section.
3. Similar relationships between type of sediment and the form of the bedrock surface were illustrated in his section independently by Mulvaney (1960) in his report on Shelter No. 2. A study of the published section from Devon Downs (Hale and Tindale 1930) suggests a similar stratigraphic situation there, although the relationship is less consistent.

This interpretation of the geomorphological pattern is relevant to the problem of the human exploitation of the shelter.

YELLOW BANDS AND NON-OCCUPATION

The reasons for the fleeting aboriginal visits during accumulation of yellow layers remains to be explained. It is possible to argue that the non-occupation, represented by the layers, results from epidemic disease or from massive walkabout for reasons unknown, but both are unlikely if only because of the duration of time represented by the yellow bands; by comparison with the thickness of non-occupational debris accumulated since the aboriginals abandoned the sites following white settlement, they represent periods of a century and more. There is, however, a physical argument that may explain the apparently periodic abandonment of the shelter, or at least that part of the shelter exposed in the excavation, though it is to be stressed that, until a much wider section is excavated, it will not be known whether the yellow layers are continuous strata or merely lenses, that is, whether the shelters were abandoned *in toto* at certain periods or whether only a part or parts were deserted at a given time and the entire shelter never wholly abandoned.

There must have been a critical minimum height for the shelters below which they were not occupied because they were physically uncomfortable,* and therefore not used save in case of urgent necessity. In caves that were high enough normally to be occupied, the floors were built up rapidly, more rapidly than the roof was raised by weathering. Thus, in shelters where the height was not much over the minimum, the aggradation of the floor would in time cause the height to decrease to such an extent as to be uncomfortable, and for the occupants to migrate either laterally or to another cave where there was more vertical space. During non-occupation, the build-up of the floor would be retarded comparatively but the weathering and raising of the roof would continue at the same rate as during occupation; however, the disparity between the two would certainly be reduced and probably reversed, for some of the debris falling from the roof migrated downslope as is clearly demonstrated by the excavated section, and it is certain in view of the fineness of the material (all passed through a $\frac{1}{8}$ mm sieve) that some has also been evacuated by wind. Thus, slowly the height of the shelter would increase until it again became suitable for habitation, when the cycle of events would recommence.

[* There are thick ash bands in Shelter No. 2 to within 2 ft of the shelter roof, indicating that the aboriginals may have sheltered and had sleeping fires in even very low caverns.]

There is no way of proving this hypothesis, but it is supported indirectly by the morphology of the bedrock slope beneath the wedge of debris exposed in the excavation, it being strongly suggested that this morphology is (most likely) the result of variations in the rate of floor accumulation as between periods of occupation and non-occupation; also, by the seeming periodicity of the occurrence of yellow bands in the section exposed, and the occasional hearths which occur even within the yellow bands and which could have been built either marginal to the fully occupied cave or during brief periods of 'population pressure' of the type suggested earlier.

HIGH LEVEL FLUVIATILE DEPOSITS

Early in the 1963 excavation, it was noted that, in the N. face of the pit, several of the layers (11-13) of ash and kitchen refuse terminated abruptly downslope forming a buried bluff (Pl. LXIX). The reason for this became apparent when a layer of pinkish sand, displaying excellent stratification and clearly of riverine origin, was exposed at the base of the buried bluff; the ancient R. Murray, flowing high above its normal modern level, had cut a low bank in the occupational debris and had deposited at its foot some of the sand it had been carrying (Pl. LXX). The two-inch thick layer of sands apparently represents a single flood. The absence of coarser debris from the traction load is not surprising in view of the elevation of the deposit above the river bed and the nature of the bedrock for miles around; the river does not flow over rocks likely to provide gravels and the like. They are absent from the modern river bed at Fromm's. Moreover, modern experience is that when the river floods it does not necessarily flow at high velocities. This flood post-dated layer 11 (1220 ± 94 B.C.) and pre-dated layer 8 (1000 ± 91 B.C.).

When a survey was taken on 9 February 1963, the thin band of stratified river deposits was 21 ft above the river level of the day. How does this ancient inundation compare with high river levels recorded in historic times?

The highest flood on record at Walker's Flat and many other parts of the Lower Murray valley was registered on 5-6 September 1956 (S.A. Govt. 1962) when the river attained an elevation of 132 ft (all levels cited are 105·70 ft above low water at Port Adelaide). Pool level up to the Lock No. 1 at Blanchetown is 109·5 ft, so that the 1956 flood reached some 22·5 ft above pool level, which may be regarded as 'normal' for this sector of the river. On the day of the survey of the archaeological site at Fromm's Landing, river level at Mannum was only 0·01 ft below pool level so that it is valid to compare the 21 ft of the ancient flood with the 22·5 ft of the 1956 flood without any adjustment for river level at the time of survey. Thus, at first sight, it seems that the flood of 3,000 years ago was lower than the 1956 flood, but allowance must be made for a number of factors in order to obtain a true comparison of the two.

First, the ancient flood pre-dated the completion of the Goolwa Barrage (1940) at the Murray mouths which caused a rise in the general river level below Blanchetown of the order of 2 ft; and which, incidentally, caused many river meadows to be permanently inundated and many majestic river gums to be killed. Thus the 1956 flood is measured in relation to a river level 2 ft higher than the pre-1940 level. On this account alone, the level of the ancient flood is worth not 21, but 23 ft by 1956 standards.

Second, it is known that sea level has fluctuated widely during the last million years or so as a result of the waxing and waning of glaciers. For example, about 10,000 years ago, when glaciers were larger than they are today, it seems likely that sea level stood about 100 ft lower. If all modern ice masses were to melt, sea level would rise considerably and many great cities, as well as extensive coastal plains, would be inundated. Thus, as all river levels and especially those near the coast and of gentle gradient, like the Murray, are closely related to sea level, flood levels must be assessed in relation to sea and river levels prevalent at the time to which reference is made. Fortunately, during the past 4,000 years, sea level has suffered only minor fluctuations, probably all within a foot of present average ocean level. It seems possible that 3,000 years ago, during the period when the ancient flood occurred, sea level and hence river level was only some 6-9 in. lower than at present. Thus, on this account, the relative worth of the 21 ft of the ancient flood must be raised to 23·5 ft.

Thus, the flood of about 1100 B.C. was apparently higher than that of 1956. Certainly a far heavier rainfall is represented. The deforestation of the Murray catchment since white settlement, especialy in the head-waters, has probably increased the rate of run-off to the river and made for conditions conducive to flood development. The figure of 22·5 ft cited for the 1956 flood is, in any case, the measured maximum level of the river, whereas the 23·5 ft calculated for the ancient flood of 3,000 years ago is the absolute minimum elevation for the highest peak of the flood; the river has left behind evidence of its former presence at this elevation, but it certainly extended higher, though its upper limit is unknown.

Thus, it is safe to refer to the flood of 1100 B.C. as 'the highest on record'.

CLIMATIC CHANGE

In the discussion above it has been tacitly assumed that no significant climatic changes have occurred over the past 5,000 years. A comparison of the flora, fauna, and molluscs of earlier times (as evidenced from remains in archaeological layers) and the present (Mulvaney 1960), supports this view (cf. Appendix 1). But it must also be pointed out that the Murray valley environment is in a sense alien to the regions surrounding it. The water of the river provides a reasonably constant basis for life in the valley and climate changes would have to be large indeed to bring about a change in the environment of the valley floor. Investigation in the more vulnerable or susceptible adjacent hill and plain areas will prove a safer guide to the climatic history of the region than does the Murray valley.

Archaeological Discoveries

ARTEFACTS: DESCRIPTION

The artefacts were few in number and of limited diagnostic value. The total number of retouched stone and bone specimens is provided in Table 1, together with the totals of struck flakes and other fragments. The description of all retouched pieces follows. Implement nomenclature follows McCarthy's scheme (1946).

LAYER 2

A thin brown chert flake 2 cm × 1·5 cm, with traces of retouch or use fracturing on 3 edges; a rough quartz core, approx. 1·5 cm in diameter. 1 fragment of brown ochre.

LAYER 4

A split bone 7·5 cm long (probably macropid tibia), cut to a point, but no evidence of grinding is present. A small brown jasper scraper, the flake possessing several narrow flake scars and slight retouch around most margins; a small brown chert flake with minute utilization fracturing on one edge.

LAYER 6

A chunky quartz fragment (4 cm × 3 cm × 1·5 cm) with attempted abrupt retouch around one curving edge, and best explained as a crude adze; a small quartz core.

LAYER 7

A small grey chert adze flake (burren type), broken in half, measuring 2·5 cm × 1·5 cm; a broken fragment of similar chert, possibly part of another adze flake; 2 quartz pebbles, one of them broken, both used as hammerstones; 2 chert and 2 quartz flakes, all showing slight traces of utilization although it could not be classed as deliberate retouch.

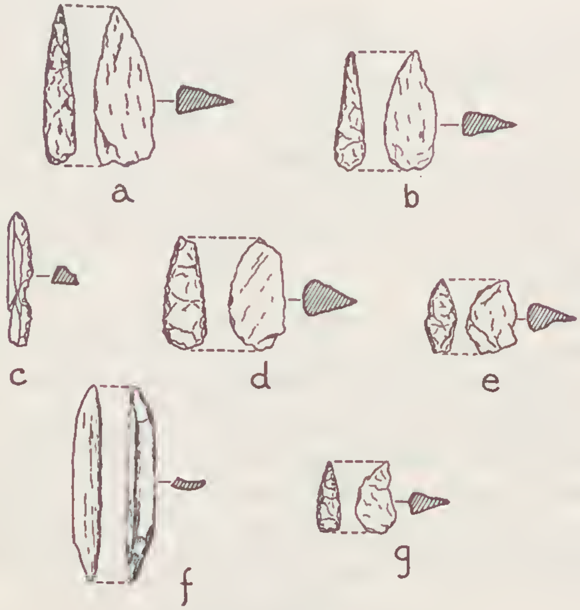

FIG. 3—Artefacts.

LAYER 8

1 bone point, 4 cm long, with tip broken and slightly flattened at base. 1 steeply retouched (burren) adze flake of grey chert, measuring 3 cm × 1·5 cm × 1·5 cm; 2 asymmetrical microlithic points of white quartz, 3 cm and 2·3 cm in length respectively, and trimmed along one margin (Fig. 3a, b). Although the trimming is rough, the stone is very intractable and this renders their fabrication more meritorious. Some might classify these points as Bondiain. 1 thin sliver of quartz, 2·5 cm in length (Fig. 3c), bears traces of trimming along one edge and may represent an attempt to produce a similar point. 1 pink-veined quartz of triangular section, 2·2 cm × 1·2 cm × 0·9 cm, with steep blunting retouch and/or evidence of use-fracture on both edges of the thick margin while the edge formed by the intersection of the two other sides is sharp and straight (Fig. 3d). This artefact is difficult to categorize. At first sight it resembles an clouera, but it is better described as a thick-backed microlithic point, with the tip of the pointed end broken off. Another specimen, 2·7 cm × 1·5 cm × 1 cm, roughly shaped from white quartz may be a crude attempt at fashioning a similar artefact. Also present was a small fragment of veined

quartz which may be part of a similar backed point, although it is more plausible to explain it as part of a geometric microlithic crescent (Fig. 3e). There are 5 quartz and 1 chert flakes or fragments which, with an effort of the imagination, might be described as utilized. There was 1 small quartz core. Two flat, broken river pebbles may have been used as hammerstones, but there are no obvious indications of percussion.

Layer 9

A brown patinated chert adze flake of tula type, 3·5 cm × 1·5 cm × 1 cm; 6 broken chert fragments, all bearing evidence of edge fracture, similar to that on adze-flakes, but too generalized to permit definite attribution; 6 quartz and chert flakes, which could be leniently described as 'utilized'; a stubby quartz point 3·3 cm long, with some suggestion of trimming along one edge (but not resembling any known type); 4 small quartz pebbles with considerable abrasion, presumably used as hammerstones; 2 flat, fine-grained sedimentary fragments of no obvious function.

Layer 10

A round bone, 4·5 cm long, ground to a sharp point and broken at the other end. 1 grey chert adze-flake (burren type ?), 3·5 cm × 1·7 cm × 1·3 cm; another probable adze specimen, broken in half; a small quartz flake with considerable edge fracture, suggesting its identity as an adze-flake; 3 chert pieces, possibly 'utilized'; a rough unifacial quartz primary flake, approximating leaf shape, but with no evidence of retouch and too rough to claim as a 'pirri blank'.

Layer 11

5 small rounded river pebbles, used as hammerstones; 1 large core.

Layer 12

A simple bone point, 3 cm long, ground to a sharp point. A flat flake of grey chert, utilized, but too indefinite to classify.

Layer 14

A red jasper scraper, finely retouched around ⅔ of the margin, 3·3 cm × 1·7 cm. As the main scraping edge is curved, it is best explained as an adze-flake in new condition. It is worth noting that a small primary bladelet, bearing further delicate flake scars was present, and this must indicate that craftsmen were capable of precision flaking techniques.

Layer 16

1 split bone, 4 cm long, cut at each end to asymmetrical points. Although not a 'text-book' example, it might be classified as a muduk (Fig. 3f). 1 geometric microlithic crescent made from milky quartz, 1·4 cm × 0·8 cm (Fig. 3g). This specimen has vertical blunting retouch on the back, and one tip is broken off, apparently representing ⅕ of the length of the specimen. 2 small flakes, designated 'utilized'; 1 small milky quartz core, 2 cm diameter.

Layer 17

1 broken flake of amber coloured chert, 'utilized'; 2 milky quartz cores, 3 cm and 2 cm in diameter respectively.

Layer 18

1 flake of fine-grained grey chert, doubtfully 'utilized'; a fragment of brown ochre.

TABLE 1

Layer C 14B.C.	Total Flakes etc.	Bone Points	Adzes	Geometric Microliths	Microlithic Points	Scrapers	Nondescript Scrapers or Used Pieces	Hammer Stones	Cores	Ochre
1	15									
2	19					1			1	1
3	3									
4	31	1				1	1			
5	0									
6	8		1						1	
7	132		2				4	2		
8 (NPL 28) 1000±91	363	1	1	1?	5?		6	2	1	
9	249		1				13	4		
10	279	1	3				3			
11 (NPL 29) 1220±94	161							5	1	
12	65	1					1			
13	24									
14	42		1				1			
15	3									
16 (NPL 63) 1500±90	36	1		1			2		1	
17	41						1		2	
18A	8						1			1
18B	5									
TOTALS	1484	5	9	2	5?	2	33	13	7	2

DISCUSSION

The report on Shelter 2 (1960, 73) deplored the meagre return of artefacts; but by comparison with the present site, the aborigines who occupied it were prodigal with their material culture. The total number of definitely classifiable retouched stone implements numbered 18 in a sample of approximately 1,500 stone flakes and fragments, while there were only 5 bone tools. The raw materials were similar in origin to those at Shelter 2. Quartz was most characteristic, while chert and small samples of quartzite, sandstone, granite, and schists made up the rest. There is no reason to believe that any of it was derived from sources of supply more distant than 20 miles.

Until further radio-carbon 14 dates become available, it is impossible to give an absolute date for the earliest occupation phase, but it seems possible that it was not as ancient as Shelter 2, which dated from about 3,000 B.C. It is interesting to observe that the rate of deposition of the upper layers at both sites appears comparable. The age of Layer 8, 4′ 6″ below the surface, was 1000 ± 91 B.C. (NPL 28); Layer 11, 7′ down, was 1220 ± 94 B.C. (NPL 29). At Shelter 2, a sample 6′ from the surface dated from 1290± 80 B.C., and another from 8′ was 1806 ± 85 B.C. The greater depth of the Shelter 2 deposit may therefore represent a longer period of deposition. This is supported by a date for layer 16, Shelter 6, of 1500 ± 90 B.C. (NPL 63), at a depth of 9′.

With type implements so rare, it is difficult to discern a cultural sequence in the assemblage, or to compare it with that obtained only 400 yds away in Shelter 2. The visual evidence for the intensity of settlement in the upper 3 ft of the deposit is apparent even in the photographs, yet the relevant layers—1 to 6—produced only 3 retouched stone tools, a single bone specimen, and 5% of the primary flakes. It is a sobering thought for the prehistorian who is dependent upon material traces for his cultural classification, that this constitutes the totality of the cultural attainments of the aborigines during almost 3,000 years of residence in this well situated habitation—a time span greater than that separating the Parthenon from the atomic bomb.

At least this negative result reproduced the pattern of the upper layers at Shelter 2 and at Devon Downs. Hale and Tindale (1930, p. 204) termed their assemblages of 'degenerate stone industries', Murundian, and supplemented it by including perishable ethnographic specimens recorded in the region a century ago. But the archaeological identity of this culture still requires confirmation, for a dearth of evidence is a dubious diagnostic feature. It is also premature to assume that the utilization of organic materials during the last century had persisted unchanged throughout more than two millennia. It seems possible that the term Murundian should be restricted to this riverine area. Following Golson's New Zealand experience (1959), it might be appropriate to consider the Murundian simply as a late-prehistoric variant, or aspect, of aboriginal society in southern Australia—a regional adaptation in which stone working was an insignificant element. The wide geographical application of the term is misleading at this stage of prehistoric research.

The occurrence of 5 quartz points in Layer 8 is interesting. Two of them have some characteristics of Bondi points, another two superficially resemble elouera. However, study of these few, rough specimens has highlighted an important problem awaiting closer definition. It seems probable that the terms 'elouera' and 'Bondi point' at present include a variety of types, with considerable merging of one type into another. Campbell and Noone (1943a and b) drew attention to some of the complexities in the South Australian situation, but a study of a collection of Bondi points from L. Illawarra, N.S.W., suggests that there are similar complications in that material. Campbell and Noone (1943, p. 379) discerned that, in addition to the conventional Bondi points and Woakwine points, there was a further type which they termed South East Bondi point. It is possible that the Layer 8 points are related to this latter category. Strict typological investigation of the backed point and 'eloueran' industries in Australia is the prerequisite for definition of this scant Fromm's materal. E.g., on quartz specimens, there is no indication of the technological process by which the primary piece was obtained; it is impossible to term them flakes or blades in these circumstances, whereas a true Bondi point is made on a flake or blade. Further, the thick-backed points seem too thick to be geometric microliths, but too pointed and carefully trimmed to be elouera.

Any definitive study should also re-investigate the meagre stratified artefacts from other sites. At Shelter 2, a possible elouera was claimed from a level dating from 1931 ± 85 B.C. (Mulvancy 1960, p. 68): Another single specimen was illustrated, though not identified as such, by Hale and Tindale (1930, Fig. 195) from Devon Downs, Layer 8 (Layer 9 was dated to 2245 ± 140 B.C.). At Fromm's 2, Layer 2 contained a classic Bondi point (1960, p. 79), while rough quartz microlithic points occurred in layers 0, 1 and 3 (1960, p. 61-66). These points should be compared with the specimens from Shelter 6, Layer 8, a hearth in which dated from 1000 ± 91 B.C.

The antiquity of the geometric microlith, which was established by the excavation at Shelter 2, receives added confirmation from the occurrence of a good specimen in Layer 16 (1500 ± 90 B.C.), and another probable specimen in Layer 8. It may be relevant to the vexed problem of their function, that each specimen lacks one tip; 3 microliths out of the 8 recovered at Shelter 2 had been broken.

No pirri points were recovered during the excavation. At Shelter 2 they preceded

1806 ± 85 B.C., and it could be argued that their absence is because this site was unoccupied until after their production ceased. Future C14 dating may confirm this, but it is relevant that, at Shelter 2, the pirris were associated with microliths, two of which were present at Shelter 6.

Tindale's use of the cultural term Mudukian has been criticized in detail elsewhere (Mulvaney 1960, p. 76; 1961b). Tindale (1957) claims the microlith and bone muduk (fish gorge) as the type implements of the Mudukian culture. But these types have not been excavated in satisfactory stratigraphic association. At Shelter 6, however, a microlith and a probable muduk came from layer 16, and Tindale may consider his claims vindicated. In the opinion of one of the writers (D.J.M.), this discovery has not invalidated his criticisms. Even if it is admitted that the evidence from Shelter 6 supports the Tindale sequence in a general way, it is difficult to invoke invasions or major cultural infusions to explain its history. It remains a plausible interpretation (as in Mulvaney 1960, p. 74) to stress the basic continuity of cultural tradition and explain changes in the industry between layers as resulting from environmental adaptation.

Only one conclusion is possible. The sample from this site is so small that definitive judgements are impossible. For a so-called stone age people, the aborigines were extraordinarily averse to using stone.

HUMAN BURIALS

BURIAL 1

The well preserved bones of an infant, about full-term (Pl. LXXI A).

The flexed skeleton lay in a bundle in a circular grave, approximately 12 in. in diameter and similar in depth. The grave was lined with grass, some of which was charred, and was situated in the NW. corner of the trench, in the dry, ashy deposit less than a foot from the rear wall. The burial was relatively recent. It occurred in Layer 1 times, when floor level was only a few inches lower than at present. The bones were wrapped tightly in a cover of plant material, so decayed and discoloured that it resembled animal skin. It was tied in two places with vegetable fibre twine, the twisted strands of which were clearly distinguishable. Several bones were missing, including 4 vertebrae, and this suggests that the body was carried around for a period before burial, because there was no evidence of post-burial interference which could explain their absence.

This burial conforms to the ritual practice in the area at the time of European settlement. Eyre (1845, 11: 344) noted that a child who died under 4 years of age was transported in a bundle by the mother for some months until the body was desiccated. In Layers 1 and 2 there were large quantities of leaves and vegetable fibre lying in matted lumps. The great bulk of this fibrous material is referable to the common riparian sedge *Scirpus fluviatilis*, Marsh Clubrush (or 'river bulrush'). It is probable that this had been chewed by aborigines in the process of manufacturing string. Tindale and Mountford (1936, p. 497) excavated similar fibrous material at Kongarati cave. Taplin (1879a, p. 40) observed the Lower Murray aborigines make twine from two fibres, and his description is relevant. 'One is a blue rush which grows in the scrub; the other is the root of a . . . bulrush . . . the rushes or roots are first . . . boiled or steamed in the native oven, and then chewed by the women. A party of them will sit round the fire and masticate the fibrous material by the hour . . . the masses of (chewed) . . . fibre are handed to the men . . . who . . . work it up, by twisting it on the thigh into hanks of twine . . .'

Price (1952, p. 26) recorded the discovery of another infant burial in Shelter 6, at a depth of about 2 ft. The bundle was 'wrapped in a kangaroo skin'. This burial came from within the area of the trench excavated by the expedition described in this report.

Burial 2

The skeleton is that of a small, adult female aboriginal. It is well preserved, as such thin, fragile bones as the lacrimals and nasal conchae are present (Pl. LXXI B).

The grave had vertical sides, 50 in. in depth and was 30 in. in diameter. The S. line of the trench cut through the grave, situated about 6 ft from the rear wall and under the protection of the overhang. The burial took place during Layer 2 times and was dug down into Layer 8, almost down to the hard white deposit which encased the dingo skeleton, directly below the grave.

The grave was too small for the body, with the result that the head and feet rested at an angle to the body, the cranium sitting at right angles to the long bones. The body lay on its left side, facing the E. (the spinal column running 150°-330°). Eyre (1845, 11: 344) describes a similar ritual amongst the Adelaide tribe, but adds that burial took place 'with the head to the west, in a grave from 4 to 6 feet deep'. In this case, however, the skull gazed steadfastly across the river towards the E. Included in the infilling were 10 large pieces of rock, one of which rested directly on the cranium. However, the only damage caused by the pressure was the splitting of two upper incisors.

Traces of plant remains were found over some long bones, and the skull. These belonged to the sedge family, probably *Scirpus fluviatilis*. The evidence suggests that it may have been buried as a desiccated bundle, after the fashion described by nineteenth century observers. Taplin (1879a, p. 20; 1879b, p. 37) refers to the smoke drying of adult bodies on the Murray, after which they were 'wrapped up in mats' or 'rugs' and kept for a considerable period before their interment. Although he does not elaborate, it is obvious from a subsequent plate in which Taplin (1879b, p. 64) illustrates aboriginal handicraft, that the mats to which he referred were woven from plant materials.

Special features of some bones:

Skull: This is in good condition, the styloid processes and the lacrimal bones (1 damaged) are present. The posterior part of the skull is more friable than the anterior. Most suture lines are present, including at least part of the coronal and most of the lambdoid: the sagittal suture is synostosed. The supra-orbital ridges are poorly defined and the mastoid processes are small. The palate is wide anteriorly. The teeth showed marked attrition, especially the molars where the attrition is most advanced on the inner aspect of the upper molars and the outer aspect of the lower ones. The first right premolar is missing; judging from the bone resorption, it was removed some years prior to death. There is no caries. The mandible is well developed with a large coronoid process. The angle between the body and the ramus is greater than a right angle. Hyoid bone: There are no lesser cornua present. Clavicle and scapula: Small and light bones. Left Humerus: There is an old fracture of the mid shaft with a definite deformity on the anterior aspect of the lower shaft. Right fibula: There is a slight bony deformity just below the upper end of the bone, probably the result of an old fracture. Hip bones and sacrum: Show the characteristics of those of a small female. Lumbar vertebrae: The bodies show definite lipping of their edges. One mid-thoracic vertebra: Has a poorly developed body, which is thin and wedge-shaped (with the narrower part anteriorly). The two sides of this body are not fused in the midline where there is a gap of varying width (maximum width ¼″).

Age: Judging from such criteria as tooth attrition, suture line fusion and lipping of lumbar vertebral bodies she was probably over 40 years and probably not in advanced age.

ORGANIC REMAINS

Detailed appraisals of mammalian fauna are given in Appendices 1 and 2. A summary of other relevant finds follows.

MOLLUSCS: The freshwater and terrestrial molluscs followed the same pattern as those reported in detail from Shelter 2 (Mulvaney 1960). There were 2 species present at Shelter 6 which had not been recorded at Shelter 2. *Salinator fragilis* Layers 9, 10) and *Chloritobadistes victoriae* (Cox)? in Layer 18. Bivalves, *Velesunio ambiguus* (Philippi) and *Alathyria jacksoni* Iredale, were abundant in all layers, although there were concentrations in bands at some depths. *Corbiculina angasi* (Prime) was also present in all layers.

Univalves present in almost all layers were *Notopala hanleyi* (Frauenfeld), *Plotiopsis tetrica* (Conrad), and *Lenameria tenuistriata waterhousei* (Clessin). The small land snail, *Austrosuccinea australis* (Ferussac), which was recorded in almost all levels at Shelter 2, only appeared in lower layers here. *Meracomelon* sp. ? appeared in Layer 15.

AVIFAUNA: Shell fragments of emu eggs were present in most layers, in addition to some bones of birds otherwise unidentified. Possible Mallee fowl egg shell in Layer 11.

REPTILIA: Fragments of carapace of *Chelodina* occurred in almost every layer. *Tiliqua scincoides* or *Trachydosaurus rugosus* occurred in Layers 4, 7, 8, 10, 11, 14, 15, *Varanus* in Layer 2.

PISCES: Fish vertebrae were common, although few were specifically identified. *Oligorous macquariensis* (Murray cod) was identified in Layers 17 and 18. An upper jaw fragment of a large specimen was found in Layer 16; a probable catfish spine in Layer 11. *Parachaerops* (Yabbie) was preserved in Layers 1, 2, , 5, 10, 11, 14.

FLORA: Large quantities of *Scirpus fluviatilis* (Marsh Clubrush) occurred in Layers 1 and 2 and in association with burial 2; carbonized fragments were recovered in Layer 5. Layers 1 and 2 also contained numerous twigs and leaves of eucalypts. *Santalum acuminatum* (Quandong nuts) occurred in Layers 1, 2 and 5.

Appendix 1

MAMMAL REMAINS

By N. A. WAKEFIELD

In the material excavated from Shelter 6 at Fromm's Landing, there were specimens of about 96 individuals of native mammals, representing 12 species. The identities of these, and their distribution in the levels, are set out in Table 2. In this table some of the figures given are based on identifications and counts are based on jaw bones.

Mulvaney (1960) gave lists of mammal genera and a few species, for the various levels of the excavation of Shelter 2 at Fromm's Landing. This material has been re-examined and identified at species level. As there are 30 species and several hundred individuals represented, it is a valuable collection, particularly as several of the levels have been dated. Table 3 presents an analysis of the mammal collection

TABLE 2

Analysis of mammal remains from Shelter 6, Fromm's Landing, showing numbers of individuals of each species at each level. Figures in parenthesis are based on identifications of limb bones.

C14 estimations: B.C.								1000±91			1220±94				1500±90				Total for each species
Levels:	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	18B	
DASYURIDAE																			
Myrmecobius fasciatus														1					1
PERAMELIDAE																			
Perameles bougainville	1	1	1		1	(2)													6
Chaeropus ecaudatus									1										1
Isoodon obesulus															1				1
PHALANGERIDAE																			
Trichosurus vulpecula	1	1	(1)		(1)				(1)	1	1	1			1			(1)	10
MACROPODIDAE																			
Bettongia penicillata		1		1	1	(1)		(1)	(1)	1		1			3	(1)	1	(1)	14
Lagorchestes leporides		1			2				1	1									5
Lagostrophus fasciatus																	1		1
Thylogale eugenii	1			1			1			1	1								5
Macropus canguru							1								1	1		(2)	5
MURIDAE																			
Hydromys chrysogaster						1	1		(1)							(1)		1	5
Rattus luterolus	6	4	4	4	7	1		1	2	3	2	1	(1)		1			(1)	38
Rattus greyii										1		1	1					(1)	4
CANIDAE																			
Canis familiaris dingo										1									1
Total for each level:	9	8	6	6	12	5	3	2	7	9	4	4	2	1	7	3	2	7	97

from Shelter 2. This greatly modifies the picture published previously, in that 4 species (*Wallabia rufogrisea, Thylogale billardieri, Potorous tridactylus* and *Phascogale*) are now omitted, 11 additional genera are listed, and adjustments have been made to grouping at most levels.

Hale and Tindale (1930) listed mammal sub-fossils, which had been identified by H. H. Finlayson, from the Devon Downs shelter. In this case, a reasonably accurate picture was presented of the mammals of the site. However, the material contains also a specimen of *Dasycercus*, one of *Thylacinus*, 2 of *Onychogalea* and about 10 of *Lagostrophus*.

Identification of Specimens

Antechinus flavipes: Although jawbones of this species are almost identical with those of *Phascogale calura*, the shape of the angle of the dentary identifies the specimens from Shelter 2 as *A. flavipes*.

Sminthopsis cf. *murina*: The entries in Table 2 are based on dentaries which cannot be identified specifically. However, these resemble specimens of the *S. murina-S. leucopus* group rather than *S. crassicaudata*, and *S. murina* is known to occur in the Murray scrubs area while *S. leucopus* favours a coastal habitat.

Dasyurinus geoffroyi: Jones (1923, p. 91, 93) indicates that this species is a larger animal than the *Dasyurus quoll* (= *viverrinus*) of South Australia. This is supported by a 'Murray R.' specimen of the former (N.M.V., No. R.1328) and sub-fossil series of the latter from W. Victoria. Size of the teeth of the specimens from shelter 2 show that they are of the larger form.

Isoodon obesulus: The several specimens from the Fromm's Landing sites demonstrate an animal considerably smaller than the W. Victorian form of this species.

Lasiorhinus latifrons: Finlayson identified this genus from the uppermost layer in the Devon Downs shelter, and it is extant along the Murray R. However, the fragmentary wombat specimens from Shelter 2 cannot be identified specifically and, therefore, may be partly or wholly of *Phascolomis mitchellii*.

Bettongia lesueur: Of the 2 specimens from Shelter 2, the one from Level 2 is of a much smaller form of the species than the one from Level 6.

Potorous morgani: The specimens from Shelter 2 are of the form which was described by this name by Finlayson (1938). This is also the identity of the 'Potorous' from Levels 1 and 6 of the Devon Downs Shelter. The question of the relationship of this form to *P. platyops* has not been considered in connection with the material from Shelter 2. (*Potorous tridactylus* has not been found in any of the 3 Murray R. shelters.)

Macropus canguru (= *major*): A number of the excavated specimens could be identified as *M. canguru*, but none was specifically identifiable as *M. rufus*. Therefore, although some fragments may be of the latter, all have been counted as *M. canguru*.

Psuedomys, Thetomys, Notomys: The fragments available are not sufficient for specific identification.

Distribution Data

Antechinus swainsonii: A typical dentary was in Level 1 of Shelter 2. The species has not been recorded previously, either living or fossil, for South Australia.

Dasycercus cristicauda: There was one dentary in Level 1 at the Devon Downs shelter and another in Level 7 at Shelter 2. The species is a desert animal and it has not previously been recorded from S. South Australia.

TABLE 3

Analysis of mammal remains from Shelter 2, Fromm's Landing, showing numbers of individuals of each species at each level

C14 estimations: B.C.					1290±80		1806±85		1931±85	2105±85	2900±100		Total for each species
Levels:	0	1	2	3	4	5	6	7	8	9	10	11	
DASYURIDAE													
Antechinus flavipes	5			1				1					7
Antechinus swainsonii		1											1
Dasycercus cristicauda ..								1					1
Sminthopsis cf. *murina* ..			1	1									2
Dasyurinus geoffroyi						1	1						2
Dasyurops maculatus					1	1					1		3
Sarcophilus harrisii						1		1					2
Myrmecobius fasciatus ..									1				1
Thylacinus Sp.								1					1
PERAMELIDAE													
Perameles bougainville ..	5		4	2		1	2	3	2	2			21
Chaeropus ecaudatus	2		1										3
cf. *Isoodon obesulus*	2		1				1	1					5
PHALANGERIDAE													
Pseudocheirus peregrinus ..	1	1	2										4
Trichosurus vulpecula	10	3	1	2									16
PHASCOLOMIDAE													
cf. *Lasiorhinus latifrons* ..	1						1	1	1		1		5
MACROPODIDAE													
Bettongia penicillata	14	2	2	4		2	24	16	4	2	1		71
Bettongia lesueur			1				1						2
Potorous morgani							2	2					4
Lagorchestes leporides	9	1	1	3	1	3	11	5	3		1		38
Lagostrophus fasciatus ..	8		2	2	2	4	20	11	3	1		1	54
Onychogalea lunata	1												1
Thylogale eugenii	3	1	2	2		2	2	3	1				16
Macropus canguru	2			3	1	3	4	3	1	1	1	1	20
MURIDAE													
Hydromys chrysogaster ..	2	1				2	1	1					7
Rattus lutreolus	138	13	20	32	2	25	15	17	7	6	2	1	278
Rattus greyii	6		1	5		1							13
cf. *Pseudomys auritus*	1			1								1	3
Thetomys sp.				1									1
cf. *Notomys*			1	1									2
Conilurus albipes	1	1				1							3
CANIDAE													
Canis familiaris dingo	1												1
Total for each level:	212	24	40	60	7	47	85	67	23	12	7	4	588

Sarcophilus harrisii: Special comment was made (Mulvaney 1960, p. 68, 81) on a single specimen of Tasmanian Devil, at Level 7, in Shelter 2. However, there was a second fragment of the species from Level 5. The presence of *Sarcophilus* at these levels demonstrates its occurrence in the locality betwen about 1900 B.C. and 1300 B.C. Judging by the date given by Tindale (1957) for Layer 9 of the Devon Downs Shelter (2300 ± 180 B.C.), the Devil had about the same time distribution in this site also.

Thylacinus sp. (Tasmanian Tiger): See Appendix 3. Its occurrence in Level 7 was contemporary with *Sarcophilus.*

Pseudocheirus peregrinus (= *laniginosus*): The species occurred only at the 3 upper levels in Shelter 2, and was not at Level 7 as reported in the 1960 paper. Similarly, in the Devon Downs shelter, it did not occur below Level 4. This indicates a time distribution of the species, for the general area, from about 1300 B.C. to the present.

Lagorchestes leporides: This was present at almost all levels in Shelter 2, not only at Level 7 as was indicated in the 1960 paper.

Lagostrophus fasciatus: This species also was represented at almost all levels in Shelter 2, not only at Level 6 as was reported in 1960. Furthermore, there are specimens of it from Levels 2, 4, 6, 7, 8, 10 and 11 in the Devon Downs shelter. Gould (1849, Pl. LVI) quoted an early report that it was frequently met with near the Murray R., but this was discredited by both Jones (1924) and Troughton (1941). The specimens from the shelters now vindicate Gould's report.

Onychogalea lunata: As well as the surface occurrence in Shelter 2, there are specimens of *O. lunata* from Layers 6 and 7 in the Devon Downs shelter.

Discussion

The mammals of the Devon Downs and Fromm's Landing shelters represent an essentially modern fauna, and this shows no major variation in composition during the time of accumulation—approximately 5,000 years. There is no evidence from these sites of any of the extinct giant marsupials of the Upper Pleistocene. Gill (1955) gave evidence that a comparatively arid period occurred in Australia, between 6,000 and 4,000 years ago. If such a period did produce conditions responsible for extinction of large Pleistocene marsupials, the lowest levels of the 3 archaeological excavations presumably post-date that period.

Competition from the dingo may have contributed to the dying-out of *Sarcophilus* and *Thylocinus* on the Australian mainland. Concentrations of mammal remains at the middle levels of both the Devon Downs shelter and Shelter 2 may indicate a period of more vigorous vegetation. Some significance may be attachable to the restriction of *Pseudocheirus* to upper levels. More excavations are needed to help clarify points such as these.

Appendix 2

A 3,000 YEARS OLD DINGO FROM SHELTER 6

By N. W. G. Macintosh

Data Received from D. J. Mulvaney

'The discovery of the skeleton of a dingo was made during the 1960 season. It was enclosed within Layer 10, and most probably became buried fairly early in Layer 10 times. It was uncovered near the S. wall of the trench, at a depth from the surface of 5′ 9″ to 6′ 3″, and 3′ 6″ out from the rear wall of the shelter at that depth. This area was completely covered by the rock overhang, and was set back too far in the shelter to have been reached by the prehistoric flood of about the same period.'

'The remains covered an area approximately 11″ by 13″. The layer in this area consisted of the hard grey "ashy" concretion, and the bones were underlain directly by an horizon of black ash and small charcoals. The skeleton was partially excavated, and upon identification, it was encased in paraffin wax and removed in a block.'

'The age of the animal can be estimated. (NPL 28), 1000 ± 91 B.C., was collected in Layer 8, 4′ 6″ below the surface; (NPL 29), 1220 ± 94 B.C., consisted of wood charcoal from Layer 11, 7′ from the surface and only 9″ below the dingo. An age intermediate between these dates is therefore indicated. It is therefore the oldest fossil dingo to be dated in Australia, although it is several thousand years later than the earliest domesticated dog in the Old World.'

THE SPECIMEN

As received, it consisted of a compacted mass of gritty sand measuring 33 × 27 × 13 cm (Pl. LXXIII A). One side of the mass, presumably the lower or base, was flat; the opposite side, presumably the top, was more convex. It contained a dingo skeleton; visible on the upper surface were the thigh bones flexed at the hip joints, the knee joints semi-flexed, the vertebral column uniformly convex, and the right side of the skull. The epiphyseal junctions of femur and tibia were not united and indicated an immature animal.

TECHNIQUE

One planned to remove the individual bones in sequence, in the hope that relationships of adjacent bones had not been disturbed within the mass and so identification and reassembly would be easier. Also posture at death and related events at the locus might therefrom be deduced. Successive photographs recorded the stages of removal of the skeleton from the matrix.

It was found that the paraffin which had been applied to the block had penetrated the sand and formed a soft cement, instead of merely providing a coating. Xylol removal proved ineffective and the bones were recovered by dissection with fine blade scalpel and needle-point forceps, the paraffin cement being pared away in wafers. Mr Burton Bailey shared equally with the writer the extraction from the matrix, identification, reassembly and mounting of the skeletal material (Pl. LXXII).

All sand and grit (Munsell 10YR 5/4) was preserved and sieved. Some 40 pieces of shell and some 30 chips of charcoal were observed, no fragment of either being more than 0·5 cm in any dimension. 3 tiny avian bones and some minute spicules (unidentified) were present. No missile, no stone or bone implement, not so much as a flake or chip of stone occurs with the remains.

POSTURE

The thoracic and lumbar vertebral column was uniformly flexed; the cervical column was also flexed and turned through an angle of about 150° to the left, so that the left and lower aspects of the skull were lying on and concealing the left scapula and humerus. The jaws were completely closed, the teeth interlocked. The forelimb bones were completely flexed at the shoulder and elbow joints. The penultimate 4 caudal vertebrae were lying ventral to the last 2 or 3 lumbar vertebrae, so the tail had either been tucked in between the hind legs or over the left hind quarter. Apparently the animal died lying right side down and curled up into a ball.

Missing Bones

Left tympanic bulla; 1st right rib; chevrons; coccygeal vertebrae 1-3, 6-12, 17-18; 3 left carpals, 4 right tarsals; phalanges—8 proximals, 8 middles, 9 distals; sesamoids—1 gastrocnemial, 2 popliteal, 9 volar; left lower 2nd molar tooth. The skeleton is therefore extraordinarily complete, even down to minute bones; which makes the absence of ⅔ of the tail bones very surprising.

Damaged Bones

Posterior 2 × 1 cm of external surface of body of left mandible missing and adjacent bone fractured; facial and palatal sutures sprung; gap, 1 cm diameter, in left scapular infraspinous fossa; gap, 1 × 4 cm, right scapular serratus area; spines T3, T4 and T9 fractured, right ribs 3, 5 and 9 fractured. All these are post-mortem and very recent; they must have occurred during excavation or subsequently.

Relationship of Bones

Only 2 vertebral bodies (both thoracic) were found to be separated from their arches, but not a single upper or lower epiphyseal plate was fused with its vertebral body. About 70% were in correct position of contact, but the remaining 30% were scattered out of contact and had to be individually selected and matched for fit, and then glued to the bodies. Diaphyses and epiphyses of the limb bones were separated but had not been grossly displaced. Relationships of the ribs presented a little difficulty; they had been compressed upon themselves antero-posteriorly and also bilaterally; hence some left ribs had been inserted between rights and vice versa and the sequence of 1 to 13 antero-posteriorly had not been maintained, overlapping displacement having occurred. This meant that each rib had to be identified by anatomical minutiae for the purpose of reassembling the skeleton. One visualizes, therefore, slow and slight but progressively increasing earth pressure uniformly distributed from above and around the perimeter of the animal compressing it upon itself and against an already compacted floor. Apparently from the moment of its death until the intrusion of the archaeologist, the animal had remained undisturbed, save for the question of its tail.

As the archaeologist so successfully recovered minutiae such as volar sesamoids and terminal phalanges and fragile bones such as the hyoid greater and lesser cornua, it seems unlikely that he would simply have failed to recover 12 coccygeal vertebrae, although there is the fact that the right 1st rib and the lower left 2nd molar are missing also. Assuming the missing vertebrae were not lost at excavation, the curious distribution of the missing vertebrae needs to be observed. There are usually 18 coccygeal vertebrae in the dingo, domestic dogs exhibiting 17 to 23. The terminal one or two, i.e. the 17th and 18th coccygeal, vertebrae in the dingo are usually extremely small and would most likely go missing at excavation. It has already been noted that the 13th-16th were lying ventral to the lumbar vertebrae, indicating the end of the tail was tucked in against the abdominal wall and so sheltered. A predator, such as a rat, might conceivably have gnawed through the proximal and middle sections of the tail; this speculation (by a member of a Sydney University symposium audience, 5-7 October 1963) seems possible. *Rattus* occurs at practically all levels in the Lower Murray Valley excavations. Of a considerable number of other suggestions advanced, the most popular was that aborigines ate the tail; this is extremely unlikely; firstly, the terminal part of the tail would also have been missing and, secondly, an immature, or even an adult dingo's tail is almost totally devoid of meat.

CONDITION OF THE BONES

They have a firm dry appearance and, with careful handling, are not particularly brittle, but will fracture in a dry-stick fashion under mild pressure; at the same time, they are not friable and exhibit no surface corrosion or erosion. At the sites of the fractures already referred to, the cancellous bone and trabecular structure show no evidence of disintegration. The bones show no trace of fire or smoke and there is no differential colouration; they are uniformly of the same hue (Munsell 7·5YR 6/6). Every tooth shows multiple fissure cracks in the enamel. They occur most prominently on the basal aspects of the crowns and run parallel in a cervico-occlusal direction or present a cross-hatched intersection pattern. Ferruginous stain has invaded the enamel via these fissures. Had the skeleton been presented out of context, there would have been no reason apart from the teeth to advocate antiquity since, to the naked eye, it presents no patina, mineralization, or incrustation. Various writers, e.g. Wood Jones (1934), in arguing against the antiquity of the mineralized Cohuna and Talgai skulls, have referred to rapid mineralization in Australia, instancing mineralization of bones of the introduced horse. The present specimen indicates that, for some regions, absence of mineralization is compatible with considerable antiquity.

CAUSE OF DEATH

There is absolutely no evidence of pre-mortem damage to the skeleton. Trauma by a blow sufficient to cause death would have fractured some bone and none is so fractured. Even death by a spear thrust might be expected to cause damage to the rib cage and such is not present. Very obviously it was not killed by the aborigines for food.

All its bones are well modelled, its teeth are well formed and the arrangement of its dental arches is completely normal. Attritional wear is present on every tooth, but it can only be classified as mild.

Neuro-muscular poisons cause death in opisthotonus, i.e. extension, not flexion; of course, as rigor mortis is not instantaneous, the ultimate position would be relaxed semi-extension.

It is most probable that the animal went to sleep in the normal curled up position assumed by *Canidae* in cold weather and simply died in its sleep.

ETHNOLOGICAL DEDUCTIONS

There is no justification for assuming that the rock shelter was being used by aborigines, either as kitchen, workshop, or shelter, or that they were even in the vicinity at the moment of death of this dingo. By elementary rule of thumb, every vertical inch of deposit at this site may represent a time span of 40 years. Mulvaney (1960 and the present report) has shown clearly that occupational debris occurs intermittently, aboriginal utilization of the sites was not continuous, not uninterrupted. He has also rightly emphasized that 'cultural material was sparse throughout' (1960, p. 73).

Evidence is against the presence of aborigines at the time of death of the dingo. It has already been stated that only 40 chips of shell and 30 chips of charcoal were recovered from the matrix (Munsell 10YR 5/4) containing the skeleton, i.e. less than 0·00001% of the cubic volume. This contrasts dramatically with the underlying horizon of black ash and small charcoals. These few shells and charcoal chips must be assumed to have drifted from adjacent horizons rather than to have been the products of contemporary occupation. The absence of any fire evidence on the bones and, indeed, the absence of any disturbance to the anatomical skeletal relationships (except the mid-proximal section of the tail) reinforces this view.

To assume, therefore, that this dingo is evidence of even symbiotic relationship, let alone domesticity, with the aborigines at that period cannot be justified. It is to be hoped there will not be more read into the occurrence of this dingo than the evidence admits.

SEX

Presence of the os penis saved necessity of any analysis to determine sex.

INDIVIDUAL AGE

Complete eruption of the permanent dentition has occurred (Pl. LXXIII B). Left lower M_2 had fallen out of its socket and was not recovered at excavation. All other teeth are present. The pattern of eruption time of dingo dentition is approximately the same as for domestic dogs. Sisson (1945) says M_3 erupts by the 6th to 7th months. On each side of the present mandible is a fully erupted and perfectly modelled M_3. It is true that process of eruption is rapid in the *Canidae*, but buccomesial wear polishing can be observed when these 3rd molars are examined under a dissecting microscope, indicating that they had been functional.

It is necessary to digress briefly. Presence of lower 3rd molar is one of the criteria aligning the dingo with wolves, domestic dogs, and jackals and separating it from the Indian red dog or dhole (Genus *Cyon* or *Cuon*), in which, incidentally the 2nd molars are relatively smaller. The validity of this 3rd molar criterion has been variously discussed by Hodgson, Cope, Lund, Huxley, Mivart, Lydekker, Wood Jones, and others. Longman (1928) referred to some of this discussion and instanced anomalies. He also remarked on the absence of wear on this tooth and quoted and apparently supported Lönnberg's version that it is a small useless tooth having no antagonist to work against. It is sufficient to remark here that attritional wear is not confined to teeth which make contact occlusion with one another. The crowns of 1st, 2nd and 3rd upper and lower premolars, in dingo, and domestic dog, do not make contact in occlusion, but nevertheless exhibit attritional wear. In this present specimen, attritional facets are most pronounced on lower 1st molar followed by lower 3rd incisor as one would expect, but no tooth is totally free from any attritional evidence. It is deduced, therefore, that the total permanent dentition had been functional for at least a brief period, suggesting the animal could have been 7 months old at death.

A second digression is appropriate at this moment and necessary with reference to the 1st upper molars. Wood Jones (1921, 257; 1925, 354) stated the continuous cingulum of this tooth as seen in jackals and foxes, 'is reduced or wanting in the middle of its length' (labially) in wolves. He claimed that similar condition in domestic dogs and dingo indicated their true wolf affinity. In the Fromm's specimen the gingulum is not 'wanting'; it is continuous and uninterrupted (Pl. LXXIII B). The term 'reduced' is a subjective one. In the comparisons I have made so far, I would not call it reduced. Before being dogmatic about it, it needs to be compared with a larger series of jackals and foxes. Wood Jones's claim about this cingulum has previously been challenged by Tate (1952). It is morphological features of this sort that make the attested archaeological specimen so valuable.

Time patterns of epiphyseal closure, as observed in a colony of dingoes bred at this Department, University of Sydney, differ from those of domestic dogs as quoted in literature, e.g. Sisson (1945).

In this specimen, no union whatever has occurred at the proximal or distal ends of humerus, radius, ulna, femur, tibia, fibula; hence, if dingo pattern matched the literature about domestic dogs, the age of this specimen at death would be some age less than 6 months.

However, the proximal ends of the metatarsals of the forelimb are almost completely fused and of hindlimb completely; their distal ends are not fused. The proximal ends of the forelimb proximal phalanges are fused with the shaft, but in the hindlimb they are not. The distal ends are almost completely fused in forelimb and completely fused in the hindlimb. Judged by comparison with domestic dogs, this animal would be very slightly under 6 months in age.

Union of the tuber scapulare does not occur in domestic dogs before 6 to 8 months. In this specimen, union is present on the lateral (dorsal) aspect. This would indicate an age of perhaps 7 months for the animal under examination. However, this is offset by our observations that the tuber scapulare, the olecranon process, the tuber calcis, and the distal ends of radius and ulna unite appreciably earlier in the dingo than the times indicated for domestic dogs. In the specimen under examination, the 3 parts of the innominate bone are fused at the acetabulum, the iliac crests and the ischial tuberosities are firmly positioned, but the inferior ischial and pubic rami are separated by 0·18 mm, and the pubic bodies by 0·21 mm. This indicates an age slightly above 6 months and a somewhat different pattern of closure from that of the domestic dog. Summarizing the total evidence, the age of this animal at death was pproximtely 23 to 27 weeks.

Size Relative to Age

Table 4 compares measurements of the Fromm's Landing 6-months-old dingo with a 4-months (No. 9) and with a 9½-months (No. 32) old dingo each bred in the Department of Anatomy, and with dingo figures quoted by Mivart. He nominated length of vertebral column as 100% and expressed all other measurements absolutely and also as percentages of the vertebral column length. This method has been used here. The relative proportions agree rather closely in all 4 columns.

The Fromm's Landing animal is absolutely small for its age of 6 months, being smaller in all dimensions than the 4-months-old dingo (No. 9). Its skull, while being absolutely smaller, is slightly larger relative to its body and limb dimensions than is the case in the Sydney animals and in Mivart's item.

Mivart's comparative table (1890-*q.v.*) for various *Canidae* indicates that the Fromm's Landing animal and the two Sydney dingoes match only the proportions for dingo. (Their nearest similarity otherwise in Mivart's table is to *C. latrans*, but they show some significant differences from it also.)

Size Relative to Modern Dingo

Tables 5 and 6 show that the teeth of the animal from Fromm's Landing lie within the size range for those of the modern dingo, and that the relative size of the teeth to one another are of a similar order. A criterion identifying certain ferals (including dingo) from other groups of *Canidae* is the observation that the mesiodistal diameter of the upper 4th premolar is about the same as the diameter from mesial aspect 1st molar to distal aspect 2nd molar and also approximates to 10% or more of the basilar length.

The occurrence of a small thylacine tooth (Appendix 3) at adjoining Shelter 2, with an antiquity of almost 4,000 years, and a small dingo with an antiquity of 3,000 years, is a coincidence which perhaps needs the comment that one is not justified in speculating that the region was *per se* producing dwarf types.

Table 4

	Dingo from Fromm's Landing		Bred in Dept Anatomy, U. of S. No. 9		Bred in Dept Anatomy, U. of S. No. 32		Mivart (1890)	
	male aged 6 months		male aged 4 months		male aged 9½ months		— adult	
	cm	%	cm	%	cm	%	cm	%
Vertebral column from front of atlas to hind end of sacrum	47·0*	100	55·0	100	70·0	100	63·5	100
Cervical vertebrae ..	11·9*	25·3	—	—	—	—	16·0	25·2
Thoracic vertebrae ..	17·5*	37·2	—	—	—	—	24·0	37·8
Lumbar vertebrae ..	14·5*	30·9	—	—	—	—	18·5	29·1
Sacrum ..	3·1	6·6	—	—	—	—	5·0	7·9
Height at T3 ..	34·0	72·3	39·2	71·3	49·5	70·7	—	—
Humerus	12·1	25·7	12·8	23·3	17·3	24·7	16·5	26·0
Radius	12·0	25·5	13·0	23·6	17·0	24·3	16·0	25·2
Ulna	14·1	30·0	15·3	27·8	20·1	28·7	—	—
Index metacarpal ..	4·7	10·0	5·4	9·8	6·3	9·0	5·7	9·0
3rd metacarpal ..	5·3	11·3	6·3	11·5	6·8	9·7	6·4	10·1
Femur	13·4	28·5	14·3	26·0	18·5	26·4	18·0	28·3
Tibia	12·8	27·2	13·6	24·7	18·4	26·3	17·6	27·7
2nd metatarsal ..	5·2	11·1	6·0	10·9	6·6	9·4	6·3	9·9
3rd metatarsal ..	5·8	12·3	6·7	12·2	7·4	10·6	—	—
Basion to sphenoideum	3·97	8·4	—	—	—	—	5·1	8·0
Sphenoideum to ant. edge of premaxilla	10·27	21·85	—	—	—	—	13·2	20·8
Sisson's Breadth/Length Index:								
Skull (nuchal crest to ant. end of pre-maxillary suture) ..	15·6	33·2	15·9	28·9	20·4	29·1	—	—
Max. bizygomatic ..	7·7	16·4	8·2	14·9	10·3	14·7	—	—
Skull index	49·4		51·6		50·5			
			(all at the extreme range of dolichocephaly)					

* Calculated, making allowance for intervertebral discs: +0·7 cervical,
+2·0 thoracic,
+1·3 lumbar,

Total: = +4·0 cm.

It has been noted that size is normal for the teeth of the dingo, it is only its skeletal framework which is small. It was our experience in breeding a colony of dingoes that, during the juvenile stages, size of animal was closely related to amount of food consumed. One may be justified in speculating that food supply was not over abundant at Fromm's Landing or perhaps that this particular dingo lacked efficiency.

TABLE 5

Mesio-distal lengths in mm of	Dingo from Fromm's Landing	Dingo No. 32 Sydney	Mivart's largest of 5	Mivart's smallest of 5
P^1	5·55	5·20	6	5
P^2	10·60	10·00	12	10
P^3	11·65	11·35	13	11
P^4	19·35	18·48	21	18
M^1	12·85	12·25	15	12
M^2	7·10	6·78	8	7
P_1	4·15	3·84	5	4
P_2	8·16	8·12	10	8
P_3	10·40	9·50	11	10
P_4	11·12	10·64	12	11
M_1	21·00	20·20	23	20
M_2	9·36	9·00	10	9
M_3	5·02	5·20	5	5

TABLE 6

Mesio-distal lengths in mm of	Fromm's Landing Dingo	Dingo No. 32 Sydney	Tichota 1937 3 samples	Wood Jones 1921 22 samples	Longman 1928. Av. of 10 samples	Tate 1952 6 samples
Mesial of M^1 to distal of M^2 ..	20·05	18·98	19–21	—	—	—
P^4	19·35	18·48	19–21	19·5–22·0 Av. 20	20	18·0–19·0 ♂ 17·6–20·3 ♀
Basilar length	140	178	170–170	165–193 Av. 177·3	181	178–184 ♂ 163–195 ♀

COMPARATIVE FOSSIL MATERIAL

McCoy (1882, Pl. 61) illustrated *Canis* teeth from Mt Macedon (Gisborne) cave and from L. Colongulae in Victoria. Etheridge (1916, Pl. 10-12) illustrated 3 of 7 *Canis* teeth from the Wellington Caves, N.S.W., which included those earlier written about by Krefft (1865). Fossil remains of extinct mainland marsupials were recovered from these sites. Gregory (1906) observed similar association at L. Eyre. Those 4 authors thought the association indicated contemporaneity and an antiquity for the dingo of early post-Tertiary time. Present opinion is that, while the fossil dingo and fossil marsupial remains may have been contemporary, proof has not been shown, as the deposits at Gisborne and Wellington cannot be stratigraphically identified.

McCoy (1882, 7) said the left mandibular fragment with 1st molar from Colongulae was slightly but 'perceptibly more robust than the modern variety'; yet two pages subsequently he said 'I find, on the most minute comparison and measurements, no difference between the fossil and the recent individuals...'; he said the Gisborne dingo remains agree very closely with the living dingo. Etheridge (1916, 50) said the Wellington Caves specimens were 'of a dog somewhat superior in size to the Warrigal'.

I thank John McNally, Director, and Edmund D. Gill, Curator of Fossils, National Museum of Victoria, for the loan of dingo specimens. This collection includes the items described and figured by McCoy. Gill (pers. comm.) observed from Flourine Phosphate Indices, that the Colongulac dingo is younger than a female aboriginal skeleton found there, but older than European advent. The enamel of the Colongulac dingo lower left 1st molar is cracked and mottled brown and, in this regard, appears to be intermediate in appearance between the older thylacine tooth and the younger dingo teeth from Fromm's Landing. While this probably indicates that the Colongulac tooth has some antiquity, it is not suggested that relative dating of items from different sites can be hazarded on such subjective observations; also Gabriel (1948) pointed out that there is individual variability in suceptibility to enamel cracking and staining.

McCoy gave measurements for the Colongulac and Gisborne teeth in inches and lines. I have remeasured these with vernier mm calipers. The Colongulac left lower 1st molar is 23·1 mm mesiodistal and 9·78 mm labio-lingual. The mesio-distal diameters of the Gisborne teeth are upper right P^2 10·7, P^3 11·9, P^4 17·83, M^1 10·88 mm. Etheridge said the lower right M_1 from Wellington measured 21 mm.

Mr F. D. McCarthy invited me to identify and comment on teeth fragments from Site 3, Layer D, Section 6, depth 19 to 24 in., Bondaian phase of the Eastern Regional Sequence, at his Glen Davis excavation. He still awaits results from carbon samples submitted for C-14 dating. They are *Canis* teeth, the majority broken into several fragments; after repair, some were complete enough to measure. Their identifications and mesio-distal diameters, where these could be measured, are as follows:

Upper left: M^1, P^4 (19·5 mm), canine.
Upper right: P^4 (19·5 mm), canine (10·0 mm), I^3 (7·2 mm).
Lower right: M_1 (22·25 mm), P_4 (12·0 mm).
Lower left: M_1.

They all come from a single animal which from the evidence of dental attrition was fully or post-mature; they are badly weathered; the enamel shows brown mottle stain but the fissure cracking seen in the Fromm's Landing and Colongulac teeth is minimal or absent. Black speckling is present which McCarthy says is a manganese effect. Under microscopy, these black patches look like deposit rather than stain. The labial cingulum on the upper 1st molars appears to be somewhat reduced. Further study on these teeth is proposed at a later date. These teeth are a useful addition here, to extend the limited series of fossil remains.

It can be observed that only the Colongulac tooth is at the extreme range of large size recorded for recent dingo teeth. All other specimens here examined are within the range.

CONCLUSION

Wood Jones (1925, 355-6) stressed the degree of uniformity of skull type in the dingo and refuted the popular belief that dingoes are so freely crossed by station dogs that a thoroughbred dingo is hard to come by. Tichota (1937) further stressed the uniformity of skull type and Macintosh (1956) also rejected the popular belief about hybridization. Mulvaney's archaeological find substantiates these views and proves that dingo morphological pattern has remained constant for 3,000 years. As the oldest genuinely dated dingo, it establishes the pattern type of the dingo. Its total and detailed anatomy, therefore, should be put on record; time and space have not permitted that in this present report and only controversial facets have been pursued. One hopes to make fuller description subsequently.

SUMMARY

This adolescent male dingo from Mulvaney's excavation at Fromm's Landing, South Australia was 23 to 27 weeks old at death.

Save for the 1st rib, the lower left 2nd molar tooth and the middle and proximal portions of tail, the skeleton is substantially complete and undamaged. There is no evidence of pre-mortem trauma or cause of death. Apart from staining and cracking of tooth enamel, there is no gross evidence of antiquity, such as patination, or mineral incrustation.

The evidence suggests that the animal died curled up on its right side in sleep and remained undisturbed until the arrival of the archaeologist. It is speculated that a predator such as *Rattus* might have been responsible for the portion of tail being absent. There is no evidence that this animal was in symbiotic or domestic association with the aborigines, rather the evidence favours that it had taken refuge in the shelter during an hiatus in aboriginal occupancy.

Its skeletal frame is absolutely small for its age when compared with modern dingoes; its skeletal indices coincide with those for dingo in the classificatory literature and differentiate it from other *Canidae*. Its teeth are indistinguishable from and are within the size range of modern dingoes and of available comparative fossil dingo specimens. It is suggested its small size may be related to poverty of food supply.

This relic proves that dingo morphological pattern has remained unchanged for 3,000 years. As the oldest genuinely dated dingo, this animal establishes the type of the dingo. It is hoped, therefore, to put on record subsequently its total and detailed anatomy.

Appendix 3

A 4,000 YEARS OLD THYLACINE TOOTH (DASYURIDAE) FROM SHELTER 2

By N. W. G. MACINTOSH AND J. A. MAHONEY

This tooth from Layer 7 at Shelter 2 was sent to me (NWGM) for confirmation or denial of a tentative diagnosis reading 'cf. *Canis familiaris* dingo'. It was obviously not a dingo permanent tooth and subsequent comparison with dingo deciduous dentition established that it was not dingo. The C14 age of Layer 7 is intermediate between 1806 ± 85 B.C. and 1931 ± 85 B.C.

Basically it has the pattern of a carnivorous permanent upper left 1st molar or deciduous last premolar and its essential morphological pattern is thylacine (Pl. LXXIV). However, its crown size is small, 8·90 × 6·26 mm; its roots are stained blackish brown and in contrast with the lighter coloured crown give a subjective impression of excessive gracility; while having the basic pattern of a thylacine upper left 1st molar in miniature, there is, 'apparently or superficially', total absence of definitive buccal styles and an aberrant looking protocone. First impression, therefore, suggested that the tooth was from a dwarf thylacine. A summary of the firm conclusions of Flower (1868), Bensley (1903), Todd (1918), Jones (1923), and others, is to the effect that in no marsupial is there more than one tooth, bilaterally in upper and lower dentition, replaced by a succeeding tooth. Replacement, when it occurs, involves the last premolar. The deciduous tooth is molariform, and so, unlike its successor and, furthermore, the deciduous tooth is vestigial in *Thylacinus*. Hence, any notion that the tooth could be deciduous is excluded.

A thylacine-like tooth from an apparently irrefutable archaeological context and attested by C14 dating as having such low antiquity on the mainland as about 4,000 years, is so important to so many facets of Australian archaeology as a whole, that it calls for thorough attention. Therefore, I invited Mr J. A. Mahoney, who has examined dasyurid material in another context, to direct me to sources of comparative material and to take part with me in the identification of the tooth. From that point, the present paper becomes one of co-equal investigation, authorship, and responsibility. We thank colleagues A. C. Gabriel DDSc., and B. C. W. Barker MDS, FDSRCS, of this Department of Anatomy for consultations and for checking our progressive observations.

Material used for comparison consisted of 18 skulls of *Thylacinus cynocephalus*, 14 in the Australian Museum; 3 in the Macleay Museum, University of Sydney; 1 in the Department of Anatomy, University of Sydney; and 6 left and 4 right fossil upper 1st molars (Australian Museum No. F50818-27) from the Wellington Caves, N.S.W.; such latter specimens have been nominated generally as *T. spelaeus*; they were observed by us to be morphologically similar to *T. cynocephalus*, although attrition restricts total comparison and the mean size of 11·9 × 8·8 mm for the left molars (F50818-23) is larger than that tabulated for *T. cynocephalus* (*v.i*); detailed comparison in this paper has been based on and limited to *T. cynocephalus*; dasyurine (*Sarcophilus*, etc.) teeth were compared at the initial stage of the examination.

We thank Dr J. Evans, Director of the Australian Museum, and Miss J. Morris, Curator of the Macleay Museum, for access to this material.

Nomenclature used by us follows that employed by Bensley (1903) and illustrated in his Fig. 1, p. 89, which designates the adult upper molariform teeth in marsupial polyprotodont forms as 1st, 2nd, 3rd, and 4th true molars; buccal styles are designated alphabetically a, b, c1, c, c2 in order mesio-distally.

DESCRIPTION

The biting surface is triangular in outline; the metaconal tip is almost centrally placed in relation to buccal, palatal, mesial and distal enamel margins. The greatest diameter, measuring 9·40 mm, is a diagonal from mesio-palatal surface of protocone to distal surface of metaconal spur. The mesio-distal axis from mesial surface of paracone to distal surface of metaconal spur is 8·90 mm, and regarded by us as length of the tooth. With one caliper blade touching mesial aspect of protocone and paracone, and the other caliper blade touching distal aspect of metaconal spur, the diameter reads 8·92 mm. The greatest transverse diameter between buccal aspect of paracone and palatal aspect of protocone is 6·40 mm. Diameter between the surfaces of paracone and protocone when measured orthogonally, i.e. at right angles to the plane of the buccal surface of the entire tooth, is 6·26 mm and this is regarded by us as breadth of the tooth. In other words, the tooth fits into a geometrical figure which is approximately a right-angled triangle, of which the hypotenuse tangential to protocone and metaconal spur is longest, the base tangential to buccal aspect of paracone and metaconal spur is intermediate in length, and the remaining side tangential to protocone and paracone is the shortest. For absolute precision, it is noted that the angle subtended opposite the hypotenuse is 86° not 90°.

The enamel margin at the base of the crown is uniform and practically horizontal when viewed from palatal and buccal aspects of the metacone and its spur, but is undulant at the base of protocone and paracone. A cingulum-like prominence of the enamel continues as a shelf without interruption right round the perimeter of the crown; it is prominent on the buccal aspect, but least evident on the palatal aspect of the metacone, and is most pronounced palatally between metacone and protocone, forming an actual bridging platform at the base of the cleft between them.

The crown bears a bucco-mesial paracone, a palato-mesial complex protocone, and a distal metacone from the posterior border of which extends a trenchant spur or blade which shears against (presumably) the mesio-buccal border and slope of the triangular pillar of a more distal lower second molar. The shearing edge is relatively long and its disposition mesio-distal, but curved, presenting a buccal concavity. From the perimeter of the metaconal summit to the distal end of the tooth, the crest of the metaconal spur measures 4·25 mm. The tips of all cusps are of a piercing type. At their bases they are conical or vaguely triangular in cross section.

Bensley describes the thylacine metaconal tip as lanceolate from a filling out of the cavity originally present on its outer side. By lanceolate, presumably, he meant two-edged and symmetrical and this is well exemplified in this specimen. One edge is a sharp ridge running from the metaconal tip mesially and slightly buccally to the cleft between metacone and paracone, which it bridges and continues up on to the paraconal tip. The other edge runs from the metaconal tip distally and slightly palatally to become continuous with the crest of the metaconal spur; obviously a cutting or shearing edge, it is heavily worn by attrition in this specimen. Presumably it had originally a sharp edge; wear has flattened the edge which has transverse dimension of 0·45 mm mesially, tapering to 0·3 mm distally, exposing secondary dentine bounded by thin plates of enamel on either side. The enamel measures 0·16 to 0·25 mm in thickness. The two edges described lie almost in the same mesio-distal line and divide the metaconal tip into buccal and palatal hemicones; near the base of the latter is a faint ridge, which runs palatally and reaches the cleft between metacone and protocone. Cross section of the metaconal tip, therefore, is scarcely triangular, although a triangular trend can be said to be imposed on an otherwise circular cross section. The base of the metaconal tip is defined from the body of the crown by a faint almost perfectly circular groove.

The paraconal tip is defined at its base by a faint, more or less circular groove, interrupted by three edges. One of these, continuous with that from the metaconal tip, has already been described. Another extends from the paraconal tip bucco-mesially; it is sharp and continues on to the bulk of the paracone itself where it assumes a more directly mesial direction. The remaining ridge begins near the base of the paraconal tip, runs palato-mesially and continues to bridge the wide cleft between paracone and protocone and links with a ridge on one element of the protoconal tip. Hence, a cross section of paraconal tip has a more marked trend to triangular form than has the metaconal. The apex of the paraconal tip has been truncated by attrition rather more vigorously than the metaconal and more secondary dentine is exposed. The apex is not centrally placed relative to the total bulk of the paracone, but is excentrically displaced in a disto-palatal position with slight deviation of its tip in a buccal direction.

The protoconal summit is complex and, to the best of our present knowledge, unique in form. It is clearly divided into two definitive and unequal sized apices or tips. The smaller is entirely mesial in position and its long axis transversely disposed. The larger is entirely distal relative to the smaller and its long axis is mesio-distally disposed. They are separated by a well defined acute-angled cleft. Each tip has suffered attrition sufficient to remove the enamel and give linear exposure of secondary dentine, transversely in the smaller mesial apex, longitudinally in the larger disto-palatal apex. The base of the two apices combined is indicated by a faint horizontal groove situated at the junction of the cervical two thirds and the occlusal one third of the protoconal enamel. From this groove in a cervical direction there is complete continuity; bifidity only commences slightly more occlusally, but at once becomes pronounced. Continuity of enamel, at the angle of the cleft separating the two deviant elements, is interrupted by a fissure. The two apices excentrically surmount the protocone so that their bucco-distal surfaces are rather vertical while their palato-mesial surfaces are considerably sloped. A distal sharp edge or border occurs on the larger of the bifid elements.

All four apices are therefore clustered, as it were, about the occlusal fossa on the mesial moiety of the tooth. The shape of the fossa between paracone, metacone, and bifid protocone is influenced by the bifurcation of the protoconal apex. It is roughly diamond-shaped, bounded disto-buccally by the metaconal apex, buccally by the paracone, palatally by the larger distal element of the protocone, mesially in its palatal half by the smaller mesial element of the protocone and, in its buccal half, only by the ridge derived from the palatal aspect of the paracone and the buccal aspect of the protoconal smaller element. This fossa is deep and roomy. No attritional wear can be detected on its floor. No attritional wear occurs on the mesiobuccal aspect of the major protoconal element. A light attritional facet is present mesially and slightly buccally on the minor protoconal tip. An elongated attritional facet is present on the distopalatal aspect of the paraconal summit. This can only mean that the disto-buccal edge of the triangular pillar (presumably) of a more mesial lower 1st molar was of slightly different relative form and dimension in this animal than in the comparative material, or it was more adequately accommodated in this roomy fossa.

The undulant character of the enamel margin has been mentioned. Diameters taken vertically from the abraided tips of the metacone, paracone, larger protoconal element, and smaller protoconal element to the maximum convexity of the enamel margin, are as follows: metacone, buccal & palatal, 5·13 mm; paracone, buccal, 3·80 mm; larger protoconal element, palatal, 4·27 mm; smaller protoconal element, mesial, 3·15 mm. Metrically and morphologically, metacone is the most dominant part of the tooth, protocone is intermediate, and paracone least.

Buccal surface of crown: Bensley, in describing the reduced nature of buccal styles in thylacine teeth, says external paraconal styles are vestigial or wholly absent. But he refers to 'style ? ab' as apparently always present in the 1st, 2nd and 4th molars. He says style c is not represented, but a small element probably equivalent to c2 is apparently always present in the 1st molar, variable in the 2nd, scarcely distinguishable in the 3rd.

His term 'style ? ab' is very useful. In the majority of upper thylacine 1st molars examined by us, the elements a and b are clearly detectable as vertically disposed prominences of the enamel separated cervical-ward by a shallow gutter, but merging occlusal-ward, or alternatively terminating in separate blunt tubercles; such observation has not been recorded by Bensley or any other writer as far as we are aware.

In this present specimen, fusion of the two elements a and b is still more complete. The enamel between them demonstrates a flat surface on which is a barely perceptible groove. Occlusal-ward they fuse to form a vetigial style surmounted by a minute apex, adpressed to the mesio-buccal surface of the paracone and bounded mesially by a sharp edge. Distally, also, its tip is bounded by a sharp edge which quickly fades into a rounded border. Styles b1, c1 and c are each absent in the definitive sense, but their classical positions are occupied by small vertically elongated bulges, clearly evident in the case of b1 and c1, barely evident in the case of c. Style c2 is absent and its classical site occupied by a well defined uniform convex bulge. At the distal extremity of the metaconal spur crest on its buccal margin is a minute style. In shape and inclination (tilted mesio-palatally), it is similar in miniature to the classical style c2, but displaced to an extreme position distally.

The buccal surface lies only approximately in a continuously mesio-distal plane. The distal third of the buccal surface of the paracone presents a prominent convexity; the buccal surface of the metacone and its spur present two less prominent convexities separated by a very shallow groove running towards the distal border of the metaconal summit; while on the buccal aspect of the distal extremity of the spur, there is a shallow notch, which gives a subjective, but untrue, impression that the extremity is deviated buccally. A well defined but shallow cleft subtending an angle of 150° intervenes between paracone and metacone; there is no fissure in its floor. Diameters from the middle of this cleft to the mesial and distal ends of the tooth are 3·64 and 6·12 mm. The buccal surface, therefore, is appreciably undulant due to the bulges and grooves described.

Palatal surface of crown: The blade-like element of the tooth is more obviously expressed palatally and is accentuated by attritional wear. The uniform concave shallow fossa on the buccal aspect of the metaconal spur is replaced on the palatal aspect by a slight uniform convexity. Adjacent to the palatal edge of the metaconal apex and spur crest is a triangular attritional facet. It extends from the disto-palatal aspect of the tip of the metacone occluso-cervically over one half of the palatal enamel and is prolonged distally to the extremity of the spur crest. An elongated oval attritional facet occurs palato-distally on the larger (distal) of the bifid summits of the protocone. It extends from the abraded tip to about one third of the distance to the enamel margin and is parallel, but not adjacent, to the distal edge of the protocone. The palatal convexity and palatal displacement of the protocone away from the mesio-distal axis of the tooth accentuate the cone-like character of the protocone in contrast to the flat shearing blade-like character of the metaconal spur. A cleft intevenes palatally between protocone and metacone. Near the enamel margin it is shallow, being bridged by a definite shelf-like prolongation of the cingulum previously referred to. As the cleft runs occlusal-ward, it has a sigmoid curve, becomes deeper and more acutely angled. It is difficult to estimate the angle subtended and indeed it varies in different parts of its course. In the vicinity of the cingular shelf it is about 144°. No fissure occurs in its floor.

On the palatal aspect of the distal end of the metaconal spur is a rather large interproximal attritional facet caused by the upper second molar. Vertically it occupies almost two thirds of the surface. The enamel has been excavated in a gutter-like fashion and in the trough, a limited area is stained dark brown. The question of whether incipient caries is indicated, could only be solved by histological examination. A little mesial to this facet, there are two additional breaks in the enamel continuity; one is rather close to the palatal margin of the metaconal spur crest; the other, more deeply gouged and more darkly stained, is situated on the most prominent convexity of the cingular bulge. Five more blemishes occur on the protocone; of these, one is about half way up the middle third of the palatal aspect of the larger (distal) element of the protocone; it is sigmoid-shaped and deeply gouged through the enamel. Another is curvilinear palato-mesial in position close to the apex of this same protoconal element, but the enamel is merely stained, not gouged. Another occurs on the mesial aspect of the protoconal cingulum and presents a deep vertical gouge. Two similar more or less vertical gouges occur at the cervico-enamel junction of the buccal aspect of the metaconal spur. On the distal aspect of the paraconal root are two punctures near the cervico-enamel junction, and a larger circular puncture occurs on the distal aspect of the middle of the metaconal root. Two more are present on the mesial aspect of the para- and protoconal roots.

The breaches of the enamel are presumably traumatic, incurred in mastication by piercing and shearing of bone, particularly as the fossil and *T. cynocephalus* comparative materials exhibit similar lesions. The puncturing of the roots is harder to explain, and may be post-mortem damage. The relatively thin enamel in this specimen parallels the relatively thin enamel in any other thylacine teeth we have examined. In proportion to tooth size, it is relatively, as well as absolutely, much thinner than in human dentition.

Mesial surface of the crown: A relatively shallow cleft intervenes between protocone and paracone and subtends an angle of 140°. There is no interproximal attritional facet on the mesial aspect; but there is a vertical gouge on the protoconal cingulum; apparently there was not direct contact with distal extremity of the upper 3rd premolar. This is a variable feature in the material examined for comparison.

Staining and cracking: Stemming from the cervico-enamel margin or close thereto, a series of parallel cracks run occlusal-ward. On the buccal aspect, 26 can be counted with a lens; the majority extend over the cingular bulge, but 6 are larger and reach almost to the summit of the crown. A further 28 occur on the palatal aspect, the majority extending at least half way towards the summit. An irregular branching fracture runs longitudinally, intersecting the larger fractures in the parallel vertical series. A more gross and recent looking fracture (unstained) runs obliquely across the palatal aspect of the junction of metaconal apex and spur; another curiously zig-zag hair-line crack (heavily stained) runs parallel and adjacent to the enamel margin of the metacone. On the mesial and distal aspects, cracking is more irregular and curvilinear. The enamel adjacent to the cracks is stained a medium brown which becomes progressively lighter as distance from the crack increases. The enamel, therefore, presents the curious impression of being vertically striped near its margin. The staining is more intense at the larger cracks. Obviously, the stain (probably ferruginous) has invaded the tooth via the cracks in the enamel. The pattern of cracking suggests a progressive post-mortem process, the vertical series being oldest, the transverse and oblique series more recent.

The Roots: The roots are much more intensely stained a dark chocolate brown; each cusp is independently supported on its own root.

Root lengths are protoconal 6·6 mm, paraconal 6·6 mm, metaconal 6·4 mm; their mesio-distal diameters adjacent to the crown are 2·8, 2·6, 3·8 mm respectively.

The paracone root is cylindrical in cross section, progressively tapers to the slender apex and is strongly curved in a palatal direction at the junction of its basal two thirds and its apical one third. The extremity of the tip is recurved bucally and distally.

The protocone root is compressed obliquely near its base resulting in a somewhat triangular cross section; in its middle third, cross section is circular. Its distal third is slightly bent buccally. Its buccal aspect is slightly guttered.

The metaconal root is strongly compressed bucco-palatally. Its distal border is straight and its mesial borders strongly curved. A very deep gutter excavates the basal two thirds mesially, shallowing in the distal one third. The tip deviates palatally. A mesio-distal ridge traverses the floor of the root fossa. The roots merge into the body of the tooth smoothly but are considerably overhung and sheltered by the cingular bulging of the enamel. Each root is united to its neighbour by a buttressed arch.

Radiological Examination: The canals are of relatively large calibre and single for each root; the pulp cavity is uncomplicated, and its cornua follow the external contours of the tooth. Thinness of the enamel is confirmed.

STATISTICAL ANALYSIS

(1) 18 crania of *Thylacinus cynocephalus* (Harris) from Tasmania (Australian Museum No. 768, 769, 770, 771, 774, 775, 776, 778, S401, S402, S789, S1180, S1730, M1821); Macleay Museum (University of Sydney) No. M1000, M1001, M1002; Anatomy Museum (University of Sydney) No. SF5: 32. Crania modern but lacking sex and precise locality data.

(2) Thylacine upper left 1st molar from Fromm's Landing, SE. South Australia.

Left M^1 of *Thylacinus cynocephalus* (Harris)

	Mean mm	95% confidence interval for mean mm	Number	Standard deviation	95% confidence interval for standard deviation
M^1 length	11·05	10·78–11·32	18	0·539	0·404–0·809
M^1 width	7·93	7·75– 8·11	18	0·371	0·278–0·556

Regression of molar width on molar length
$\beta = 0 \cdot 636$ 95% confidence interval 0·498–0·774
Regression of molar length on molar width
$\beta = 1 \cdot 346$ 95% confidence interval 1·054–1·638

Fromm's Landing thylacine:
Left M^1 length 8·9 mm; Left M^1 width 6·4 mm;
t value for molar length 3·880; t value for molar width 4·017.

The probability that the Fromm's Landing thylacine measurements for molar length and for molar width belong to the distribution shown by modern Tasmanian *Thylacinus cynocephalus* is less than 0·01 and 0·001 respectively. Relevant, however, is the statement by Thomas (1888, 257) that the two sexes in *T. cynocephalus* differ in their cranial and dental characters far more than do the sexes of any other marsupial. Therefore, consideration must be given to possible sexual dimorphism in molar size when evaluating the taxonomic significance of the results obtained by the present analysis.

Estimated lines for regression of molar width on molar length and of molar length on molar width are drawn in Fig. 4 for *T. cynocephalus*, and the position of the Fromm's Landing Molar is indicated in the same figure. The Fromm's Landing molar is seen to lie close to the extended regression lines for *T. cynocephalus.*

We thank Professor H. O. Lancaster, Dept of Mathematical Statistics, and Dr A. A. Day, Dept of Geology and Geophysics, University of Sydney, for discussing the statistical analysis.

CONCLUSION

The tooth is a thylacine permanent upper left 1st molar. In four traits—miniature size, bifid protocone, absence of a definitive style c2, presence of a minute style buccally on the extremity of the metaconal spur—it differs from the comparative material of *T. cynocephalus* examined by us; in all other morphological traits and in metrical proportions, it is identical or within the range of individual variability of *T. cynocephalus.* We consider the four outstanding differences, when summated, prevent inclusion of the Fromm's Landing Tooth in *T. cynocephalus.*

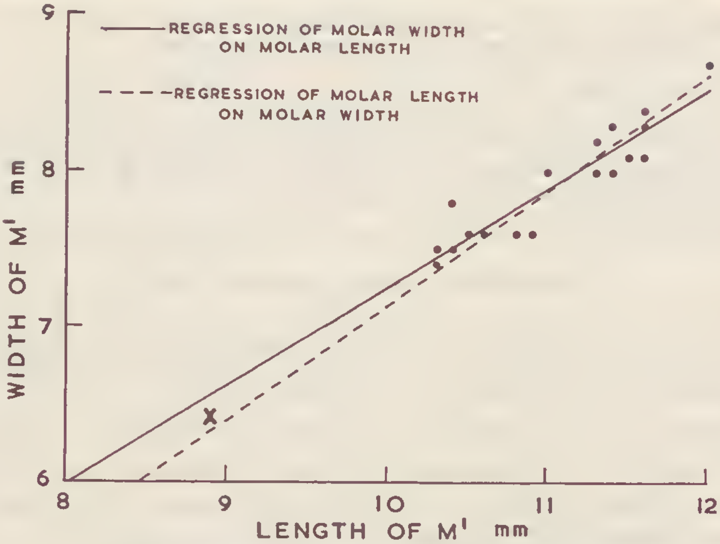

FIG. 4—Regression lines for *T. cynocephalus*.
Legend: • *T. cynocephalus* (Tasmania)
× Fromm's Landing (Mainland, S. Aust.)

Small forms have not been recorded for fossil species of *Thylacinus*; indeed, Lydekker (1887, 264) and De Vis (1894) indicate that these species are no less robust and are perhaps more robust than *T. cynocephalus*; however, the named fossil species of *Thylacinus* have not been defined adequately.

The Fromm's Landing thylacine is known to us from a single tooth only, and so specific determination of this animal is premature at this stage and it is recorded here as *Thylacinus* sp.

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All the finds are being deposited in the South Australian Museum, Adelaide.

References

Bensley, B. A., 1903. On the evolution of the Australian Marsupialia; with remarks of the relationships of the marsupials in general. *Trans. Linn. Soc. Lond.* 9, 2nd Ser. Zool. 83-217.

Campbell, T. D., and Noone, H. V., 1943a. South Australian microlithic stone implements. *Rec. S. Austr. Mus.* VII: 281-307.

————, 1943b. Some aboriginal camp sites in the Woakwine Range... ibid. VII: 371-396.

De Vis, C. W., 1894. A thylacine of the Earlier Nototherian Period in Queensland. *Procs Linn. Soc. N.S.W.* 2nd s., 8: 443-7.

Etheridge, R. Junr, 1916. The Warrigal, or 'Dingo', introduced or indigenous? Dept Mines, *Mems. Geol. Surv. N.S.W.* Ethnol. Ser. 2: 43-54, Pl. 10-12.

Eyre, E. J., 1845. *Journals of Expeditions of Discovery.* 2 vol. London.

Finlayson, H. H., 1938. On a new species of *Potorous* (Marsupialia) from a cave deposit in Kangaroo Island, South Australia. *Trans. Roy. Soc. S. Aust.* 62: 132-140.

Flower, W. H., 1868. On the development and succession of the teeth in the Marsupialia. *Phil. Trans. Roy. Soc. Lond.* 157, 631-41.

Gabriel, A. C., 1948. *Genetic Types in Teeth.* ps 61, Aust. Med. Pub. Co., Syd.

Gill, E. D., 1955. The Australian arid period. *Aust. J. Sci.* 17 (6): 204-206.

Golson, J., 1959. 'Culture change in prehistoric New Zealand', in *Anthropology in the South Seas.*

Gould, J., 1849. *Mammals of Australia.* London.

Gregory, J. W., 1906. *The Dead Heart of Australia.* ps 384, Lond.

Hale, H. M., and Tindale, N. B., 1930. Notes on some human remains in the lower Murray valley. *Rec. S. Austr. Mus.* IV: 145-218.

Jones, F. W., 1921. The Status of the Dingo. *Trans. Roy. Soc. S. Aust.* 45: 254-63.

————, 1923. *The Mammals of South Australia* Pt 1. Government Printer, Adelaide.

————, 1924. ibid. Pt 2.

————, 1925. ibid. Pt 3.

————, 1934. Contrasting types of Australian skulls. *J. Anat.* 68, 3: 323-330.

Krefft, G., 1865. Notes on the fossil mammals of Australia. *Geol. Mag.* 2: 572-4.

Longman, H. A., 1928. Notes on the dingo, the Indian wild dog, and a Papuan dog. *Mems Queensland Mus.* 9, 2: 151-7.

Lydekker, R., 1887. *Catalogue of the Fossil Mammalia in the British Museum* Pt 5, ps 345.

McCarthy, F. D., 1946. The stone implements of Australia. *Mem. Aust. Mus.* IX.

McCoy, F., 1882. The Dingo, Prodromus of the Palaeontology of Victoria. *Geol. Surv. Vict.* 7: 7-10, Pl 61, figs 1-4.

Macintosh, N. W. G., 1956. Trail of the Dingo *The Etruscan* 5, 4: 8-12.
1956. reprinted in *The Australian Junior Farmer* 3, n.s, 7: 3-9.

Mivart, St G., 1890. *Dogs, Jackals, Wolves and Foxes. A Monograph of the Canidae* ps 216, Lond.

Mulvaney, D. J., 1960. Archaeological excavations at Fromm's Landing on the Lower Murray River, South Australia. *Proc. Roy. Soc. Vict.* 72: 53-85.

————, 1961a. Australian radio-carbon dates. *Antiquity* 35: 37-39.

————, 1961b. The stone age of Australia. *Proc. Prehistoric Soc.* 27: 56-107.

Price, A. G., 1952. St Mark's College scientific work at Fromm's Landing. *Proc. Roy. Geog. Soc. Australasia, S. Austr. Branch* 53: 25-27.

Simpson, G. G., 1930. Post-Mesozoic Marsupialia. *Fossilium Catalogus* 1: Animalia, Pt 47: 52 & 80. Berlin.

Sisson, S., 1945. *The Anatomy of the Domestic Animals,* 3rd Edn, 3rd Rpt, ps 972, Phil.

South Australian Government, Engineering and Water Supply Dept, 1962. *Surface Water Resources* Vol. 1.

Taplin, G., 1879a. in (ed.) Woods, J. D., *The Native Tribes of South Australia.* Adelaide.

————, 1879b. *The Folklore, Manners, Customs...of the South Australian Aborigines.* Adelaide.

TATE, G. H. H., 1952. Results of the Archbold Expeditions, No. 66 (Canidae). *Bull. Amer. Mus. Nat. Hist.* 98, 7: 612-4.

THOMAS, OLDFIELD, 1888. *Catalogue of the Marsupialia and Monotremata in the Collection of the British Museum.* ps. 401. London. Brit. Mus. (Nat. Hist.).

TICHOTA, J., 1937. Das Verwandtschaftsverhältnis des australischen Dingos zu den prähistorischen Typen des Haushundes. Kraniologische Studie *Zool. Anz.* 120, 9/10: 177-190.

TINDALE, N. B., 1957. Culture succession in south-eastern Australia... *Rec. S. Austr. Mus.* XIII: 1-49.

————, and MOUNTFORD, C. P., 1936. Results of the excavation at Kongarati cave. *Rec. S. Austr. Mus.* V: 487-502.

TODD, T. WINGATE, 1918. *An Introduction to the Mammalian Dentition*, ps. 290. St Louis.

TROUGHTON, E., 1941. *Furred Animals of Australia.* Sydney.

Explanation of Plates

PLATE LXVIII

View of trench looking N., 1963.

PLATE LXIX

General view of part of N. wall showing erosion of layers by flood and subsequent deposition.

PLATE LXX

Detailed view of flood sediment.

PLATE LXXI

A. Burial 1; B. Burial 2.

PLATE LXXII

Fromm's Landing Dingo. Note immaturity indicated by ununited epiphyseal junctions. The vertebrae have been assembled in completely adjacent contact; by calculation, allowance for intervertebral discs would add 4·0 cm to the length of the vertebral column. Reconstruction and reassembly by Burton Bailey and N.W.G.M.; photo by G. L. Williams, scale by K. Smith, Dept of Anatomy, University of Sydney.

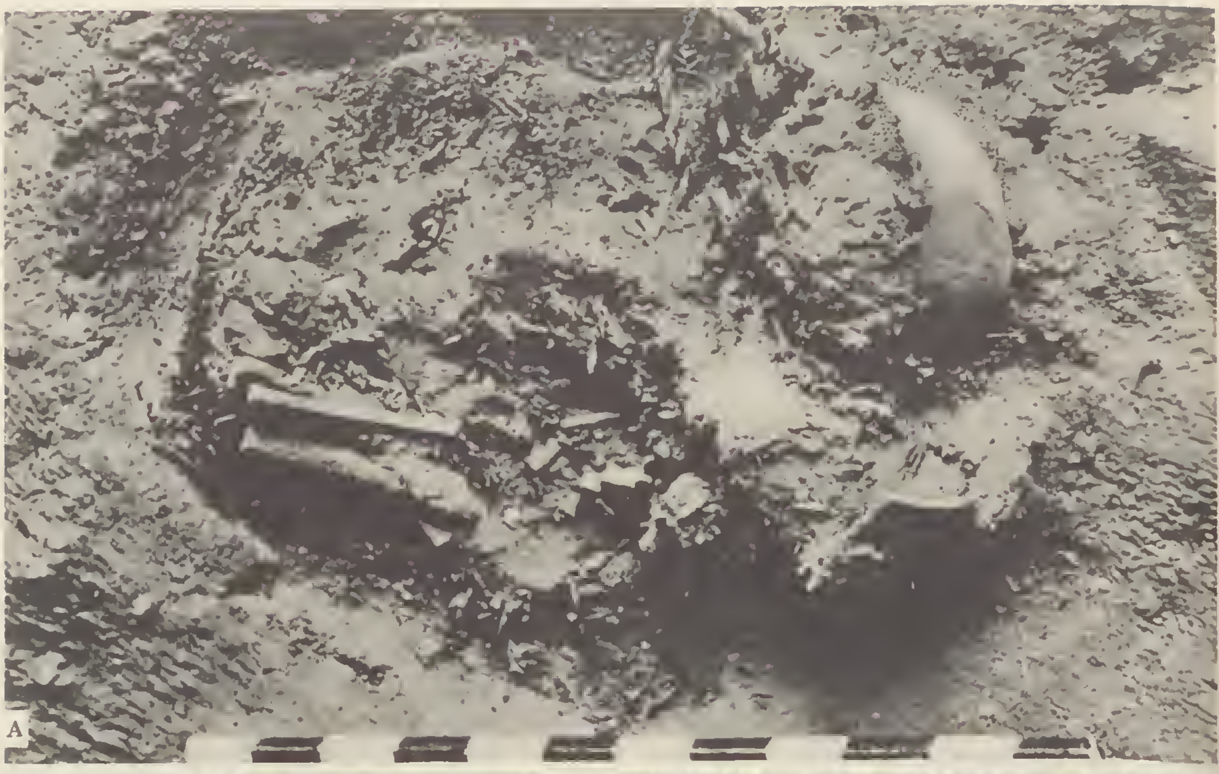
PLATE LXXIII

A. Fromm's Landing Dingo, paraffin coated as delivered. Note: Vertical aspect of right side of skull at margin of block; thigh bones fully flexed at hip joints; knee joints semi-flexed; left side of skull rests on left scapula and left forelimb bones which are fully flexed and tucked under against chest wall. Scale and photo by K. Smith and G. L. Williams, Dept of Anatomy, University of Sydney.

B. Reconstructed skull. Note permanent dentition and fully erupted, well formed lower 3rd molars; the left lower 2nd molar was not recovered. Note also the uninterrupted and unreduced cingulum on the upper 1st molars. Photo by G. L. Williams.

PLATE LXXIV

Upper left 1st molar *Thylacinus* sp. Greatest length 8·9 mm. 1. Buccal, 2. Palatal, 3. Mesial, 4. Occlusal, 5. Distal. Photo by G. L. Williams and D. H. Joy, Dept of Anatomy, University of Sydney.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AN AMMONITE FROM THE UPPER CRETACEOUS OF VICTORIA

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Abstract

An occurrence of the ammonite *Hauericeras angustum* Yabe in a core from a bore between Warrnambool and Port Campbell on the coast of W. Victoria is described. A Lower Senonian age is indicated.

Description and Discussion

A core (No. 16) from Flaxmans No. 1 Well, depth 5958-5961 ft, containing an ammonite was received from Frome-Broken Hill Co. Pty Ltd in June 1961. The location of the bore, which was situated on the coast of W. Victoria between Warrnambool and Port Campbell, the section penetrated, and the foraminifera found in it are described by Taylor (1964). The core was taken from the lower part of the Belfast Mudstone. Kenley (1958-9) had previously reported occurrences of Ammonoidea in the Belfast Mudstone of the Belfast No. 4 Bore, Port Fairy, but because of crushing and incompleteness of the shells he could only refer one to the Placenticeratidae while the other was said to have closest relationships with the Acanthoceratidae.

The specimen from Flaxmans No. 1 Well (Pl. LXXV; Fig. 1, 2) was found in a hard, dark grey, splintery claystone. The periphery of the core has cut off about ⅔ of the ammonite, just missing the protoconch. The conch is flattened and not filled with sediment, the lower side being pressed against the inner surface of the upper side. The shell is brittle, dark brown, and partly nacreous. The greatest measurable distance from the protoconch to the periphery is 36·8 mm, the maximum measurable whorl height is 25·5 mm.

The fossil can be assigned to *Hauericeras angustum* Yabe 1904. This species was recently revised by Matsumoto and Obata (1955, p. 137) and placed in a new subgenus *Gardeniceras* which was apparently not accepted as such by Arkell, Kummel, and Wright (1957, p.L 371). The genus *Hauericeras* has, according to Matsumoto and Obata (1955, p. 133), the following diagnostic characters which are recognizable in the present specimen: 'Very compressed, discoidal and polygyral shell, with a . . . keeled venter and subangular umbilical shoulder in more or less later growth stages. . . . Surface of the shell is nearly smooth or very faintly ornamented with the striae and/or riblets which are flexiradiate on the flanks and show a prominent projection on the venter . . .'. The subgenus *Gardeniceras* (type species *Ammonites gardeni* Baily 1855) was proposed for the 'Fairly evolute and fairly widely umbilicate subgroup of *Hauericeras* . . .' (Matsumoto and Obata 1955, p. 134). The species *angustum* Yabe was diagnosed as follows: 'Discoidal, evolute, polygyral shell of moderate size, usually about 150 mm and occasionally over 170 mm when full-grown, consisting of much compressed whorls, keeled in the later stages, rather flattened on flanks and gently convergent in section, with the maximum breadth near the umbilical margin. The umbilicus is fairly wide and is surrounded by a steep but low wall and subangular shoulder. Surface of the shell is nearly smooth, with only faint, irregular fine riblets or striae, which are better developed on the inner half of the flanks and weakened towards the venter showing

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FIG. 1—*Hauericeras angustum* Yabe. Outline of fragment from the Cretaceous of Victoria (with umbilical shoulder shown by broken line) reconstructed by superimposition on a specimen from Hokkaido (Matsumoto and Obata 1955, Pl. 29, fig. 1a, reversed), to show identical coiling. The umbilical shoulder of the distal part of the Japanese specimen is missing. About ⅘ nat. size.

FIG. 2—*Hauericeras angustum* Yabe. Outline of the distal profile of the shell of the body chamber as preserved (partial whorl section at whorl height about 25 mm, showing ventral keel and umbilical shoulders). Cretaceous of Victoria. About ⅘ nat. size.

gentle flexuosity on the sides and prominent projection on the venter. Constrictions are very faint or hardly discernible in the inner whorls and occasionally better marked but infrequent on the outer whorl. They run nearly parallel to the striae, with only slight flexuosity on the sides . . .' (Matsumoto and Obata 1955, p. 139). In these quotations, the characters of the very young and very old stages have been omitted, also all references to the suture line which is not preserved in the present specimen. Although this may be considered to make a positive identification hazardous, there are sufficiently distinctive characters of shell form and sculpture clearly in full agreement with the diagnosis. In addition, the ventral keel is as described by Matsumoto and Obata for shells of the size of the Victorian specimen, i.e. indistinct on the inner but distinct on the outer surface of the shell.

The question whether the distinction between *H. angustum* Yabe 1904 from Japan, India, and Canada and *H. gardeni* Baily 1855 from Africa and Madagascar is justified, was discussed at length by the Japanese authors. Their conclusion is that the two species are closely allied but specifically separated, a distinction which can apparently be made only when numerous specimens showing various growth stages are available. The main distinctions are seen in the constrictions which, however, are indistinct in individuals below 80 mm diameter, and in the ratio of whorl width and height. In the present specimen one half of the shell of the best preserved whorl is unbroken and uncompressed so that its width can be estimated (Fig. 2). On the basis of the published comparative diagram (Matsumoto and Obata 1955, Fig. 11), it is closer to the position for *H. angustum* than to that for *H. gardeni* for a whorl height of 25 mm. Whether the suggested taxonomic distinction indicates a species or a subspecies difference cannot be decided without a detailed comparative study of a large amount of material. The question of a possible existence of geographic subspecies has to be approached with care, as the time range of *H. angustum* and *H. gardeni* in various areas is relatively long and possible intraspecific evolutionary changes have to be considered.

AGE: The genus *Hauericeras* ranges from Coniacian to Maestrichtian (Arkell, Kummel, and Wright 1957). It is thought to have evolved either in the Coniacian from *Tragodesmoceras* or, at the beginning of the Turonian from the Desmoceratinae close to the origin of the family Municriceratidae to which *Tragodesmoceras* is now assigned (Arkell, Kummel, and Wright 1957). *H. angustum* is reported doubtfully from the Coniacian and occurs occasionally in the Lower Campanian and fairly commonly in the Santonian of Hokkaido and South Saghalien (about 42-53°N.). It occurs also in the Upper Cretaceous of South India and British Columbia. Matsumoto (1959, Pl. 8) showed the range of this species as Coniacian (upper) to Campanian (lower) and said (p. 70) that it is rather abundant in the zone of *Inoceramus naumanni* (placed in Santonian-Lower Campanian) 'but ranges somewhat upward and probably also downward'. He expressed the opinion that species of *Hauericeras* cannot define a narrow zone. The age of *H. gardeni* as restricted by the Japanese authors is apparently Santonian to Campanian.

The evidence from foraminifera indicates Turonian to Lower Senonian (including Coniacian and possibly Santonian) age of the Belfast Mudstone. *Hauericeras* was found in the lower part of the Belfast Mudstone, above Taylor's Zonule B and in the lower part of his Zonule A. It is noted that *Hauericeras* is not known from the Turonian. A Lower Senonian, possibly Coniacian, age of the specimen from Victoria is consistent with macrofaunal and foraminiferal evidence.

Acknowledgement

I am grateful to the management of Frome-Broken Hill Co. Pty Ltd, Melbourne, for permission to publish this paper. The specimen has been deposited in the collection of the National Museum of Victoria (No. P22888).

References

ARKELL, W. J., KUMMEL, B., and WRIGHT, C. W., 1957. *Mesozoic Ammonoidea.* Treatise on Invertebrate Paleontology (L) Mollusca 4: L81-L472, Geol. Soc. Amer. & Univ. Kansas Press.

KENLEY, P. R., 1958-9. The occurrence of marine Cretaceous sediments in the Belfast No. 4 Bore, Port Fairy. *Mining & Geol. Jour. Vict.* 6 (3): 55-56.

MATSUMOTO, T., 1959. Zonation of the Upper Cretaceous in Japan. *Mem. Fac. Sci., Kyushu Univ.*, Ser. D, Geology 9 (2): 55-93.

MATSUMOTO, T., and OBATA, I., 1955. Some Upper Cretaceous Desmoceratids from Hokkaido and Saghalien. ibid., Ser. D, Geology 5 (3): 119-151.

TAYLOR, D. J., 1964. Foraminifera and the stratigraphy of the Western Victorian Cretaceous sediments. *Proc. Roy. Soc. Vict.* (this volume).

Explanation of Plate

PLATE LXXV

Hauericeras angustum Yabe. From Flaxmans No. 1 Bore, W. Victoria, 5958-5961 ft. A preserved portion of the ventral keel is outlined in black (top). The outline of part of the bore core is indicated by a broken line. × 2. Photo Dr Mary Wade, University of Adelaide. National Museum of Victoria Reg. No. P22888.

22

ON *Deflandrea victoriensis* N.SP., *D. tripartita* COOKSON AND EISENACK, AND RELATED SPECIES

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§ Institute for Geology, University of Oslo

Abstract

The Victorian form of *Deflandrea* included in *D. tripartita* by Cookson and Eisenack (1961) has been removed from that species and redescribed under the name *Deflandrea victoriensis*. An emended description of *D. tripartita* Cookson and Eisenack (1960) is given. Comparisons between *D. victoriensis* and closely related species are included.

Introduction

Deflandrea tripartita Cookson and Eisenack (1960) was originally based on a few specimens of distinctive shape from an Upper Cretaceous deposit in Western Australia. In the specific description the theca-membrane was given as 'finely to coarsely granular'. Later (Cookson and Eisenack 1961), some specimens from the Belfast Mudstone, a Victorian Upper Cretaceous deposit, were identified with *D. tripartita*. These, while resembling the holotype in shape, were said to be ornamented 'with minute rods rather than granules'.

Some difficulty in distinguishing between *D. tripartita sensu* Cookson and Eisenack (1961) and another Australian species *D. micracantha* Cookson and Eisenack (1960) has been expressed by Douglas (1961, p. 20). In order, therefore, to clear the position regarding these 3 Australian forms of *Deflandrea*, the type specimens of both *D. tripartita* and *D. micracantha*, generously made available by the Director of the National Museum of Victoria, have been re-examined and compared with 60 examples of the Victorian form referred by Cookson and Eisenack to *D. tripartita*.

As a result, the conclusion has been reached that the 3 types mentioned above are specifically distinct and that the Victorian form attributed to *D. tripartita* should be raised to specific rank.

The relationship of these 3 Australian species to *D. granulifera* Manum (1964) will be considered.

Descriptions

Genus **Deflandrea** Eisenack

Deflandrea tripartita Cookson and Eisenack 1960 emend.

(Pl. LXXVI, fig. 1, 2; holotype Nat. Mus. Vic. P17795)

Deflandrea tripartita Cookson and Eisenack 1960, p. 2, Pl. 1, fig. 10.

Occurrence: N. of Gingin, Western Australia. Wapet's Seismic shot hole Bore 1 at 160 ft.

Age: Probably Upper Turonian to Middle Senonian.

Description: Emended on the basis of the holotype. Theca elongate, equally divided by an inconspicuous girdle. The middle portion of the theca, which is almost entirely filled with a large capsule, is widest in the region of the girdle and rather abruptly narrowed from thence towards both the upper and lower limits of the capsule. Above the upper limit of the capsule the theca bulges prominently before terminating in a short, broad, bluntly pointed horn. The theca-membrane is *c.* 1·0 μ thick and perfectly smooth in optical section; in surface view a fine pattern is faintly visible under an oil immersion lens (n.a. > 1·0). The wall of the capsule, which is finely but distinctly granular, varies in thickness being *c.* 2·5 μ anteriorly and posteriorly and *c.* 1·0 μ where it is in contact with the theca. The intercalary archeopyle is somewhat elongate and trapezium-shaped.

DIMENSIONS OF HOLOTYPE: 100 μ long, 59 μ broad.

COMMENT: The girdle in the holotype is ill-defined and mainly indicated by two pairs of short, low, parallel ridges, one on either side of the ventral surface at short distances from the lateral margins of the theca. The direction of these ridges indicates that the girdle was slightly laevo-rotatory. In the middle of the dorsal surface, a fold-like line which seems to represent a portion of the girdle and its borders is indicated. The apparent discontinuity of the girdle on the ventral surface suggests that it may have been 'broken' in a manner similar to that characterizing certain other species of *Deflandrea* (Manum 1964), including *D. victoriensis* n. sp. As in these forms, the more prominent antapical horn in *D. tripartita* is on the left hand side of the hypotheca.

Deflandrea victoriensis n. sp.

(Pl. LXXVI, fig. 3-8; holotype fig. 3, 4; Nat. Mus. Vic. P22986)

Deflandrea tripartita Cookson and Eisenack 1961, p. 70, fig. 1.

AGE AND OCCURRENCE: SW. Victoria—Belfast Mudstone intersected by the Belfast No. 4 Bore between 4,492 and 4,499 ft and at 4,652 ft, and by Frome-Broken Hill's Pretty Hill No. 1 Bore at 2,726-2,734 ft, Port Campbell No. 2 Bore at 7,093-7,103 ft and Port Campbell No. 3 Bore at 4,400-4,410 ft. Age probably Senonian.

DESCRIPTION: The theca is elongate and divided approximately equally by a slightly laevo-rotatory girdle, the borders of which are interrupted dorsally at some distance on either side of the mid-line of the theca and ventrally near the lateral margins. The middle portion of the theca is conspicuously convex when viewed dorsoventrally and is filled with a large capsule. Above the upper limit of the capsule the theca bulges to varying degrees. The apex is rounded and the apical horn broadly triangular. The hypothecal portion below the lower limit of the capsule is of almost uniform width or slightly widened towards the antapex, which is more or less obliquely truncate with the longer left-hand side usually terminating in a short, pointed horn. The wall of the theca is *c.* 1·0-1·7 μ thick and ornamented with fairly evenly scattered rod-like projections *c.* 0·5-1·5 μ long; in surface view the rods appear as dots usually between 0·5 and 1·0 μ in diameter but a few smaller and larger ones are usually present. The girdle is bordered by conspicuous ridges or by linearly arranged wart-like thickenings of varying size and shape. The wall of the capsule varies in thickness, being thinnest, less than 1 μ, where it is in contact with the theca and thicker, over 1 μ, in both anterior and posterior regions where it is also more conspicuously granular. The intercalary archeopyle is rounded to equilaterally hexagonal.

DIMENSIONS: Holotype: 112 μ long, 73 μ wide. Range: overall length 76-116 μ, width 49-73 μ. Average of 57 examples 98·0 × 59·5 μ.


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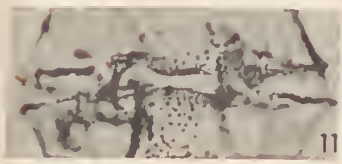
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Comparisons with Related Species of Deflandrea

D. tripartita:

The chief distinction between *D. victoriensis* and *D. tripartita* lies in the constant development in the former of an ornament composed of small, scattered rods. Even when, as occasionally happens, the wall shows little sign of projecting rods in optical section, small, more or less widely spaced dots can be seen in surface view. In *D. tripartita*, on the other hand, there is no conspicuous ornamentation. Other contrasting features are the distinctness of the girdle in *D. victoriensis* and the shape of the archeopyle which, basically, is almost equilaterally hexagonal in contrast to the more elongate heterolateral shape in *D. tripartita*.

D. micracantha:

D. micracantha, the holotype of which is refigured on Pl. LXXVI, fig. 9-11, differs from *D. victoriensis* in its larger size; the narrowing of the theca towards both apices; the denser arrangement and finer character of the rods (not spinules as given in the original description) comprising the ornament which are *c.* 1·0 μ rarely 1·5 μ long and, in surface view, appear as small dots usually less than 0·5, occasionally up to 1·0 μ; the greater coarseness and concentration of the ornament in the capsular region as compared with that in the more distal parts of the theca; the more obvious linear arrangement of the larger rods suggestive of a tabulation corresponding with that of some other species of *Deflandrea* (Manum 1963); and the inconspicuousness of the interruptions in the girdle.

D. granulifera Manum (1964):

D. victoriensis seems to be related to *D. granulifera* from Graham Is., Arctic Canada, which is one of a group of species (Manum 1964) having interrupted girdles comparable in all respects to those of *D. victoriensis*. However, *D. granulifera* has a finer and denser ornamentation, a smaller apical horn in proportion to the size of the theca with a narrower base and is distinctly larger, the average size being 112·5 × 79·5 μ, as against an average of 98·0 × 59·5 μ (Manum 1964, Fig. 4) for *D. victoriensis*.

Acknowledgements

We wish to thank Mr Alan McQueen, of Frome-Broken Hill Co. Pty Ltd, for providing samples of the Belfast Mudstone from the Port Campbell and Pretty Hill Bores. One of us (I.C.C.) has had financial assistance from the Commonwealth Scientific and Industrial Research Organization.

References

COOKSON, ISABEL C., and EISENACK, A., 1960. Microplankton from Australian Cretaceous sediments. *Micropaleontology* 6: 1-18.

——— ———, 1961. Upper Cretaceous microplankton from the Belfast No. 4 Bore, South-Western Victoria. *Proc. Roy. Soc. Vict.* 74: 69-76.

DOUGLAS, J., 1961. Microplankton of the Deflandreidae group in Western District sediments. *Min. Geol. J. Vict.* 6: 4, 17-32.

MANUM, S., 1963. Some new species of *Deflandrea* and their probable affinity with *Peridinium*. *Norsk Polarinst. Årbok 1962*. Oslo 1963, 55-67.

Explanation of Plate

PLATE LXXVI

All figures × 500.

All photographs are from untouched negatives. D or V following the names of the fossils indicates that the dorsal or ventral side, respectively, is facing the viewer.

Fig. 1, 2—*Deflandrea triparitita* Cookson and Eisenack (V). Holotype. Near Gingin, W.A., West Aust. Petrol Co. Seismic shothole B1 at 160 ft.

Fig. 3, 4—*Deflandrea victoriensis* n. sp. (D). Holotype Nat. Mus. Vic. P22986. Frome-Broken Hill Co.'s Port Campbell No. 3 Bore between 4400 and 4410 ft.

Fig. 5—*Deflandrea victoriensis* n. sp. (D). Port Campbell No. 3 Bore between 4400 and 4410 ft.

Fig. 6, 7, 8—*Deflandrea victoriensis* n. sp. Frome-Broken Hill Co.'s Pretty Hill Bore No. 1 at 2726-2734 ft. 6, 7, the same specimens at two foci (V); 8, another example (V).

Fig. 9, 10, 11—*Deflandrea micracantha* Cookson and Eisenack (V). Near Carnarvon, W.A., Brickhouse Bore between 435 and 715 ft.

23

THE TAXONOMIC STATUS OF *Dasyurus affinis* McCOY [1865] (DASYURIDAE) AND *Hypsiprymnus trisulcatus* McCOY [1865] (MACROPODIDAE), TWO MARSUPIALS FROM A HOLOCENE CAVE DEPOSIT NEAR GISBORNE, VICTORIA

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With Appendix by Edmund D. Gill

National Museum of Victoria

Abstract

Dasyurus affinis McCoy [1865] and *Hypsiprymnus trisulcatus* McCoy [1865] are recorded as junior synonyms of *Dasyurops maculatus* (Kerr 1792) and *Potorous tridactylus* (Kerr 1792), respectively. Some comments are made on the identity of a further 3 species, not specifically identified by McCoy, but included by him in his list of mammals from the Gisborne Bone Cave. Identification of these species is not effected. The year of issue of McCoy's list of mammals from the Bone Cave is stated by D. E. Thomas in a private communication to be 1865. The origin and age of the Bone Cave is discussed by Edmund D. Gill in an Appendix. The age of the Bone Cave is recorded by him as Holocene.

Introduction

Two species, *Dasyurus affinis* McCoy and *Hypsiprymnus trisulcatus* McCoy, were erected by a note on the Geological Survey of Victoria Quarter Sheet 7 NW. when, in a list of mammals from the Bone Cave (Mt Macedon Cave (Etheridge 1878); Gisborne Cave (Chapman 1930)), in Bone Cave Ravine at the head of Toolam Toolern Ck, 5 miles S. by E. from Gisborne, McCoy recorded '*Dasyurus affinis* (McCoy) New Species nearly as large as *D. maculatus* but differing in proportions' and '*Hypsiprymuus trisulcatus* (McCoy) a New Species a little smaller than the living *H. minor* and having only 3 sulci on large premolar in the lower jaw'.

The date of publication of McCoy's list has been in doubt (*vide* Gill 1953a, p. 163); however, in a private communication to the author, dated 18 December 1958, Dr D. E. Thomas, Chief Government Geologist, Department of Mines, Victoria, provided the following information:

> 'The Quarter Sheet had not been published by March 1861 when it was still in course of preparation, but had been published before the 30th June 1862. This edition did not contain the drawings of the caves and the fossil list which was issued in 1865. By 31st December 1865, 31 copies had been issued gratuitously but no sales had been made. The main distribution, however, was on 16th February 1865.'

A note on the Bone Cave contained in a letter dated 'Geological Survey Office, Melbourne, 14 Feb. 1859' and written by A. R. C. Selwyn (Selwyn 1860), recorded:

> 'The only other interesting discovery of the Survey here is the Bone-cave at Gisborne, about 25 miles north of Melbourne. Enclosed is a sketch of the locality, also a plan and section on true scale from actual measured survey (see figs. 1, 2 & 3). In it, imbedded in light powdery and perfectly dry soil, we found great quantities of the osseous remains of Birds and Mammals; the most remarkable being perfect skulls of the Dingo, the Devil of Tasmania, and another carnivorous animal, which M'Coy thinks is quite a new genus: the skull is in shape somewhat similar to that of a domestic cat, but not more than half the size; and there are only two molars. The roof and sides of the passages, where narrow,

> were quite smoothed and polished, evidently from the frequent passage of the animals that have inhabited the cave. When discovered, all these passages were so completely filled up with earthy matter, that no animal much larger than a rat could have obtained entrance; when cleared out, some of them were four feet high. The above would, I think, prove our basaltic lava-flows, in which the cave occurs, and which rest on the older gold-drifts, to be very old Pliocene. The bones are being figured and described by M'Coy.'

FIG. 1—Locality Map, Victoria.

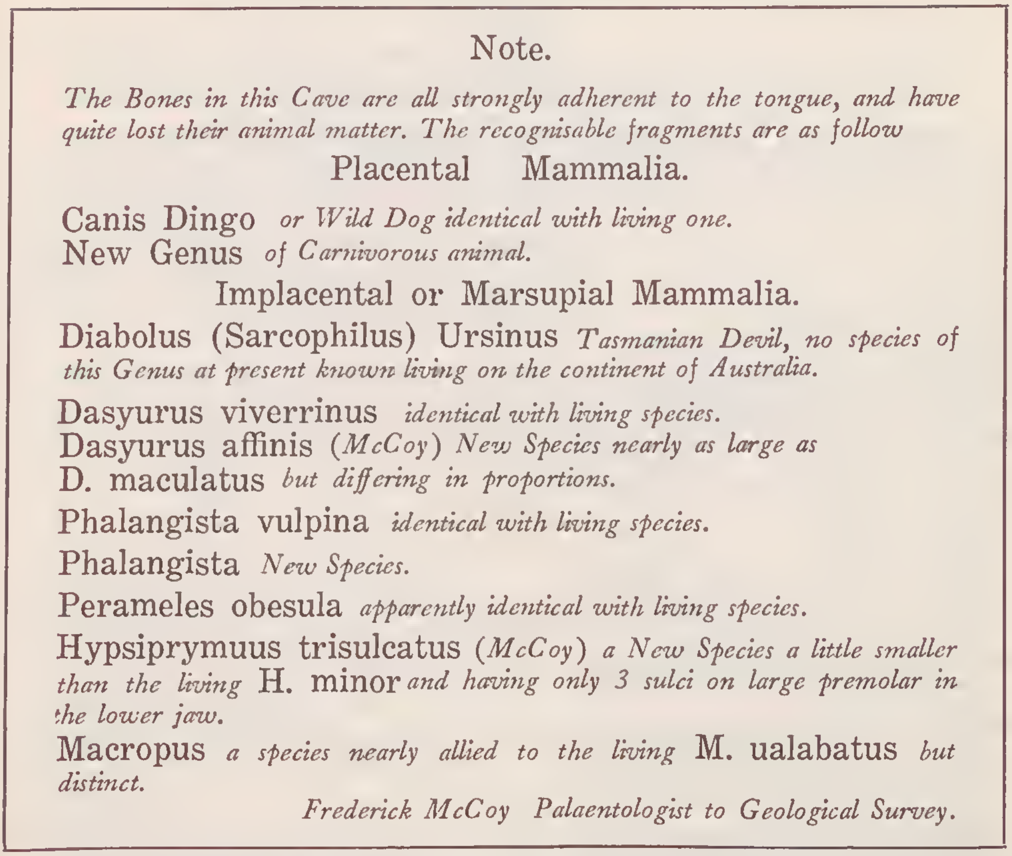
No further description of *D. affinis* or *H. trisulcatus* has appeared in the literature but two syntypes of the former (Nat. Mus. Vict. No. P7425-6) have been figured by Gill (1953a, Pl. 1, fig. 1-9). Also figured from this site (McCoy 1882, Pl. 61, fig. 1, 1a, 3, 3a, 4, 5, 5a) are the fragmentary left mandibular ramus of *Sarcophilus harrisii* (NMV No. P1857) and 3 cranial fragments of *Canis familiaris* (NMV No. 7443, P7447-8)*. A further 4 fragments from the Bone Cave (NMV No. P7427-30)** referred by Gill (1953b, p. 88) to *Thylacinus cynocephalus* belong, not to *Thylacinus*, but to *Canis familiaris*. McCoy's list has been emended by Mahony (1912) and by Chapman (1930) but these authors did not discuss the status of *D. affinis* or *H. trisulcatus*.

[* P7448 is recorded by Gill (1953a, p. 163) as P1488.]
[** These specimens are recorded by Gill (1953b, p. 88) as P7427-1430.]

The two syntypes of *D. affinis* and the figured specimens of *S. harrisii* and *C. familiaris* are the only Bone Cave material, definitely known to have been handled by McCoy, that can now be traced. Specimens from this site are not represented in the collections of the Department of Mines, Victoria, or in those of the Department of Geology and Mineralogy, University of Melbourne. The possibility of finding additional material at the site itself is remote. However, there is a small collection of Bone Cave material in the National Museum of Victoria (NMV), in addition to the specimens mentioned above. This collection was made, in part, by the Geological Survey of Victoria and may contain material examined by McCoy. Observations made on the NMV Bone Cave collection are presented in this paper.

Dasyurus affinis McCoy

Two specimens, P7425-6, are entered in the Palaeontological Register of the National Museum of Victoria as '*Dasyurus maculatus*, Kerr', with the note '[These specimens constitute the type (not fig^{d}.) of *D. affinis*, McCoy MS.—see ¼ sheet 7 NW., Geol. Surv. Vic., Note]'. This entry, dated 31 December 1904, was made after McCoy's death and during Mr F. Chapman's tenure of office as Palaeontologist



Note.

The Bones in this Cave are all strongly adherent to the tongue, and have quite lost their animal matter. The recognisable fragments are as follow

Placental Mammalia.

Canis Dingo *or Wild Dog identical with living one.*
New Genus *of Carnivorous animal.*

Implacental or Marsupial Mammalia.

Diabolus (Sarcophilus) Ursinus *Tasmanian Devil, no species of this Genus at present known living on the continent of Australia.*

Dasyurus viverrinus *identical with living species.*
Dasyurus affinis (*McCoy*) *New Species nearly as large as*
D. maculatus *but differing in proportions.*

Phalangista vulpina *identical with living species.*

Phalangista *New Species.*

Perameles obesula *apparently identical with living species.*

Hypsiprymuus trisulcatus (*McCoy*) *a New Species a little smaller than the living* H. minor *and having only 3 sulci on large premolar in the lower jaw.*

Macropus *a species nearly allied to the living* M. ualabatus *but distinct.*

Frederick McCoy Palaentologist to Geological Survey.

Fig. 2—Note by McCoy on the Bone Cave Mammalia, included on some early copies of Geological Survey of Victoria Quarter Sheet 7 NW.

at this museum. Similar information has been provided for a type of *D. affinis* by Mahony (1912), who quoted data recorded on a museum label. A search was made for a manuscript by McCoy on the Bone Cave during preparation of the present paper. Manuscript material of McCoy's could not be found within the University of Melbourne, in the Public Library of Victoria, in the Library of the Department of Mines, Victoria, or in that of the Royal Society of Victoria. A collection of McCoy's notes and correspondence is preserved in the National Museum of Victoria, but no reference to the Bone Cave fauna was found in these writings.

The syntypes, 2 left mandibular rami, fall, both in mensuration and morphology, within the range of variation in *Dasyurops maculatus*. Therefore, *Dasyurus affinis* McCoy [1865] is recorded here as a junior synonym of *Dasyurops maculatus* (Kerr 1792). *D. maculatus* is still found in Victoria (Brazenor 1950). Its occurrence in Victorian cave deposits has been noted by Wakefield (1960, 1963a, 1963b).

A third mandibular ramus of *D. maculatus* (P22841) and 2 edentulous right premaxillae (P17642, P17648) resembling those of this species (P17648 is atypical in that only 3 incisor alveoli are developed) are included in the NMV Bone Cave collection. Mensuration for the 3 Bone Cave mandibular rami and for a mandibular

TABLE 1

Measurements (mm) for 2 syntypes of Dasyurus affinis *McCoy and for 2 comparative left mandibular rami of* Dasyurops maculatus *(Kerr). NMV No. P7425-6, P22841—specimens from the Bone Cave near Gisborne, Victoria. M7659 ♀ Australian Museum specimen from Major's Ck, Braidwood District, N.S.W.*

(Measurements in this Table and in Tables 2 and 3 were taken by vernier calipers graduated to read to 0·05 mm; tooth measurements do not include roots; measurements for alveoli have been taken at the level of the alveolar border.)

	D. affinis P7425 Syntype	*D. affinis* P7426 Syntype	*D. maculatus* P22841	*D. maculatus* M7659♀
Length of mandibular ramus	69 approx.	73 approx.	59 approx.	74
Mandibular depth measured labially below tip of bone between roots of M_1 ..	9·9	10·7	7·5	10·6
Mandibular depth measured labially below tip of bone between roots of M_3 ..	10·9	11·9	8·4	11·9
Mandibular depth measured below alveolar border at posterior extremity of M_4	10·6	11·2	8·3	10·4
Width of mandibular ramus at anterior extremity of M_2	4·4	4·4	3·6	4·4
Width of mandibular ramus at posterior extremity of M_4	5·4	5·4	4·1	5·5
Width of mandibular ramus measured from labial edge of masseteric flange to lingual edge of angular process with coronoid process held vertical	16 approx.			17
Minimum length from anterior edge of mandibular foramen to posterior margin of mandibular ramus	8·3	6·9		9·7
Height of coronoid process measured lingually above level of alveolar border	18 approx.	20 approx.		22
Angle of slope of anterior edge of coronoid process measured from line joining labial edges of alveoli of M_3	115°	122°	115°	125°
Angle of slope of inferior border of symphysis measured from alveolar border	31°	34°	35°	40°
Length from anterior extremity of alveolus of I_1 to posterior extremity of M_4 ..	42 approx.	40 approx.	37	42
Length from anterior extremity of alveolus of anterior root of P_1 to posterior extremity of M_4	34	32	30	34
Length of incisor alveoli		3·3 approx.	3·8 approx.	4·0
Length from anterior extremity of alveolus of anterior root of P_1 to posterior extremity of alveolus of posterior root of P_3	9·7	8·8	7·7	9·2
Length from anterior extremity of alveolus of anterior root of P_1 to posterior extremity of alveolus of posterior root of P_1	4·3	4·3	3·6	4·4
Length from anterior extremity of alveolus of anterior root of P_3 to posterior extremity of alveolus of posterior root of P_3	4·5	4·4	4·1	4·8
P_1 Length × width			3·7×1·8	3·9×2·0
P_3 Length × width			4·0×2·0 approx.	4·2×2·3
M_1 Length × width	5·0×3·0	4·8×3·2	4·6×2·9	4·8×3·2
M_2 Length × width	5·9×3·8	5·6×3·8	5·4×3·5	5·8×3·7
M_3 Length × width	6·5×3·9	6·3×4·0	6·1×3·6	6·5×3·8
M_4 Length × width	6·9×3·9	6·3×3·8 approx.	6·3×3·5	6·7×3·8
M_{1-4} Length	24·0	22·7 approx.	22·0	23·0

ramus of *D. maculatus* from Major's Ck, N.S.W., is recorded in Table 1. The 4 mandibular rami are figured in Pl. LXXVII.

Hypsiprymnus trisulcatus McCoy

The specimen (or specimens) on which this species was erected cannot be traced. 4 cranial fragments (P17633-5, P22843) and 7 mandibular fragments (P17636-41, P22842) of *Potorous tridactylus* (Kerr 1792) (= *Hypsiprymnus minor* (Shaw 1800)) are included in the NMV Bone Cave collection. The number of sulci developed on the labial and lingual surfaces of P_4 can be accurately determined for 3 of these fragments (P17639-40, P22842), and on the lingual surface alone for a further 3 (P17636-8). 4 sulci are present on P_4 in these specimens; the

TABLE 2

Measurements (mm) for NMV specimens of Potorous tridactylus *(Kerr) from the Bone Cave near Gisborne, Victoria. P17633 fragmentary cranium. P17634–5 fragments from left side of crania. P22843 fragment from right side of cranium. 4 individuals represented.*

	Potorous tridactylus			
	P17633	P17634	P17635	P22843
Length from anterior extremity of intermaxillary suture to basisphenoid–presphenoid suture	47 approx.			
Length from anterior extremity of premaxilla to posterior extremity of interpremaxillary suture		14	12 approx.	
Length of interfacial suture	27			
Length of interparietal suture	15			
Length from labial edge of alveolar border between M^1 and M^2 to frontomaxillolacrymal point	15			
Bizygomatic width	39			
Interorbital width	16			
Width across nasals between nasofrontomaxillary points	11·1			
Width of palate between alveoli of antero-internal roots of M^2	12·8			
Length of diastema between I^3 and C ..		2·5	3·1	
Length of diastema between C and P^4 ..	6·2	5·0	6·5	6·7
Length from posterior extremity of alveolus of I^3 to anterior extremity of alveolus of P^4		11·5	12·6	
Length from anterior extremity of alveolus of I^1 to posterior extremity of alveolus of M^4			44	
Length from anterior extremity of alveolus of I^1 to posterior extremity of alveolus of I^3		8·7	7·9	
Length from anterior extremity of alveolus of P^4 to posterior extremity of alveolus of M^4	24		24	
I^2 Length × width		2·8 × 1·6		
P^4 Length × width		7·3 × 3·2		6·9 × 2·8 approx.
M^1 Length × width	4·2 × 3·6	4·4 × 3·7	4·3 × 3·8	4·1 × 3·6
M^2 Length × width	4·5 × 4·1	4·6 × 4·0	4·7 × 4·1	4·4 × 3·9
M^3 Length × width	4·7 × 3·9	4·5 × 3·9	4·7 × 3·8	4·6 × 3·7
M^{1-3} Length	13·4	13·5	13·5	12·9

posterior sulcus is typically not as well defined as the more anteriorly placed sulci and is susceptible, on the labial surface of the tooth, to early obliteration by wear. A smaller number of sulci are developed, however, on P_4 in some individuals of *P. tridactylus.* A male *P. tridactylus* (NMV No. R7725) from near Wynyard, NW. Tasmania has 3 sulci on P_4 while only 2 sulci are present on P_4 of a female *P. tridactylus* (NMV No. R8370) from Clark Is., Bass Strait. It is clear, then, that the presence of 3 sulci on P_4 of *H. trisulcatus* does not distinguish this species from *P. tridactylus.*

On the evidence available, discrimination between *H. trisulcatus* and *P. tridactylus* is untenable and *Hypsiprymnus trisulcatus* McCoy [1865] is recorded here as a junior synonym of *Potorous tridactylus* (Kerr 1792). *P. tridactylus* is still found in Victoria (Brazenor 1950). It has been recorded from Victorian cave deposits by Wakefield (1960, 1963a, 1963b). Mensuration for the Bone Cave *P. tridactylus* is recorded in Tables 2 and 3. Specimens of it are figured in Pl. LXXVIII.

TABLE 3

Measurements (mm) for NMV specimens of Potorous tridactylus (*Kerr*) *from the Bone Cave near Gisborne, Victoria. P17636–8, P17641, P22842 left mandibular rami. P17639–40 right mandibular rami. Seven individuals represented.*

	Potorous tridactylus						
	P17641	P17640	P17639	P17638	P17637	P17636	P22842
Mandibular depth measured labially below tip of bone between roots of M_1 ..		7·2	8·0	8·0	8·4	8·2	6·7
Mandibular depth measured labially below tip of bone between roots of M_3 ..				8·1	8·5		
Width of mandibular ramus at anterior extremity of M_1 ..		4·0	3·9	4·8	4·5	3·9	4·0
Width of mandibular ramus at posterior extremity of M_3 ..				6·0	5·7		
Length of diastema		4·5	6·0	6·3			
P_3 Length × width ..	3·8×2·0	3·4×1·8					
dP_4 Length × width ..		3·4×2·2					
P_4 Length × width ..			6·1×2·7	6·3×2·6	6·2×2·8	6·1×2·4	5·9×2·4
M_1 Length × width ..		4·4×3·0	3·8×2·8	4·1×3·2	4·1×3·1	3·6×3·0	4·0×—
M_2 Length × width ..		4·7×3·2	4·3×3·2	4·7×3·5	4·7×3·5	4·3×3·5	4·5×3·4
M_3 Length × width ..				4·8×3·5	4·7×3·5	4·4×3·6	4·7×3·5
M_4 Length × width ..					4·4×3·3	4·3×3·2	4·0×3·1
P_4–M_4 Length					23·1	22·3	22·4
M_{1-4} Length					17·5	16·4	16·9

Other Observations

A further two animals, designated new in McCoy's list, are neither named nor described, and their identity cannot now be determined. However, the mammalian remains in the NMV Bone Cave collection belong to a modern fauna (*Sarcophilus harrisii*, now confined to Tasmania, has only recently become extinct in Victoria, a radiocarbon date of 538 ± 200 years (before present) having been obtained for an aboriginal kitchen midden, containing remains of this species, at Koroit Beach in W. Victoria (Gill 1953b)) and, as extinct Quaternary mammals found elsewhere are not included in McCoy's list, McCoy's collection possibly consisted of modern species only; identification of his two unnamed animals as new might have resulted from incomplete comparison with species already known. The Bone Cave, itself, postdates the Pleistocene in its development (*vide* Appendix) and the Bone Cave fauna is Holocene in age.

A brief description of McCoy's new genus is given by Selwyn (*vide supra*). The only Australian placental mammals, other than *Canis* (and *Vulpes*) with 2 molars in each maxillary row, belong in the *Megachiroptera,* a species of which, *Pteropus poliocephalus*, has been recorded from Victoria (Brazenor 1950), and in the *Hydromyinae,* also with a species, *Hydromys chrysogaster*, known from Victoria (Brazenor 1950). It might be, however, that Selwyn was referring to the presence of but one molar in each maxillary row. This molar count is found in the introduced domestic cat *Felis catus* and in *Putorius* skeletal remains of which were recorded by Wakefield (1963a) from the main lava cave at Mt Hamilton, 110 miles W. of Melbourne. These mammals, with the exception of *Canis*, were not identified in the NMV Bone Cave collection. Although the identity of McCoy's genus cannot be resolved here, it appears likely that his determination was in error as he makes no mention of this animal in his later publications on Victorian mammals.

The identity of McCoy's *Phalangista* is also unknown. Modern phalangerids are represented in the NMV Bone Cave collection; possibly, one of these is McCoy's 'New Species'.

Unnamed, and again of uncertain identity, is the species of *Macropus* 'nearly allied to the living *M. ualabatus* but distinct'. Recognizable remains of *Wallabia bicolor* (Desmarest 1804) (= *Macropus ualabatus* (Lesson and Garnot 1827)) are not included in the NMV Bone Cave collection. However, this species is found in Victoria (Brazenor 1950) and, here again, McCoy might have confused individual with specific variation in discriminating between *W. bicolor* and the Bone Cave macropod.

Conclusions

Available evidence supports the view that McCoy's fauna was modern. The presence of new mammals in McCoy's Bone Cave collection has not been satisfactorily demonstrated; *D. affinis* and *H. trisulcatus*, erected by him on Quarter Sheet 7 NW., are junior synonyms. The most perplexing problem is that of the identity of McCoy's new genus of carnivorous placental. This animal might have been the domestic cat. A false conception of the antiquity of his material might have led McCoy to believe that the cat could not be included in his Bone Cave collection.

Acknowledgements

I am endebted to Mr Edmund D. Gill, Curator of Fossils, National Museum of Victoria, for facilitating my examination of the NMV Bone Cave collection. Messrs R. Wilkins and D. Woodruff assisted Mr Gill and me in an examination of the Bone Cave. For the loan of comparative material, I wish to thank Mr C. W. Brazenor, Director (since retired) of the National Museum of Victoria, and Dr J. W. Evans, Director of the Australian Museum. Valuable information has been provided by Dr D. E. Thomas, Chief Government Geologist, Department of Mines, Victoria. The absence of Bone Cave specimens in the collections of the Department of Geology and Mineralogy, University of Melbourne was confirmed for me by the Curator, Mr A. A. Baker. Negatives of the syntypes of *D. affinis* and prints of McCoy's list of mammals, included on some early copies of Quarter Sheet 7 NW., were provided by Mr Gill and Dr Thomas respectively. The rest of the photography was done by the Department of Illustration, University of Sydney. Correspondence

containing information recorded in this paper has been placed in the archives of the National Museum of Victoria.

References

BRAZENOR, C. W., 1950. The mammals of Victoria and the dental characteristics of monotremes and Australian marsupials. *Nat. Mus. Vict. Handbook* 1.

CHAPMAN, F., 1930. Australian cave faunas. *Vict. Nat.* 47 (6): 99-100.

ETHERIDGE, R., Jr., 1878. *A Catalogue of Australian Fossils*. Cambridge.

GILL, E. D., 1953a. Catalogue of Quaternary types and figured specimens in the National Museum, Melbourne. *Mem. Nat. Mus. Melbourne* 18: 157-168.

————, 1953b. Distribution of the Tasmanian devil, the Tasmanian wolf, and the dingo in SE. Australia in Quaternary time. *Vict. Nat.* 70 (5): 86-90.

IREDALE, T., and TROUGHTON, E. Le G., 1934. A check-list of the mammals recorded from Australia. *Mem. Aust. Mus.* 6.

MAHONY, D. J., 1912. On the bones of the Tasmanian devil and other animals, associated with human remains near Warrnambool: with a note on the dune sand. *Vict. Nat.* 29 (3): 43-46.

McCOY, F., 1865. Note. Quarter Sheet 7 NW. (Mt. Aitken). *Geol. Surv. Vict.*

————, 1882. Prodromus of the palaeontology of Victoria, Dec. 7. *Geol. Surv. Vict.*

SELWYN, A. R. C., 1860. Notes on the geology of Victoria. *Quart. Journ. Geol. Soc. Lond.* 16: 145-150.

SIMPSON, G. G., 1930. *Fossilium catalogus 1: Animalia. Post-Mesozoic Marsupialia*. 47. (Ed. J. F. Pompeckj). W. Junk: Berlin.

WAKEFIELD, N. A., 1960. Recent mammal bones in the Buchan district—1. *Vict. Nat.* 77 (6): 164-178.

————, 1963a. Sub-fossils from Mount Hamilton, Victoria. ibid. 79 (11): 323-330.

————, 1963b. Mammal sub-fossils from near Portland, Victoria. ibid. 80 (2): 39-45.

Appendix

AGE AND ORIGIN OF THE GISBORNE CAVE

By EDMUND D. GILL
Curator of Fossils, National Museum of Victoria

The Gisborne Cave was formed during the Holocene Period, and is unusual in origin. It has been excavated in basaltic tuff which lies between bedrock of Upper Ordovician siltstone (Harris and Crawford 1921), and a thick flow or flows of olivine basalt. Quarter Sheet 7 NW. of the Geological Survey shows the site of the cave, its ground plan, and a geological section (which does not include the tuff).

Volcanics

The tuff is clayey through partial decomposition. It contains, especially near the base, pieces of basalt (volcanic bombs). The tuff with coarse ejectamenta suggests the point of eruption was not far away. Dr A. W. Beasley, Curator of Minerals, National Museum of Victoria, examined this material and confirmed its tuffaceous nature. A rounded 'pebble' of basalt about 4 in. in diameter selected from the lower part of the tuff was submitted to Dr A. B. Edwards and Dr G. Baker who determined it as a Newer Basalt, probably of the Gisborne type. The overlying flow or flows are mapped as being of this type (Edwards and Crawford 1940), which is one of the commonest in the district.

Origin of the Cave

The cave is excavated in clayey tuff, but not by water erosion. It appears to have been dug out by fossorial animals. Wetting and drying effects, and wind erosion, have modified the entrance to the cave, and the part of the cliff face formed of tuff. After the somewhat large entrance, the cave consists of a number of anastomosing tunnels and the direction of these appears to be controlled only by the occurrence of any heavy ejectamenta.

Age

The Gisborne Cave is on the E. side of a steep gully which is one of the headwaters of the Toolern Ck where it is back-cutting into the Gisborne Highlands. The gully, therefore, is one of the very youngest waterways. The thalweg is very steep, the contours on the Military Map (Sunbury Sheet) indicating a declivity of the order of 1 in 5 in the vicinity of the cave. The stream has only recently exposed the tuff at the cave site, so the cave cannot be of any great antiquity. The Keilor Terrace was built from about 20,000 years ago to about 6,000 years ago, as shown by radio-carbon dates. Consideration of the relationship of these sediments and those of the succeeding Maribyrnong Terrace to young valleys, leads to the conclusion that the time when the tuff band was fully exposed at the cave site (so making cave formation possible) was later than Pleistocene, and until more detailed dating is done in the area, the age of the cave has to be given simply as Holocene.

References

Crawford, W., 1940. The physiography of the Gisborne Highlands. *Proc. Roy. Soc. Vict.* 52: 262-280.

Edwards, A. B., and Crawford, W., 1940. The Cainozoic volcanic rocks of the Gisborne district. ibid. 52: 281-311.

Harris, W. J., and Crawford, W., 1921. The relationships of the sedimentary rocks of the Gisborne district, Victoria. ibid. 33: 39-78.

Explanation of Plates

Plate LXXVII

Fig. 1-4—*Dasyurus affinis* McCoy. (1) P7425 (Syntype), lingual view; (2) labial view; (3) P7426 (Syntype), lingual view, (4) labial view.

Fig. 5-8—*Dasyurus maculatus* (Kerr). (5) P22841, lingual view, (6) labial view; (7) M7659 ♀, lingual view, (8) labial view.

Fig. 9, 10—*Dasyurus affinis* McCoy. (9) P7425 (Syntype), occlusal view; (10) P7426 (Syntype), occlusal view.

Fig. 11, 12—*Dasyurops maculatus* (Kerr). (11) P22841, occlusal view; (12) M7659 ♀, occlusal view.

P7425-6, P22841 NMV specimens from the Bone Cave near Gisborne, Victoria. M7659 ♀ Australian Museum specimen from Major's Ck, Braidwood District, N.S.W. Magnification × 1·0 approx.

Plate LXXVIII

Fig. 1-14—*Potorous tridactylus* (Kerr). (1) P17633, dorsal view, (2) palatal view, (3) lateral view; (4) P17634, palatal view, (5) lateral view; (6) P17641, occlusal view; (7) P17640, occlusal view; (8) P17639, occlusal view; (9) P17636, occlusal view; (10) P17638, labial view, (11) occlusal view, (12) lingual view; (13) P22842, occlusal view; (14) P17641, lingual view.

NMV specimens from the Bone Cave near Gisborne, Victoria. Note fused dP_4M_1 and alveolus of single rooted tooth between I_1 and P_3 in P17641. Fig. 1-5, 10-14 × 1·0 approx.; Fig. 6-9 × 2·0 approx.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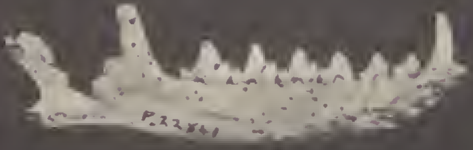

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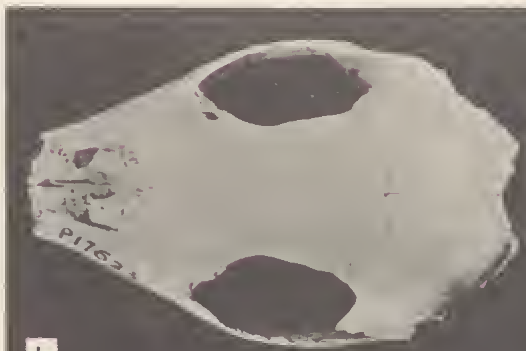

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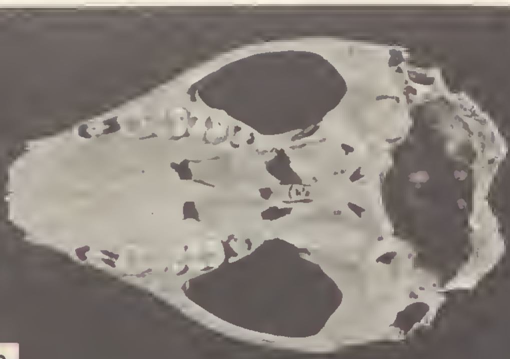

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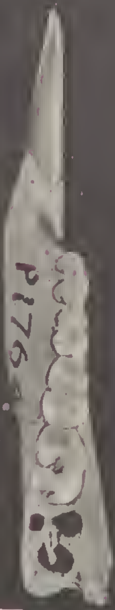

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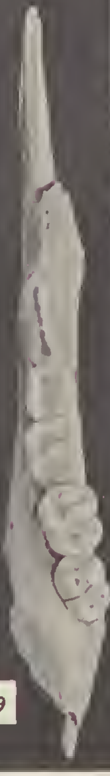

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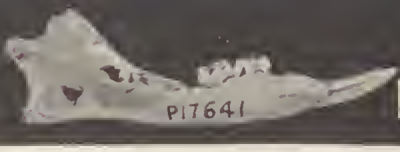

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FORAMINIFERA AND THE STRATIGRAPHY OF THE WESTERN VICTORIAN CRETACEOUS SEDIMENTS

By D. J. Taylor

Department of Mines, Melbourne, Victoria

Abstract

This paper gives the results of a detailed examination of the foraminiferal faunas of the W. Victorian Cretaceous rocks. The study is based on bore material, as the marine Cretaceous rocks have not been recognized from outcrop in Victoria. Primarily the study was taxonomic, but an analysis of the vertical and lateral distribution of species resulted in the establishment of a stratigraphic framework and a depositional history of the sediments.

Marine Cretaceous sedimentation commenced in the Cenomanian or Turonian (Upper Cretaceous) with the deposition of detrital material. Foraminifera are not present at the base of the section, probably because of deleterious chemical conditions. With the deposition of finer grained dark mudstones, Foraminifera appear and the species present indicate a Turonian age. These Turonian sediments are limited in areal distribution and the faunas are inhibited by anaerobic conditions due probably to restriction of water circulation, under 'barred basin conditions'. Dark mudstone deposition continued into the Senonion and the areal extent of the deposits increased. The highest dark mudstones contain planktonic faunas and uninhibited benthonic faunas suggesting that water circulation was not restricted, probably due to the removal of off-shore barriers. Contemporaneously with the deposition of the Senonian dark mudstone, marginal-marine sands and silts were deposited closer to the shoreline. Interdigitation between the dark mudstone and the marginal-marine deposits is apparent. The known depositional area was inundated with marginal-marine deposits in the middle Senonian (Santonian). This marginal-marine deposition continued into the lower Tertiary, without apparent break. In some sections, 2,000 ft of sediment is barren of fauna between the Upper Cretaceous (Santonian) and Lower Tertiary (Paleocene and lower Eocene) faunas. All the marine and marginal-marine Upper Cretaceous sediments are regarded as being of paralic origin.

The structural configuration of the unconformably underlying Otway Group controlled the transgressive Upper Cretaceous sedimentation. Faulting and warping initiated Upper Cretaceous sedimentation and continued contemporaneously with it and Lower Tertiary sedimentation.

53 species of Foraminifera are described and illustrated. The following new species are erected: *Allomorphina pyriformis, Ceratobulimina kremnoides, Colomia austrotrochus, Gyroidinoides cruachin, Pallaimorphina heliciformis* and *Textularia trilobita.*

Introduction

No Cretaceous sediments were recognized in Victoria until 10 years ago when Kenley and others collected angiosperm leaves from the Runnymede Formation (highest unit of the Mesozoic Merino Group of the Casterton area—Kenley 1954). Baker and Cookson (1955) reported the presence of Upper Cretaceous microplankton from the 'Nelson Bore' (Glenelg No. 1—near the South Australian border). Further palynological work led Cookson (in Cookson & Dettmann 1958) to believe that the non-marine Mesozoic sediments, outcropping in W. Victoria, were of Lower Cretaceous age. These rocks had always been regarded as Jurassic in age.

No Mesozoic marine faunas had been found until the Victorian Mines Department drilled the Belfast No. 4 Bore at Port Fairy. From this bore, a core contained a molluscan fauna which was recognized by Kenley (1959) as being of Upper Cretaceous age. 10 subsequent bores have penetrated marine or-marginal marine Cretaceous sediments at depth below 2,000 ft. Douglas (1960) and Cookson &

Eisenack (1961) have studied the microplankton content in the Upper Cretaceous sediments from some of these bores.

This study is based on the distribution of Upper Cretaceous Foraminifera in all bores drilled in W. Victoria. The results are divided into two parts. Part A deals with the depositional history of the sediments which contain Upper Cretaceous Foraminifera, while in Part B the species of Foraminifera are described.

Acknowledgements

This study is part of the Victorian Mines Department's investigations into the underground water and petroleum potentialities in W. Victoria.

The author expresses his gratitude to Dr D. E. Thomas, Director of the Geological Survey, for his supervision, encouragement, and permission to publish the results of this study. The author benefited greatly from discussions with many of his colleagues in the Geological Survey, especially those with Mr R. C. Glenie and Mr P. E. Bock on the sub-surface stratigraphy of the W. District. Dr J. A. Talent, Mr J. B. Hocking, and Mr Glenie assisted in many matters connected with the preparation of the final manuscript.

The close co-operation of the management and geological staff of Frome-Broken Hill Co. Pty Ltd was an essential feature of this study. Advice and information provided by A. F. McQueen and S. Benedek (company geologists) was most helpful.

The author is extremely grateful for the guidance given him by Dr M. F. Glaessner of the University of Adelaide, and appreciates his detailed reading of the original manuscript. Dr B. McGowran made many valuable comments on the original manuscript and he and Dr Mary Wade answered many queries sent to them at Adelaide.

Mrs I. G. Knight assisted the author at all stages of this work. Her detailed camera lucida drawings were invaluable for specific identification and are an essential part of this text. The author is deeply indebted for her assistance and interest.

The final drafting of the figures was done by the Drafting Branch of the Mines Department.

The Mines Department assisted financially in the production of this paper.

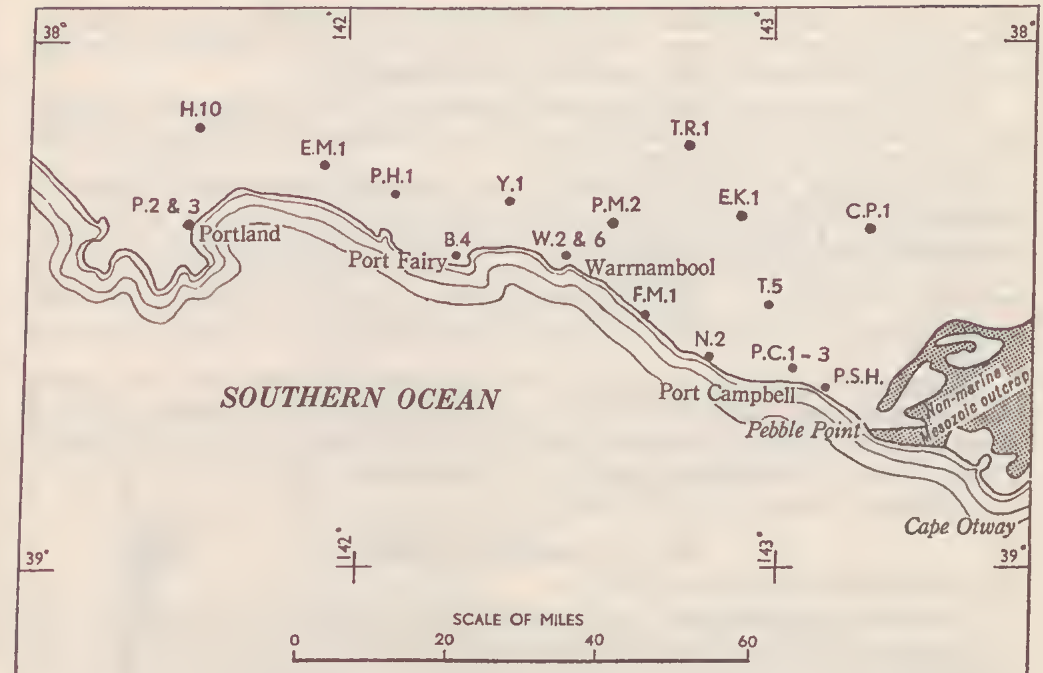
Localities and Sampling Methods

Marine Cretaceous sediments occur at depth along the coastal strip in W. Victoria extending from Port Campbell W. to Portland (see Fig. 1) which is within the Portland Sunkland as defined by Boutakoff (1952). The marine Cretaceous has not been reported more than 10 miles inland from the present coastline and is not recorded at less than 2,000 ft below sea level.

There is only one reported occurrence of the Victorian marine Cretaceous W. of Portland. This is in the 'Nelson Bore' (Glenelg No. 1). The 'Nelson Bore' has not been examined by the author as it is felt that the little remaining material from this bore should be preserved, especially as Crespin (1954) found no Cretaceous Foraminifera in the samples. Other aspects of the 'Nelson Bore' sediments have been published (Baker & Cookson 1955, Douglas 1960, Baker 1961).

The bores examined are those drilled in the Western District Basin before May 1963.

The bores are tabulated and positioned on Fig. 1. The term 'well' implies drilling in search of petroleum, while the term 'bore' is used for all other drilling. The plural 'bores', without geographic prefixes, is used collectively implying all bores and wells mentioned. Unless specified, all depths mentioned are 'drilled depth'



BORES EXAMINED
MARINE CRETACEOUS PRESENT

H.10	— *Heywood No.10 (V.M.D.)*
E.M.1	— *Eumeralla No 1 (F. - B.H.)*
P.H.1	— *Pretty Hill No.1(F. - B.H.)*
B.4	— *Belfast No.4 (V.M.D.)*
Y.1	— *Yangery No.1 (V.M.D.)*
W.2	— *Wangoom No.2 (V.M.D.)*
W.6	— *Wangoom No.6 (V.M.D.)*
F.M.1	— *Flaxman's No.1 (F. - B.H.)*
N.2	— *Narrawaturk No.2 (V.M.D.)*
P.C.1	— *Port Campbell No.1 (F. - B.H.)*
P.C.2	— *Port Campbell No.2 (F. - B.H.)*
P.C.3	— *Port Campbell No.3 (F. - B.H.)*

BORES EXAMINED
NO MARINE CRETACEOUS RECOGNISED

P.2	— *Portland No.2 (V.M.D.)*
P.3	— *Portland No.3 (V.M.D.)*
P.M.2	— *Panmure No.2 (V.M.D.)*
T.R.1	— *Terang No.1 (V.M.D.)*
E.K.1	— *Ecklin No.1 (V.M.D.)*
T.5	— *Timboon No.5 (V.M.D.)*
C.P.1	— *Carpendeit No.1 (V.M.D.)*
P.S.H.	— *Princetown Shot Hole (F. - B.H.)*

F.-B.H. Oil search well drilled by Frome-Broken Hill Co.

V.M.D.— Water bore drilled by Victorian Mines Department

FIG. 1—Bore locality map W. Victorian coast.

which have not been adjusted to sea level. Ground level is the datum taken in Mines Department water bores, while the height of the kelly bushing (above sea-level) is taken as datum in the Frome-Broken Hill wells.

The limiting factors in this study were the position of bores, rig capacity, coring interval and rotary cutting contamination. Economic factors dictated the positions of bores and did not lead to pattern drilling.

Port Campbell No. 2 is established as the standard section of the Cretaceous foraminiferal sequence as is known at present in Victoria. This is because the samples provided adequate information, the sequence is at its thickest (2,600 ft), and there is no facies interfingering to interfere with foraminiferal distribution. The well was 'side-tracked' at 5,600 ft giving another section below 7,000 ft with better samples than those of the 'first cut' hole. Information from both holes have been combined.

Because of difficulties in preparing the indurated mudstones and the varying amounts of samples available, it was not possible to prepare a constant amount of each sample. Therefore, in order to ascertain relative frequencies of species present, 5 trays (9 cm × 5 cm), single spread with residue, were picked. Selective picking was conducted on any remaining residue.

Part A: Depositional History

ROCK STRATIGRAPHY

The non-marine Mesozoic rocks outcrop in the Western District Basin, on the E. margin in the Otway Ra., and on the NW. margin in the Casterton area. The remaining area is covered by Tertiary sediments which are concealed, in part, under late Tertiary to Quaternary basalts and along the coast by Quaternary dune limestones.

The Tertiary sequence is exposed on the E. margin of the area, where 2,790 ft of sediments were measured by Baker (1950, p. 29) along the coast between Pebble Point and Princetown. This section shows an almost complete sequence from the Paleocene to at least middle Miocene. Two broad lithological units can be subdivided in this sequence:

(i) The higher predominantly calcareous unit—The Heytesbury Group.
(ii) The lower predominantly arenaceous and argillaceous unit—The Wangerrip Group.

These units are proposed by Baker (1953, p. 126), who also suggests there is a transitional unit between the two.

The Wangerrip Group is apparently of paralic origin with distinct marine incursions. The Pebble Point Formation is the basal member of the Group and consists of conglomerates and grits with some mud lenses. Above the base of the Formation the grits are fossiliferous (Mollusca and Foraminifera), marking the Paleocene marine transgression mentioned by Glaessner (1959, p. 61). A littoral origin is indicated which may account for the difficulty of recognizing this Formation away from the marginal area.

In outcrop, the Pebble Point Formation rests unconformably on the felspathic sandstones of the Mesozoic Otway Group. However, deep drilling in the Port Campbell area has revealed sediments between the Wangerrip Group and the Otway Group. These sediments have been divided into four units by Bain & McQueen (in press), whose formal definitions are summarized in Fig. 2 in this paper. (A summary is given in McQueen 1961.)

As seen in Fig. 2, the Cretaceous Foraminifera are restricted to the Belfast

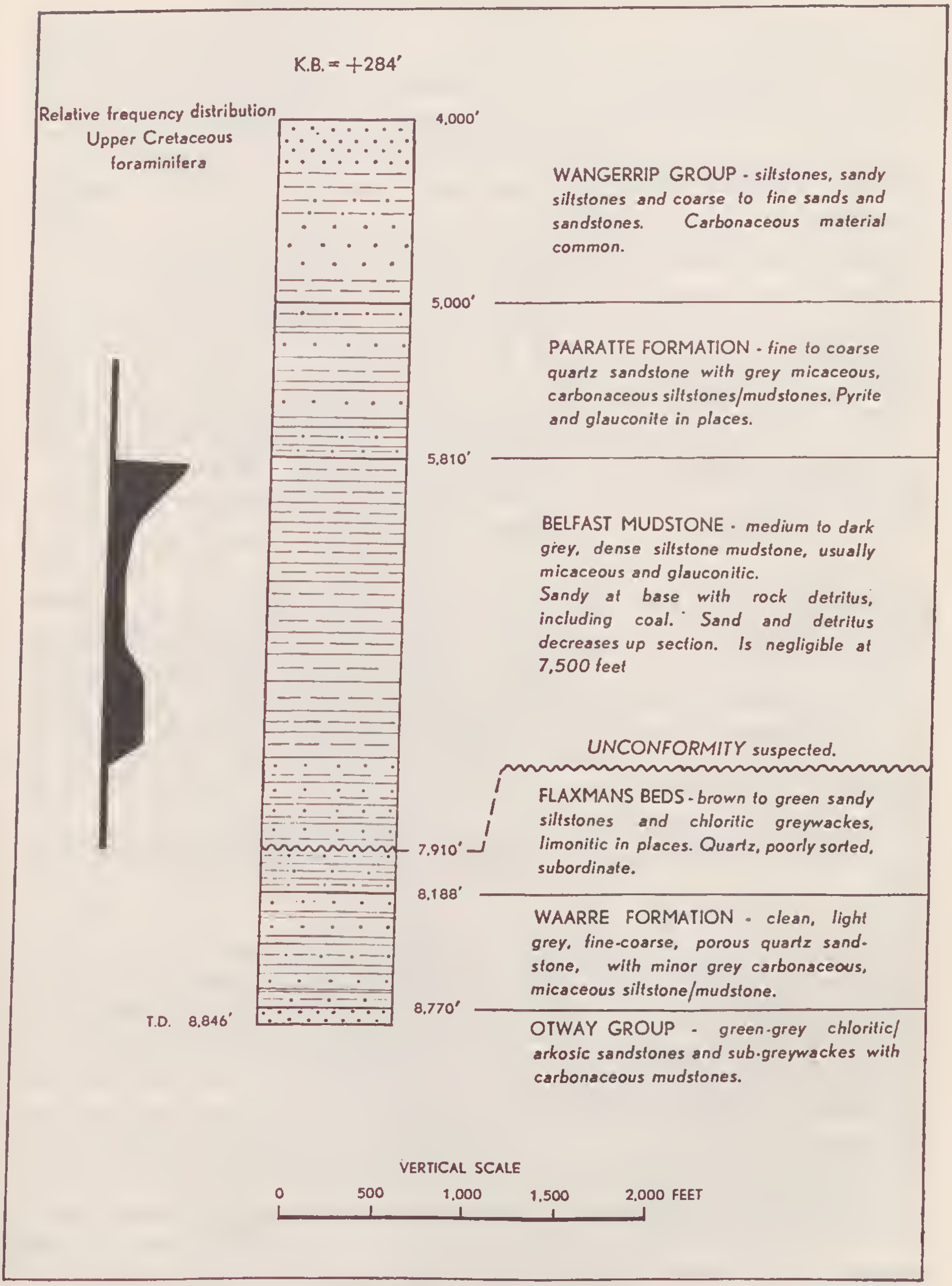


FIG. 2—Rock-stratigraphic column, Port Campbell No. 2 Well.

Mudstone and the Paaratte Formation in the Port Campbell No. 2 section. The frequency diagram in the figure indicates that the Foraminifera are most abundant at the top of the Belfast Mudstone, but rare at the base and also rare in the Paaratte Formation. Although there is a report of Foraminifera below the Belfast Mudstone, the author has not observed any, despite the examination of numerous samples.

The base of the Waarre Formation intergrades with the Otway Group and is considered to be a formation within this group. Although there appear to be disconformities within and at the top of the Flaxmans Beds, it may be best to consider this unit as the result of weathering contemporaneous with the exposure of the older sediments (Otway Group). This marks the beginning of a new cycle of sedimentation which led to the subsequent deposition of the Belfast Mudstone.

There is no evidence of an unconformity between the Belfast Mudstone and the Paaratte Formation. In fact, the upper horizons of the Belfast Mudstone in Port Campbell No. 2 are synchronous with the basal horizons of the Paaratte Formation in other sections (e.g. Port Campbell No. 1 and Flaxmans No. 1). The Paaratte Formation may contain sediments lithologically and palaeontologically similar to the Belfast Mudstone, but separated from it by sandstones and sandy siltstones.

There is no apparent depositional break between the Paaratte Formation and the overlying Wangerrip Group and the lithological break between these units is hardly clear cut. The Cretaceous foraminiferal sequence extends into what is considered as Wangerrip Group in Flaxmans No. 1 Well.

Little is known of the marine Cretaceous sediments W. of Port Fairy. Portland No. 2 and 3 bores ceased drilling while still in Tertiary rocks. Heywood No. 10, Eumeralla No. 1, and Pretty Hill No. 1 revealed thin developments of sediments analagous with the Paaratte Formation and Belfast Mudstone. The sub-surface Tertiary stratigraphy of the Portland area is discussed by Glenie and Reed (1960). To the N. of Portland, the non-marine Mesozoic Merino Group sediments are unconformably overlain by the Bahgallah Formation (Kenley 1951) in the Casterton area. The Bahgallah Formation is similar in lithology and fauna to the Pebble Point Formation. As the Merino Group is equated with the Otway Group, the situation on the exposed NW. margin is identical with that on the E. margin of the basin.

A reappraisal of the Victorian Cretaceous rock stratigraphy is attempted in a later section. This is felt necessary as a result of evidence accumulated in this study.

BIOSTRATIGRAPHY

(a) The fauna

As first reported by Kenley (1959), the Cretaceous marine fauna consists of representatives of the following Groups: Foraminifera, Pelecypoda (*Inoceramus* sp. absent), Schaphopoda, Gastropoda, Pteropoda (?), Ammonoidea, rotularid worm tubes, Echinoidea (plates), and fish remains. This fauna was found near the top of the Belfast Mudstone in Belfast No. 4 Bore between 4649 ft and 4655 ft (cored interval). Even though Cretaceous fossils have been found in 11 other bores, this broad faunal list has not been greatly expanded. Notable additions are 4 species of Ostracoda in many samples, belemnite fragments, *Inoceramus* shell fragments near the base of the Belfast Mudstone, and moulds of a different species of *Inoceramus* in the Paaratte Formation.

Foraminifera are the most abundant, widespread, and specifically diverse element of the fauna. Macro-fossils are sparse within the sequence, but their observation depends on the chance factor of coring. It would appear that the macro-faunas (especially mollusca) are congregated at certain horizons near the top of the Belfast

Mudstone. The exception is *Inoceramus*, which is most abundant in the lower horizons of the Belfast Mudstone.

Arenaceous forms are dominant within the foraminiferal fauna. Calcareous Foraminifera are restricted in distribution and never comprise more than 30% of the total fauna in any one sample. The planktonic foraminiferal fauna is neither specifically rich, nor distributed throughout the sequence.

The Belfast No. 4 core, at 4649 to 4655 ft, contains a rich foraminiferal fauna with species typical of the upper part of the Belfast Mudstone. This fauna is listed below:

Arenaceous Foraminifera: *Ammobaculites* cf. *fragmentaria, Dorothia filiformis, Haplophragmoides* spp. (3 species), *Hyperammina elongata, Marssonella oxycona, Reophax* sp., *Textularia anceps,* and *T. semicomplanata.*

Calcareous Foraminifera: *Alabamina australis, Buliminella* cf. *parvula, Ceratobulimina kremnoides, Cibicides excavatus, C. ribbingi, Frondicularia* sp., *Globulina lacrima, Gyroidinoides cruachin, G. nitida, Hanzawaia californica, Hoeglundina subcretacea, Lenticulina* spp., *Marginulina inaequalis, Nodosaria obscura, N. navarroana, Pallaimorphina heliciformis, Praebulimina ovulum, Quinqueloculina* sp., *Stilostomella alexanderi, Valvulineria undulata, V. erugata.*

Planktonic Foraminifera: *Guembelina reusii* and *Hedbergella trocoidea.*

The lower levels of the Belfast Mudstone (as present in Port Campbell No. 2) contain some of the above species, together with such restricted species as *Colomia austrotrochus, Gavelinopsis cenomanica,* and *Textularia trilobita.*

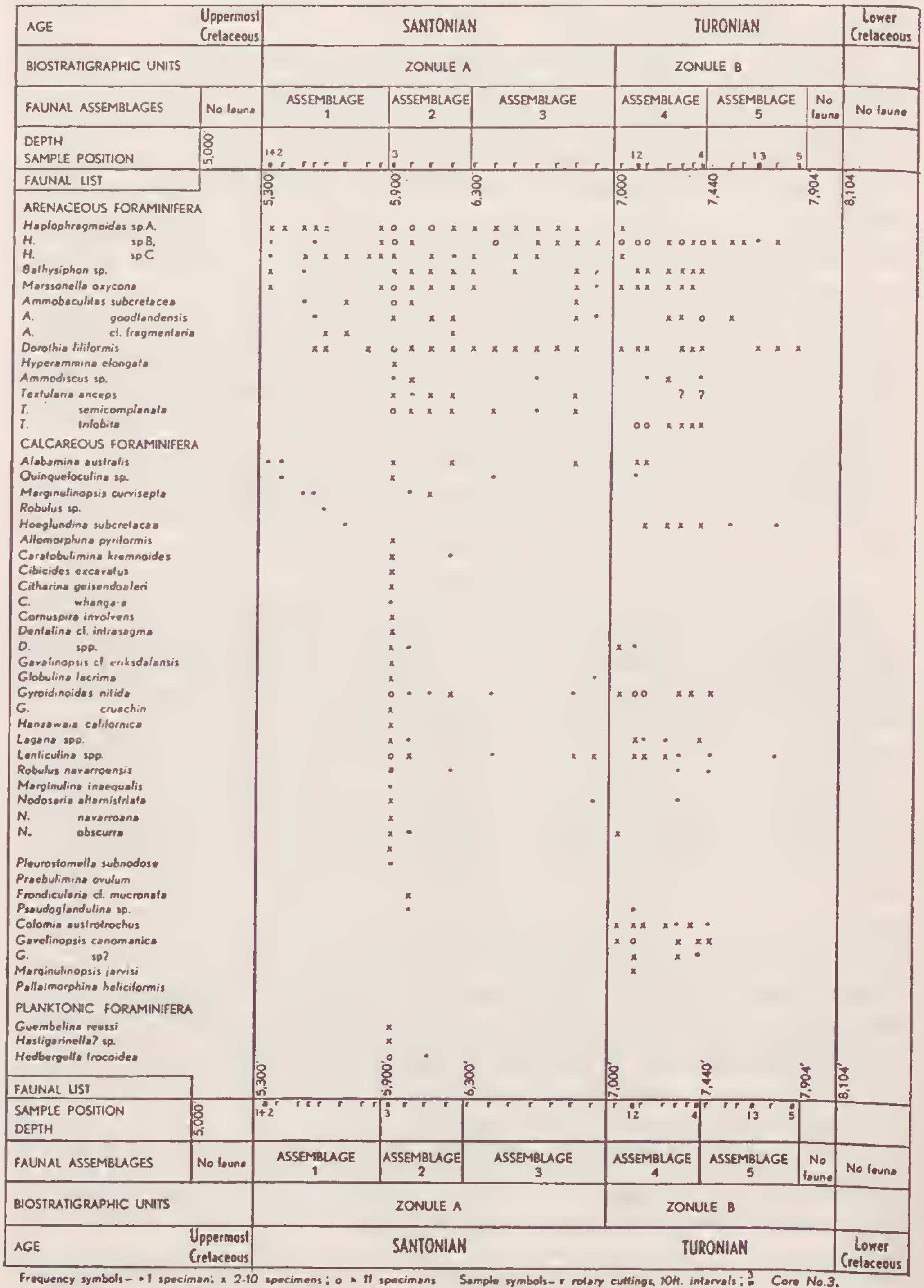
(b) The faunal sequence

The outstanding feature of the Victorian Cretaceous foraminiferal sequence is the alternation of predominantly arenaceous assemblages of Foraminifera with mixed arenaceous/calcareous assemblages. The Cretaceous faunal distribution chart for Port Campbell No. 2 Well (Fig. 3) shows 3 horizons marked by arenaceous faunas and 2 horizons of mixed arenaceous/calcareous faunas.

The faunal distribution in Port Campbell No. 2 would appear to be the basis of a biostratigraphic sequence. The horizons within the sequence are defined on the presence or absence of selected species, and not on evolutionary changes within one or few genera. The main correlatable features are the horizons of extinction of selected species. Glaessner (1955, p. 6) suggests that 'the theoretical basis for this procedure which results from the preoccupation of practical stratigraphic micropalaeontology with bore material, is not clear'. The difficulties in applying this procedure are mainly due to facies changes. A facies change may result in the extinction of certain species in a sequence. One must consider whether this facies change happens on the same time-plane throughout the area under study. E.g., in the Port Campbell No. 2 sequence, one must consider if the faunal changes between Assemblage 2 and Assemblage 1 were due to the vertical facies change that is expressed in the change from black mudstone to silty and sandy sediments. Later in this text, it will be shown that the faunal differences between Assemblage 2 and Assemblage 1 are, in fact, a facies change and it is believed that this facies change did not take place on the one time-plane through the area.

Therefore, it is necessary to assess the faunal changes in the Port Campbell sequence in order to see if they can be reliably correlated throughout the area of study. Faunal changes which are involved with facies changes will be mentioned, but will be dealt with fully in the section on depositional environment which appears later.

No calcareous species are constantly present throughout the sequence. Mainly



Frequency symbols — • 1 specimen; x 2-10 specimens; o ≥ 11 specimens Sample symbols — r rotary cuttings, 10ft. intervals; ▪ Core No.3.
Drilling information: Datum (Kelly Bushing) +284 feet Total Depth 8,864 feet (Otway Group)
Hole diverted and recut from 5,650 feet 9 5/8" casing set at 5,650 feet; 5 1/2" casing set at 8,846 feet.

FIG. 3—Faunal distribution chart, Cretaceous section, Port Campbell No. 2.

they appear in 'waves'. No doubt these appearances indicate that environmental conditions were suitable and that chances of preservation were not limited. The presence of a calcareous 'wave' has facies implications. Thus a 'wave' in one bore may not be the exact biostratigraphic correlate of an horizon containing the same 'wave' in another bore.

Some calcareous species occur in all waves in the section, e.g. *Alabamina australis* and *Gyroidinoides nitida.* This suggests that the restocking of the fauna with calcareous species was the result of immigrations (or 'waves') which originated from the same source area. For the purpose of biostratigraphy, we must then postulate a 'source section' and assume that this 'source section' was deposited throughout a period (= the depositional period of the Port Campbell No. 2 section) when conditions were suitable for many genera of calcareous Foraminifera.

If a species is restricted to a particular 'wave' in a known section, then this species probably has a restricted range in the 'source section'. As this species is absent from all other 'waves' in the known section, then it is probably absent from equivalent horizons in the 'source section'. However, the full range of this species in the 'source section' may include horizons in the known section which do not contain calcareous species.

It is assumed that this principle can only be applied for species whose appearances are not dictated by ecological factors other than those affecting the 'wave' as a whole. Planktonic species are limited to one sample in the section, which suggests they mark a sudden entry of off-shore currents. Thus. planktonic species have no biostratigraphic significance in the section.

The distribution of calcareous species has biostratigraphic limitations in the sequence because the complete range of any species is uncertain. However, the presence of certain calcareous species can be used in identifying a horizon, but the absence of calcareous species cannot be used as a criterion; thus Assemblage 2 cannot be distinguished from Assemblage 3 for the purposes of correlation.

Further critical examination of the faunal distribution shows that the arenaceous fauna of Assemblage 1 is similar to those of Assemblages 2 and 3 except that *Textularia anceps* and *T. semicomplanata* are absent from Assemblage 1. Assemblage 1 is within the *Paaratte Formation* which resembles a shallow water deposit. Palaeoecological studies (Burnaby 1962; Jefferies 1962) conclude that *Textularia* shows a preference for relatively deep water. Therefore, the faunal differences between Assemblages 1, 2 and 3 are due to environmental factors and are not reliable criteria for correlation. Similarly, the faunal differences between Assemblages 4 and 5 are ecological.

(c) The biostratigraphic units

In the Port Campbell No. 2 section the sequence of assemblages may be expressed as follows:

Association =	Assemblage
HA	1
HA + (T + C)	2
HA + (T)	3
ha + (t + c)	4
ha	5

Where **HA** = *Haplogragmoides* sp. *A, H.* sp. *B, H.* sp. *C, Ammobaculites* cf. *fragmentaria, A. goodlandensis,* & *A. subcretacea*;
T = *Textularia anceps* & *T. semicomplanata*;

C = *Cibicides excavatus, Hanzawaia californica, & Gyroidinoides cruachin*;
ha = *H.* sp. *B & Ammobaculites goodlandensis*;
t = *Textularia trilobita*;
c = *Colomia austrotrochus & Gavelinopsis cenomanica.*

As the distribution of *Textularia* and calareous species appear to be ecologically controlled, the sequence of 5 assemblages is a facies sequence rather than a biostratigraphic sequence. Therefore, an assemblage may not identify the one horizon throughout its lateral extent, even in the Port Campbell area. But a combination of the assemblages forms more reliable units for correlation. Thus:

Unit A (assemblages 1, 2, & 3) may comprise—
Association **HA** : or Association **HA** + **(T)** : or
Association **HA** + **(T** + **C)**;

and

Unit B (assemblages 4 & 5) may comprise—
Association **ha** : or Association **ha** + **(t)** : or
Association **ha** + **(t** + **c)**.

Obviously Association **HA** is the basic association of Unit A. Likewise Association **ha** is the basic association of Unit B. The auxiliary associations **T** & **C** or **t** & **c** help establish the entity of the unit, for, though they are facies faunas, the ranges of **T** & **C** do not overlap with those of **t** & **c**. E.g., the range of *Textularia trilobita* does not overlap that of *T. anceps* and *T. semicomplanata*. The replacement of the former by the latter 2 species marks the boundary between Unit B and Unit A.

These faunal units are established so that the sediments which contain them in one bore can be recognized in other bores, no matter what lateral facies changes occur. Of course the limitation is the absence of Foraminifera and the recognition of arenaceous species which are simple in structure, thus flexible in specific character in areal distribution.

As these units distinguish one group of sediments from another on faunal criteria they are biostratigraphic units.

The units are localized units, thus not biostratigraphic zones which Oppel defines as 'Palaeontologically identifiable complexes of strata' (in Teichert 1958a, p. 109). Teichert furthers this definition by stating that a zone is 'a bed or beds characterized by one or more than one fossil species or genera, used for intercontinental or world-wide correlation'.

The world-wide foraminiferal zonation of the Upper Cretaceous is based on the vertical distribution of certain genera, such as *Globotruncana*, which are absent throughout the Victorian sediments. (Proof of the Upper Cretaceous age will be given later.) Within the Victorian sequence there are species which have worldwide range, but their biostratigraphic ranges are either vague or cover more than one *Globotruncana* zone. No other fauna present is of value in zonation.

The term 'zonule' is an adequate one for the two biostratigraphic units in the sequence. Fenton & Fenton (1928) proposed the term zonule as 'the strata or stratum which contains a faunule, its thickness and area being limited by the horizontal and vertical range of that faunule'. Kleinpell (1938) more precisely defines a zonule as a 'locally recognizable biostratigraphic unit'.

Fenton & Fenton's definition of a zonule employs the term faunule which they define as 'an assemblage of fossil animals associated in one or few contiguous strata and dominated by one community, commonly either an association or a layer society'. The 3 assemblages which comprise Zonule A (Unit A) cannot be regarded as faunules, but the combined assemblages are a faunule as they are dominated by the Association **HA**. Likewise, Assemblages 4 & 5 combine to form Zonule B. The individual assemblages have been dismissed for biostratigraphic correlation because of their facies implications. However, they will be used in illustrating the changes in depositional environment both laterally and vertically throughout the area.

(d) Correlation of biostratigrahic units

Table 1 lists the vertical distribution of the biostratigraphic units in each Cretaceous foraminiferal sequence examined. The bores are arranged in order of distance W. of Port Campbell No. 2.

TABLE 1

Bores	Depths of Zonules (ft)		Unit at Base	Distance from Port Campbell No. 2 (miles)
	A	B		
Port Campbell No. 2	5016 to 5716	6716 to 7620	Flaxmans Beds	—
Port Campbell No. 1	3902 to 5002	5002 to 5308	Waarre Form	1·8
Port Campbell No. 3	3878 to 4448	Absent	Waarre Form	4·6
Narrawaturk No. 2	4858 to 5498	? (Total depth)	—	6
Flaxmans No. 1	3777 to 6077	6077 to 6437	Flaxmans Beds	13
Wangoom No. 6	2873 to 3277	Absent	Otway Group	31
Yangery No. 1	2435 to 2658	Absent	Otway Group	40
Belfast No. 4	?4300 to 5279	Absent	Otway Group	44
Pretty Hill No. 1	2180 to 2647	Absent	Flaxmans Beds	55
Eumeralla No. 1	2572 to 2940	Absent	Otway Group	70
Heywood No. 10	4800 to 5298	? (Total depth)	—	81

N.B. All depths adjusted to sea level.

The biostratigraphic correlations are illustrated on the panel diagram of Fig. 6. The faunal distribution charts for Flaxmans No. 1 and Port Campbell No. 1 (not included in this paper) show that the diagnostic species are distributed so that it is possible to recognize the 2 Zonules of the Port Campbell No. 2 sequence. The gross faunal content is much the same in each of the 2 faunules in all 3 wells. The main additions to the fauna are the presence of *Valvulineria erugata* and *V. lenticula*, both restricted to Zonule A, appearing in the calcareous 'waves'.

The Cretaceous foraminiferal sequence reaches a maximum thickness of 2600 ft in Port Campbell No. 2 and Flaxmans No. 1, but sediments containing the 2 Zonules vary in thickness between the 2 bores. In Flaxmans, Zonule A is 600 ft thicker while Zonule B is 550 ft thinner. Between Port Campbell No. 2 and Flaxmans there is little biostratigraphic information, as Narrawaturk ceased drilling while still in Zonule A.

Both Zonules can be recognized in Port Campbell No. 1 but there is considerable thinning of sediments over the 1·8 miles from Port Campbell No. 2.

The sequence is only 560 ft thick in Port Campbell No. 3 and Zonule B is absent. Zonule B is absent from all other bores listed, in fact its distribution is restricted to a narrow coasal belt between Port Campbell and Flaxman's Hill. Marine Cretaceous sedimentation would appear to have initiated in this belt.

The top of the Cretaceous foraminiferal sequence does not coincide with the

FIG. 4—Documented time ranges of foraminifera described from Victorian Cretaceous.

base of the Tertiary foraminiferal sequence in any bore section. There is more than 2000 ft of sediment barren of Foraminifera, between the last occurrence of Cretaceous forms and the first occurrence of Tertiary forms, in Narrawaturk No. 2. This barren interval is only 400 ft thick in the Warrnambool area. Sedimentation (non-marine) appears to be continuous between the marine Upper Cretaceous and the marine lower Tertiary.

In Timboon No. 5 and Wangoom No. 2, no Cretaceous Foraminifera were found in the 500 ft (approx.) interval between the early Tertiary marine sediments and the Otway Group. Biostratigraphic correlation of these 2 bores is therefore impossible, although it is extremely doubtful if any of this sediment is the equivalent of Zonule B. An ammonite fragment found in a core at 3106 ft in Wangoom No. 2 is of no biostratigraphic value as it is probably derived, being badly worn.

TIME STRATIGRAPHY

Fig. 4 is a tabulation of the time distribution of all described species from the Victorian Cretaceous foraminiferal sequence. The European stage classification of the Cretaceous by Muller & Schenck (1943) is followed. The time ranges of the species are those given by the authors listed in the synonomy included with each specific description (Part B of this text).

The reported ranges of 40 species are tabulated. All but 2 species have been recorded from the Upper Cretaceous and 29 species have been recorded only from the Upper Cretaceous. 20 of the species are restricted to beds of Senonian age, while the Senonian is within the range of 12 other species.

A comparative age determination only can be reached as species with precise vertical ranges are absent (e.g. *Globotruncana* spp.). A summation of reported ranges of species suggests a Senonian age. The entire Victorian fauna must then be compared with a well documented Senonian fauna close at hand. Such faunas are discussed and partially monographed by Belford (1958 & 1960) from Western Australia. Belford assigns these faunas to the Santonian and Campanian. The Santonian age is established on crinoid plates of the genus *Marsupites*, which is a zone fossil of the European section. Also the Western Australian Senonian microfaunas contain *Globotruncana* spp. Neither upper Turonian nor Coniacian faunas have been recognized from Western Australia. On this evidence, Belford (1958, p. 637, Fig. 9) infers that a general regression commenced, probably in the lower Turonian, and that deposition was resumed in the Santonian.

The following species occur in the Victorian sequence and are listed by Belford (loc. cit.) as being restricted to the Santonian Gingin Chalk and the Santonian-lower Campanian Toolonga Calcilutite: *Alabamina australis, Cibicides excavatus, C. ribbingi, Citharina geisendoerferi, Nodosaria obscura, Pleurostomella subnodosa, Praebulimina ovulum, Valvulineria erugata, V. lenticula, & V. undulata.* Belford also lists *Frondicularia mucronata* and *Gavelinopsis eriksdalensis*, which are not positively identified in the Victorian sequence. *A. australis, V. undulata,* and *V. erugata* were first described by Belford (1960) and have only been reported by him. The first 2 species are restricted to the Santonian beds, while the third species extends into the lower Campanian. As the Coniacian and upper Turonian faunas are not known in Western Australia, the ranges of these 3 species could well extend from the upper Turonian. The species listed from Western Australia are not all restricted to the Santonian-lower Campanian outside Australia, but their tabulated ranges overlap in the Santonian.

These species listed from Western Australia are reported mainly from Zonule A, the upper zonule, of the Victorian sequence. Other species recorded only from Zonule A do not contradict a Santonian age. Purely Campanian and Maastrichtian species have ranges which are not well documented (e.g. *Hanzawaia californica* and *Ceratobulimina cretacea*). The pre-Senonian ranges of listed species of *Ammobaculites* and *Cornuspira* are dismissed because a simplicity of structure. The full range of *Dorothia filiformis* is difficult to ascertain and may range into the Senonian, and the determination of *Hedbergella trocoidea* is a generic rather than specific determination and thus is of no stratigraphic value. Thus, the species present suggest a Santonian age for the sediments of Zonule A of the Victorian sequence.

Gavelinopsis cenomanica is restricted to Zonule B of the Victorian sequence and this species has an established range of upper Albian into Turonian in Europe. Of the other species restricted to Zonule B, *Textularia trilobita* and *Colomia austrotrochus* are new species, while *L.* (*Marginulinopsis*) *jarvisi* is not well documented. Species recorded in this zonule have ranges which include the Turonian, with the exception of species of *Lenticulina* and *Nodosaria*, while *Alabamina australis* could extend into the upper Turonian (see above). Thus, the species present suggest a Tronian age for the sediments of Zonule B.

Some of the new species described in this text are of genera which are of limited vertical distribution elsewhere. The generic ranges of the new species are now discussed, as well as the range of species with affinities to the new species.

Allomorphina pyriformis:

This genus is reported from the Coniacian to the Recent. This species has no close affinities with the Cretaceous species of *Allomorphina*, but has close affinities with the Paleocene forms, *A. halli* Jennings and *A. paleocenica* Cushman.

Ceratobulimina kremnoides:

The generic range extends from the upper Albian to the Recent. This species has no close affinities with the Cretaceous species of *Ceratobulimina*, but has close affinities with the Paleocene form *C. westraliensis* Parr which occurs in the Pebble Point Formation which overlies the Victorian Cretaceous sediments.

Colomia austrotrochus:

This genus is represented by 3 species, 2 occur in the Maastrichtian while the third occurs in the Campanian. This species may be a more 'primitive' member of the Genus *Colomia* (see specific description later).

Gyroidinoides cruachin:

The genus is a long ranging one, but the species has affinities with *G. pontoni* Brotzen of the upper Campanian to Paleocene of Europe.

Pallaimorphina heliciformis:

This genus is represented by 3 species, two of which occur in the Albian and the third in the Turonian. The Victorian species is distinct. As this genus is of limited occurrence, the generic range could extend upwards.

The reported occurrences of the genera discussed have not altered the age determinations already made. It is interesting that 3 of the new species have affinities with Paleocene species, while a fourth species, *Buliminella* cf. *parvula*, appears to intergrade with the Paleocene species *B. westraliansis* Parr. This could indicate gradual specific transitions between the Santonian and the Paleocene.

The lowest calcareous foraminiferal assemblage is no older than Turonian, while the higher calcareous assemblages are Senonian and probably no younger than Santonian. Though Zonule B contains species suggesting the Turonian age and Zonule A contains species indicating a Santonian age, it does not follow that each of the 2 Victorian biostratigraphic units represent distinct ages. Calcareous species provide the major evidence for these age determinations. The assemblages containing calcareous species of Zonule A (e.g. Assemblage 2 in Port Campbell No. 2) are not contiguous with the assemblages containing calcareous species of Zonule B (e.g. Assemblage 4 in Port Campbell No. 2). There is always an assemblage of arenaceous species (Assemblage 3 in Port Campbell No. 2) between the two calcareous assemblages. Neither is there any other palaeontological, lithological, or structural evidence of a discontinuity of sedimentation between the two Zonules which would indicate a depositional break between Turonian and Santonian (during the Coniacian).

The outlined evidence implies that sedimentation of the Victorian Upper Cretaceous marine rocks commenced during the Turonian and continued till the Santonian. During or at the end of the Santonian there was a marine regression, though non-marine sedimentation appears to be continuous until the marine transgression in the Paleocene. The marine regression was gradual (see following discussion of depositional environment) and the arenaceous assemblages at the top of the foraminiferal sequence (e.g. Assemblage 1 in Port Campbell No. 2) could be Campanian in age. The uppermost Cretaceous was a period of marine regression from the Australian continental areas (Glaessner 1962, p. 246).

The Santonian age assigned to the upper part of the marine Cretaceous sediments (Zonule A) is in agreement with the Senonian age given by Cookson and Eisenack (1961) for the microplankton in these sediments in the Belfast No. 4 Bore. It is noted that Zonule B is absent in the Belfast No. 4 section. However, a new pollen tetrad, *Amosopollis cruciformis*, is recorded by Cookson and Balme (1962) from levels within Zonule B in Port Campbell No. 1 and No. 2, and Flaxmans No. 1, as well as in sediments below this Zonule. This pollen tetrad was described from the ? Aptian to Cenomanian Osbourne Formation in the Perth Basin (Western Australia). Therefore, it would appear that the Victorian Cretaceous marine sequence can be divided into an older unit and a younger unit on other than foraminiferal evidence.

Dr M. F. Glaessner has examined the Cretaceous faunas in all cores from Port Campbell No. 1, No. 2, No. 3, and Flaxmans No. 1. His report is to be published as an appendix to the completion reports in the forthcoming Commonwealth Petroleum Search Subsidy Acts Publications. Dr Glaessner concludes that the faunal evidence favours a Turonian age, although a Coniacian age is possible for the upper part of the Belfast Mudstone. His evidence is against any upper Senonian being present.

Dr Glaessner comments that 'this fauna includes the previously unknown ancestors of a number of Tertiary foraminifera from Southern Australia'. The author arrived at the same conclusions which are noted above.

DEPOSITIONAL ENVIRONMENT

The gross character of the Victorian Cretaceous foraminiferal fauna is not constant throughout any of the thicker sections. The distribution of many of the genera is sporadic and suggests that their presence or absence is dictated by the depositional environment. By an ecological interpretation of both the lithological and palaeontological characters of the rocks, the basic framework of the depositional environment can be postulated.

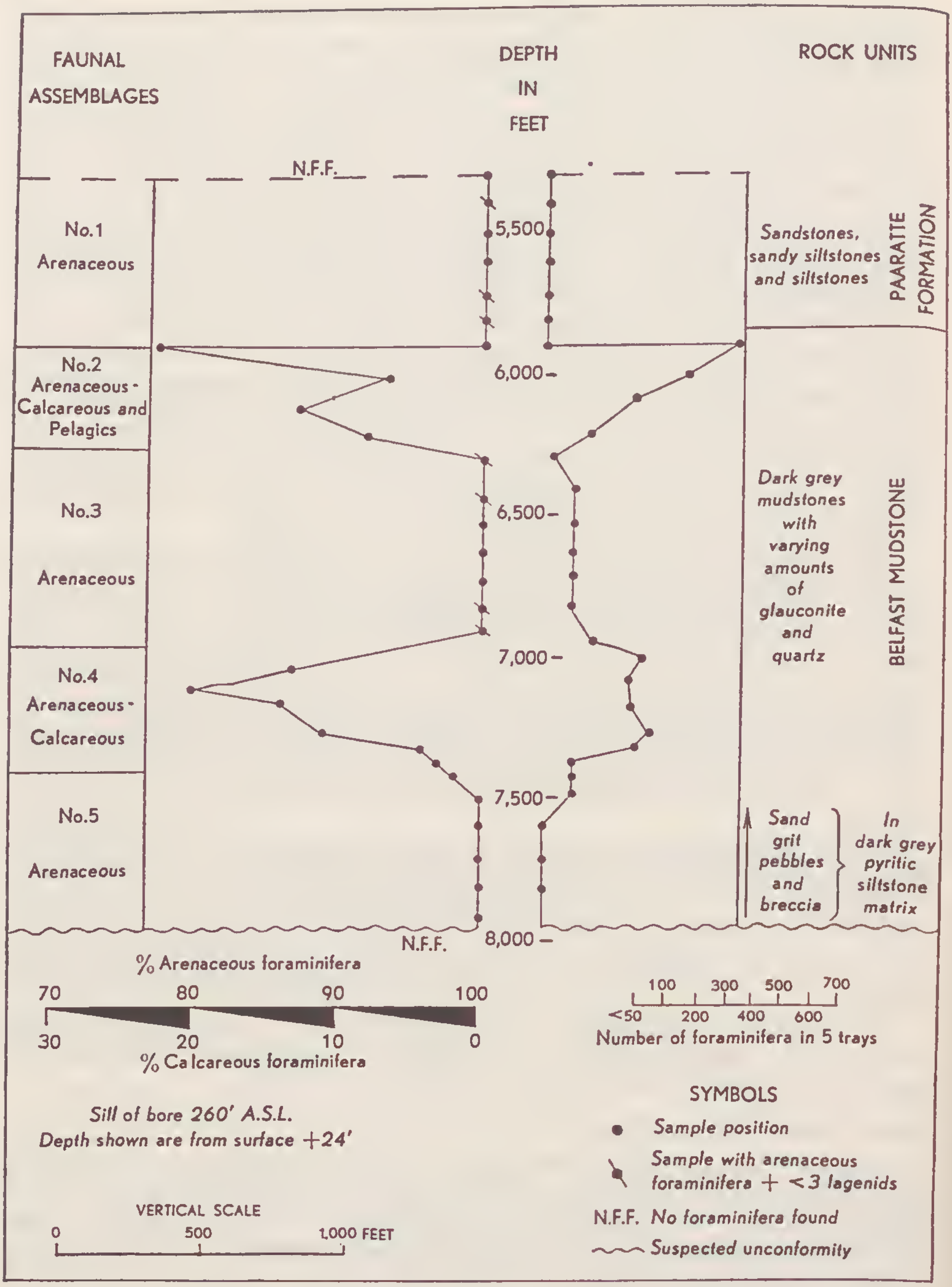


FIG. 5—Variation in gross character and frequency of Cretaceous foraminifera in Port Campbell No. 2 section.

(a) Palaeoecology

A major palaeoecological character is the alternation of assemblages of arenaceous species with assemblages of associated arenaceous and calcareous species. This alternation of faunas is well illustrated in Fig. 5 where the total number of Foraminifera is plotted against the percentage of calcareous forms. The 2 plots correspond with 5 distinct intervals on each plot. Obviously these 5 intervals represent the 5 faunal assemblages discussed earlier in the text.

The Port Campbell No. 2 section contains a predominantly arenaceous fauna, as the percentage of calcareous forms never exceeds 30% and ¾ of the samples contain less than 5% calcareous forms. Many authors (e.g. Glaessner 1945, p. 100) interpret cold water conditions for the predominance of arenaceous species in a fauna. If cold water conditions are assumed for the whole period of Cretaceous sedimentation, water temperature fluctuations are not reasonable explanations for the appearance of 'waves' of calcareous species in a section. Lowman (1949, p. 1957) states that '*Haplophragmoides, Trochammina* and their associates tolerate bottom conditions that normal assemblages will not tolerate'. Such conditions are listed below:

(i) Cushman (1950, p. 44) is of the opinion that arenaceous forms prefer shallow brackish water conditions, while Lowman (loc. cit) shows that living assemblages, dominated by *Haplophragmoides* and *Trochammina*, can be characteristic of brackish marshes. Various authors (e.g. Stelck & Wall 1954, Tappan 1960) have postulated a brackish water origin of certain Turonian sediments which contain purely arenaceous foraminiferal fauna.

(ii) Unsettled benthonic conditions caused by rapid sedimentation and turbidity currents which produce muddied water. According to Stainforth (1952, p. 24) a robust microfauna is typical of a near shore environment of high turbidity.

(iii) Restriction in water circulation resulting in an anaerobic benthonic environment. Baas Becking et al. (1960, p. 259-261) discuss such conditions in the deposition of green and black clays in a neritic environment. Calcareous forms could not tolerate such environments, especially as bacterial activity can release H_2S. Any test transported into such an environment probably would be dissolved, particularly if they are perforate forms (e.g. planktonic species). Such conditions exist at present in Toyama Bay (Japan) and arenaceous forms are the only Foraminifera living in this environment (summarized by Takayanagi 1960, p. 59). Similarly, in the Gulf Coast, marine environments with low oxygen content are dominated by arenaceous forms (Lowman loc. cit.).

(iv) Extremely deep water, by tolerance to low temperature and low oxygen content.

A series of environmental events can be deduced for the Port Campbell No. 2 section, purely on the alternation of the faunal assemblages. These assumptions are discussed in ascending order.

Assemblage 5 appears at a definite marine transgression with the deposition of unsorted detrital material. Total number of Foraminifera gradually increases with the decrease in grain size and amount of detritus. The nature of the sediments suggests muddy, turbid water conditions, thus explaining the absence of calcareous Foraminifera.

Assemblage 4 is in black mudstone. Sedimentation would have been slow as the sediment is extremely fine-grained and glauconite was forming. The total number of Foraminifera increases and calcareous species appear.

Assemblage 3 is in the same kind of sediment as Assemblage 4, although the amount of glauconite increases. Anaerobic conditions are suggested for this interval to account for little lithological change, yet the absence of calcareous Foraminifera. Restricted water circulation would influence the benthonic environment in such a manner.

Assemblage 2 is still within the black mudstones. There is a sudden increase in the total number of Foraminifera accompanied by a definite 'wave' of calcareous forms. Thus, benthonic conditions were undisturbed and circulation of water unrestricted. It is noted that there was little glauconite in the samples.

Assemblage 1 is within silts, siltstones, silty-sandstones, and sands. There is a sudden decrease in the total number of Foraminifera. This total number decreases further until Foraminifera are absent, higher in the section. Calcareous forms are rare and are mainly lagenids. Disturbed, turbid water conditions are lithologically evident and the progression from abundant faunas to no faunas suggests marginal marine conditions under probable brackish water (low salinity) conditions.

The distribution of some genera provides additional environmental information:

Textularia spp. are absent from the predominantly arenaceous Assemblages 1 and 5. They are present only in the black mudstone sediments. Burnaby (1962) and Jefferies (1962) show that *Textularia* spp. preferred relatively deep water during the deposition of the Upper Cretaceous in Western Europe. Stainforth (loc. cit.) states that *Textularia* is not affected by turbid water conditions.

Gyroidinoides spp. occur commonly in Assemblages 2 and 4 and are absent from Assemblages 1 and 5. Many authors, including Burnaby (loc. cit) and Jefferies (loc. cit.), regard *G. nitida* as a deep water form, while Burnaby adds that no living species of *Gyroidina* or *Gyroidinoides* has been found at less than 60 fathoms.

Therefore, Assemblages 2, 3, and 4 are within a neritic sediment, deposited at a depth of 60 to 100 fathoms. These assemblages are within the Belfast Mudstone of the Port Campbell No. 2 section. The initial deposits, containing assemblage 5 (= the base of the Belfast Mudstone), and the final silt and sand deposits (= the Paaratte Formation), were deposited in shallow water (i.e. upper neritic to littoral).

The highest samples of dark mudstones in Port Campbell No. 1 and Flaxmans No. 1 contain a relative abundance of *Quinqueloculina* sp. with few *Gyroidinoides* spp. and *Textularia* spp. An abundance of *Quinqueloculina* spp. signifies shallow water deposits (Phleger 1960, p. 258). These facts suggest that the final dark mudstones were deposited in shallower water in Port Campbell No. 1 and Flaxmans No. 1 than in Port Campbell No. 2.

In Port Campbell No. 2, planktonic species were found only in Assemblage 2. Ammonite fragments were found associated with this foraminiferal assemblage. The absence of planktonic forms (including Mollusca) from Assemblage 1 & 5 is not surprising, as these faunas are within sediments which indicate a moderately high coastal runoff. Such conditions form a natural barrier to planktonic Foraminifera according to Phleger (1960, p. 259). The absence of planktonic forms from Assemblage 4 is puzzling, as this assemblage contains calcareous species in a slow forming sediment. In the case of Assemblage 3, it has already been stated that the depositional environment was anaerobic and would hinder the preservation of planktonic foraminiferal tests. But thick-shelled benthonic Mollusca (e.g. *Inoceramus*) are associated with Assemblage 3, so one could reasonably expect the preservation (original shell or at least moulds) of planktonic Mollusca. Enough samples have been examined to conclude that planktonic species (Foraminifera and Mollusca) did not reach the depositional area during the accumulation of sediment which contains Assemblages 3 and 4 (in Port Campbell 2 and equivalent horizons in other bores). It follows that the depositional area must have been isolated from the open ocean during the accumulation of the dark mudstones which contain Assemblages 3 and 4.

An interesting feature of the planktonic Foraminifera is the absence of *Globotruncana* spp. and other planktonic genera of worldwide distribution in Turonian and Senonian sediments. There are few Turonian and Senonian deposits known at or south of the latitude of the Western Victorian deposits (38° 30′ S.), but there is no reference to *Globotruncana* and associated genera in such deposits (refer to Wellman 1959, for New Zealand; and to Macfadyen 1933, for Terra del Fuego-Graham Land). It is also noted from Belford (1960) that *Globotruncana* is rare in the Gingin Santonian (Western Australia, Lat. 31°S.) but in much more common to the N. in the Santonian of the Lower Murchison R. (Lat. 27°S.). Although evidence is not conclusive, it does suggest that *Globotruncana* had a latitudinal distribution in the Southern Hemisphere.

A definite latitudinal oceanic distribution of *Globotruncana* would imply a distribution influenced by latitudinal temperature variations, if the analogy with the present day was correct. Such latitudinal temperature variations are shown by oxygen isotope studies on the Senonian sediments of North America; Lowenstam & Epstein (1959, p. 71) illustrate a decrease in temperature towards the N. and give a palaeo-temperature of 20°C. for Lat. 50°N. These palaeo-temperatures are interesting as there are no reported occurrences of *Globotruncana* in the Turonian and Senonian of N. Alaska (Tappan 1960) and Turonian in N. Alberta (Stelck & Wall 1954). Cold water could account for the absence of *Globotruncana* in N. Alberta and N. Alaska. The Victorian Turonian and Senonian faunas have the same generic makeup as those of N. Alaska and N. Alberta. Therefore, the Victorian fauna could well have been a cold water fauna by reason of the above arguments, and because of the predominance of arenaceous forms.

(b) Facies

A facies sequence can be established for the series of vertical facies changes in the Port Campbell No. 2 Cretaceous section. The individual facies are numerous and have been grouped together into what is best described as 'vertical facies complexes', as each facies is the result of the same general environment as the complex to which it belongs. These 'vertical facies complexes' appear to be similar in concept to the 'facies tracts' which is a translation by Teichert (1958b, p. 2737) from a work in Russian by Nalivkin. But 'facies tract' implies more lateral facies changes within the same broad environment.

These 'vertical facies complexes' are identified by their broad lithological and palaeontological characters. The palaeontological characters have already been discussed. The 'vertical facies complexes' of the Port Campbell No. 2 sequence are discussed in ascending order. This facies sequence is fully detailed in Fig. 3.

(i) Initial Detrital Deposits: Unsorted detrital material in a dark mudstone matrix. The amount and grain size decreases up the section, suggestive of the beginning of a sedimentary cycle. Arenaceous Foraminifera are present only. Palaeoecological studies suggest that the depositional environment was shallow, turbid, marine or semi-marine.

(ii) Dark Mudstone Deposits: Black to dark grey mudstone-siltstone with amounts of glauconite and quartz. Lithologically, this 'complex' is homogeneous, but palaeoecologically it can be divided into 3 depositional environments:

(a) The lower arenceous-calcareous assemblage which signifies a neritic, clear water environment with good circulation on the sea floor but isolation from oceanic currents which would bear planktonic faunas.

(b) The arenaceous assemblage which signifies deep, clear water with apparently anaerobic benthonic conditions due to restrictions in water circulation.

(c) The upper arenaceous-calcareous assemblage which signifies deep, clear benthonic conditions with good water circulation both on the sea floor and on the surface which is open to oceanic currents, evident by the presence of a planktonic fauna.

(iii) Marginal Marine Deposits: The term 'Marginal Marine Deposits' implies those deposits on the margins between land and sea, such as deltas, estuaries, lagoons and bays. The extent of marine influence can only be gauged by the presence or absence of marine faunas in the resultant sediment. In the Port Campbell No. 2 section there is a complex interval of sands and silts in varying grades and mixtures which could have been deposited in marginal marine environments. At the base of these deposits (at the top of the dark mudstones) there is a sudden decline in the total number of Foraminifera present (see Fig. 5) and palaeoecological interpretation indicates shallow, turbid, brackish water. Higher in these deposits, the Foraminifera are less frequent and then completely disappear at what is probably the subtle (vertical) boundary between tolerable (brackish) and intolerable (fresh water) conditions. Essentially, this interval is within the same 'vertical facies complex' of Marginal Marine Deposits, but it is noted if Foraminifera are found, as they mark the vertical transition between marine and non-marine environments.

Ideally these 'vertical facies complexes' should have genetic designation referring to the broad depositional environment, thus retaining the analogy with Nalivkin's 'facies tracts'. The term 'Dark Mudstone Deposits' may appear incongruous, but the lithological homogeneity strongly implies genetic similarity; moreover, individual facies are indicated by palaeontological (and probably mineralogical) features which result from variations in the chemical environment on the depositional surface.

(c) The probable depositional environment

In Fig. 6, an attempt has been made to extrapolate the facies complexes between the known sections. This attempt is handicapped by the small number of control points and the distance between them. Yet a number of conclusions can be surmised, mainly along the Port Campbell to Warrnambool coastal strip. These conclusions are illustrated by the hypothetical three-dimensional diagram in Fig. 7.

The Initial Detrital Deposits are recognized in the two thickest sections, Port Campbell No. 2 and Flaxmans, although they are probably present in other sections. The unsorted detrital material is angular and often friable, with a matrix of clay and precipitated cement. These deposits may be diachronous as referred to elsewhere in this article.

The amount of coarse material decreases higher in the sequence and the finer grade Dark Mudstone Deposits predominate. The lowest Dark Mudstone Deposits contain neritic faunas, biostratigraphically assignable to Zonule B. These deposits are only present in Port Campbell No. 1 and No. 2 and in Flaxmans No. 1. Biostratigraphic equivalents of these deposits are found in no other facies. This suggests that the lowest Dark Mudstone Deposits (containing Assemblage 4 of the Port Campbell No. 2 section) formed in deep water at a time when Marginal-Marine

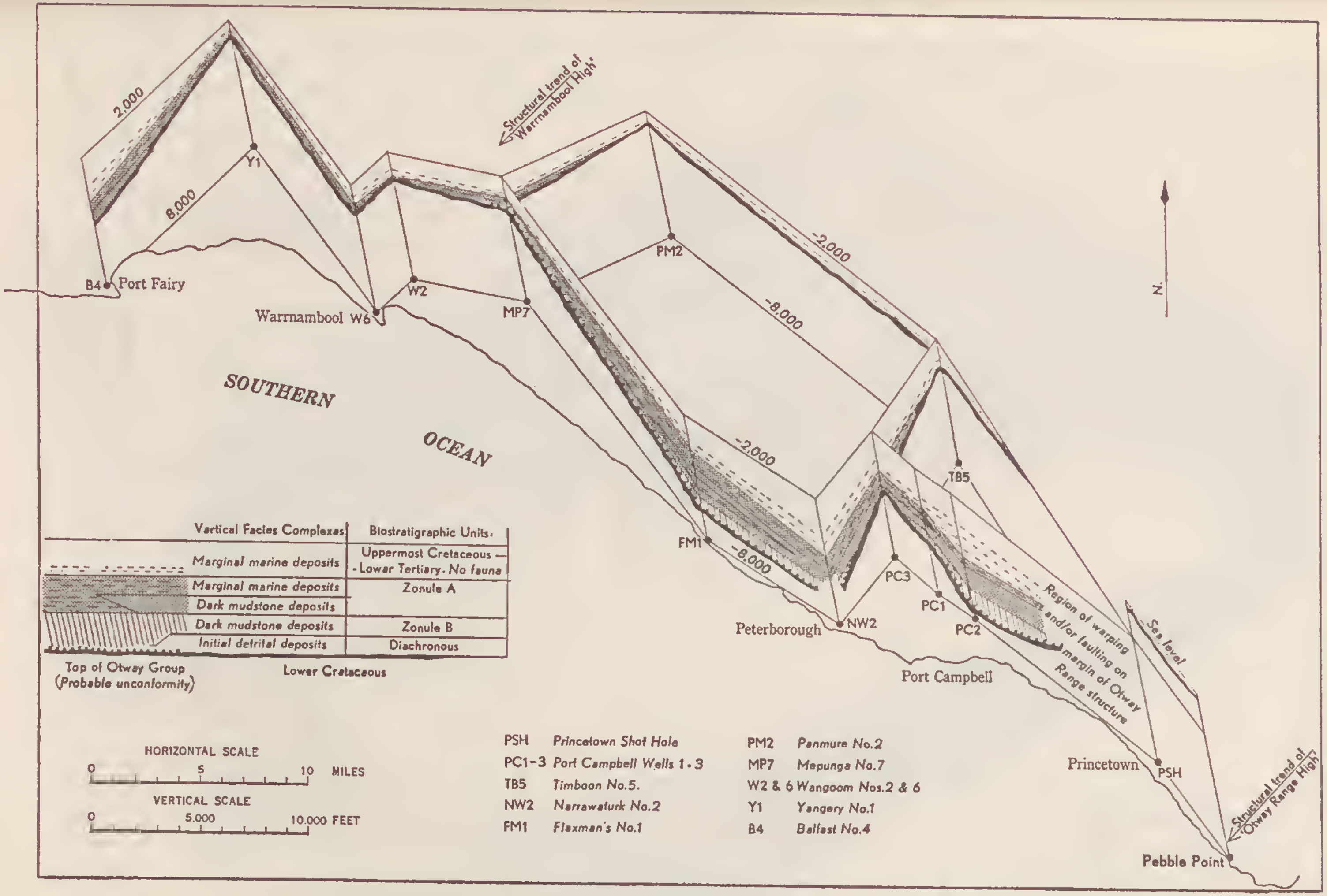


FIG. 6—Panel diagram showing Upper Cretaceous sediments in Port Campbell embayment.

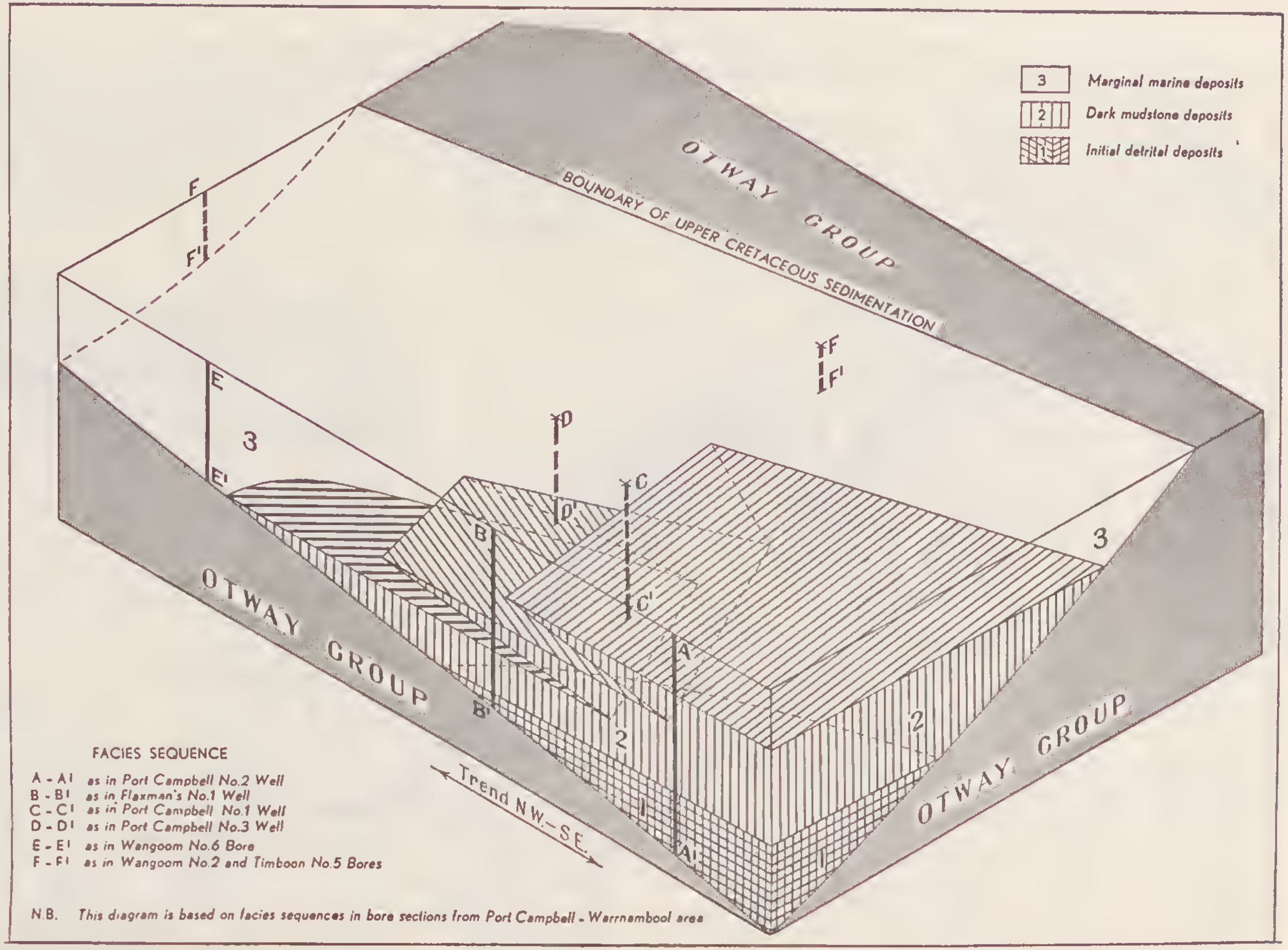


FIG. 7—*Hypothetical block diagram of marine Cretaceous facies relationships in Victoria.*

Deposits were not accumulating. This could imply slow contemporaneous downfaulting or downwarping from a low-lying land surface, the sediment being of an extremely fine nature.

Sediments containing the higher biostratigraphic unit, Zonule A, are found over a wider area, showing that sedimentation spread out to the N. and W. Zonule A faunas are found in both Dark Mudstones and Marginal-Marine Deposits. A sharp boundary, between the Dark Mudstone Deposits and overlying Marginal-Marine Deposits, is exhibited only in the Port Campbell No. 2 section. In all other sections, the transition between the two deposits is repetitious. This is clearly shown in the Flaxmans sequence where thin developments of Dark Mudstones Deposits recur within the Marginal-Marine Deposits over an interval of 1,000 ft. These repetitious Dark Mudstone Deposits contain faunas which indicate that they were formed in shallower water than the main mass of the Dark Mudstone Deposits. It is evident that shallow water conditions with facies interfingering existed to the N. and W., while the highest deep water Dark Mudstone Deposits were accumulating in the Port Campbell No. 2 section. This facies repetition and interfingering is illustrated in Fig. 7.

Thin Dark Mudstone Deposits are present in Port Campbell No. 3, while only marginal marine deposits are recognized in Timboon No. 5, Yangery No. 1, and the Wangoom bores.

The accumulated evidence shows the trend of sedimentation to have been from the SE. to the NW., though also trending slightly to the N. It would appear as if the depositional area was inundated with Marginal-Marine Deposits from the N. and W. At first, these deposits were deltaic or estuarine silts and sands, and were then covered by fresh-water lagoonal or marsh deposits (identified by absence of Foraminifera). Most of the Dark Mudstone Deposits were deep water sediments, but their relationship with the Marginal-Marine Deposits suggests that they were formed close to the shoreline. The Upper Cretaceous shoreline was at first retreating, but then gradually encroached over the depositional area, until its position was S. of the present shore line.

The sudden appearance of planktonic fauna is significant. These faunas occur in the top horizons of the Dark Mudstone Deposits. Their appearance indicates the breakdown of barriers which protected the depositional area from off-shore currents. Such barriers could include the actual direction of the currents (i.e. parallel to the shoreline), as well as off-shore rock or sand bars. Rock or sand bars could also inhibit the bottom water circulation which is believed to have influenced the fauna in portion of the Dark Mudstone Deposits. All evidence indicates that these mudstones were deposted, mainly, under 'barred basin conditions'.

To the W. of the Warrnambool area (Wangoom and Yangery bores) there appears to be a similar Upper Cretaceous marine transgression, evident in the Belfast No. 4 Bore, where there are 450 ft of Dark Mudstone Deposits with open marine conditions near the top. But the full extent and nature of Upper Cretaceous sedimentation is not known farther to the W. Only Marginal-Marine Deposits are recognized in the Pretty Hill section. Dark Mudstone Deposits are present, over a thin interval, in both Eumeralla No. 1 and Heywood No. 10. The dark mudstones in these wells are rich in glauconite and contain faunas suggestive of anaerobic conditions.

A Reappraisal of the Rock Stratigraphy

From the preceeding discussion, it can be concluded that all Upper Cretaceous sediments in SW. Victoria were deposited in a paralic environment. Under these circumstances, a clear cut rock stratigraphy at a formation level may not be practical.

From the preliminary discussion on rock stratigraphy earlier in this article (Fig. 2), it could be concluded that there is a precise, natural delineation between the defined rock units; such a delineation is not verified by this study.

By definition, the term 'Belfast Mudstone' is restricted to a continuous sequence of dark grey mudstone/siltstone with varying amounts of quartz, mica, glauconite, and pyrite. Such a definition precludes any recognition of facies interaction, which is illustrated by the recurrence of Belfast Mudstone equivalents (Dark Mudstone Deposits) within the Paaratte Formation (e.g. Flaxmans No. 1 and Port Campbell No. 1). This is illustrated in Fig. 7; the two interdigitations of Dark Mudstone Deposits would be placed, by definition, within the Paaratte Formation as they are discontinuous in vertical sequence. Yet these interdigitations are laterally continuous and are clearly related to the main bulk of the Dark Mudstone Deposits which are designated as Belfast Mudstone. A reverse of this designation may be considered more logical. However, it is pointless to argue on this issue, as the Paaratte Formation and the Belfast Mudstone must be considered as having close affinities.

The boundary between the Belfast Mudstone and the underlying Flaxmans Beds is difficult to establish. The intervals assigned to the Flaxmans Beds do not contain Foraminifera. As a result of a detailed chemical and petrological investigation, Baker (1963) concludes that the Flaxmans Beds were deposited under marine conditions and mark the beginning of marine cycle of sedimentation. Baker's work suggests chemical conditions during the deposition of the Flaxmans Beds which would explain the absence of Foraminifera. The basal beds of the Belfast Mudstone (The Initial Detrital Deposits) are lithologically similar to the upper part of the Flaxmans Beds in Port Cambell No. 2 (as noted by Baker loc. cit., p. 31). It is apparent that the Flaxmans Beds are the basal part of the marine Cretaceous sequence and are closely allied to the Belfast Mudstone.

The marine Cretaceous sequence is composed of 3 rock units, but the boundary between any two of these units is not clearly defined. Obviously the 3 units, Flaxmans Beds, Belfast Mudstone, and Paaratte Formation, should be placed within one rock unit of group status. Among other considerations, this would clearly separate these units from the non-marine Mesozoic Otway Group (including the Waarre Formation). No samples from the Otway or Merino Groups have been found to contain spores or pollen younger than Lower Cretaceous (see Cookson & Dettmann 1958). The base of the Belfast Mudstone is regarded as Turonian and the upper part of the Belfast Mudstone, as well as the Paaratte Formation, is within the Senonian. The age of the Flaxmans Beds is not yet clearly stated, but is probably Upper Cretaceous (Cenomanian or Turonian). These Cretaceous units are therefore stratigraphically above the Otway Group and could not be laterally interconnected with the Otway Group.

However, the group of marine Cretaceous units is not clearly separated from the overlying Wangerrip Group. The Paaratte Formation is basically a paralic unit of sands and silts in various grades and mixtures; sediments of a calcareous nature are rare. The Wangerrip Group fits the same broad description. Both units contain glauconite and marine fossils at various horizons. There is no evidence of a disconformity between them. In fact, the designated base of the Wangerrip Group in Flaxmans No. 1 Well contains Cretaceous Foraminifera; usually the designated base is devoid of Foraminifera.

It should be remembered that the Wangerrip Group was defined by Baker (see

Baker 1953) from outcrop section with the Palaeocene Pebble Point Formation as the basal unit. Moreover, Baker (1943, p. 244) comments on the overlap of the Pebble Point Formation on Otway Group and states—'On account of this overlap, it is reasonable to assume that still older members of the Eocene series may be hidden below sea level west and north-west of the Pebble Point Beds. Boring operations will be required to establish this point.' Baker's assumption has been established in that sediment exists conformably below the Pebble Point Formation and unconformably overlying the Otway Group. But instead of being older members of the Eocene series, they are of Upper Cretaceous age and, once again, it should be noted that the Pebble Point Formation is now considered to be of Paleocene age.

It is shown in this paper that Upper Cretaceous sedimentation took place on a sloping surface and that there was a gradual transgression up this slope. Baker (loc. cit.) has already commented on the transgressive nature of the Pebble Point Formation over a short distance. It is probable that the Pebble Point Formation represents the ultimate extension of this 'up slope' transgression, while the Flaxmans Beds (in Port Campbell No. 2) represent the beginning of this cycle of transgressive sedimentation. There are close lithogenetic similarities between these two units but, at the present time, it is not certain if they represent the same diachronous facies. This implies that the Wangerrip Group (of Baker 1953) could be extended down to include lithogenetically similar rock units of Upper Cretaecous age. A thorough study of the basal Tertiary sediments is now being undertaken and no firm decision on this matter will be made until the final results are compiled.

However, the present situation is unsatisfactory because of difficulties in recognizing the Pebble Point Formation away from the marginal area as is to be expected from the preceding discussion. Palaeontology does not assist in identifying the equivalents of the Pebble Point Formation, for, although Paleocene foraminiferal faunas are common in sub-surface sections, these faunas are younger than the 'Pebble Point Fauna'.

An alternative suggestion is that the Wangerrip Group be made a sub-group of a new unit which embraces all these paralic, lower Tertiary and Upper Cretaceous sediments.

Structural Relationships

There is a direct relationship between the areal distribution, nature and thickness of the Upper Cretaceous sediments and the present sub-surface contours of the top of the Otway Group. The Upper Cretaceous is thickest where the top of the Otway Group is deepest (e.g. Port Campbell No. 2), where the top of the Otway Group is shallower the Upper Cretaceous is poorly developed, and is absent where the top is above 2,000 ft. Biostratigraphic studies (illustrated in Fig. 6) show that the oldest Upper Cretaceous faunas (Zonule B) are present only where the top of the Otway Group is below 5,300 ft. Similarly, facies studies (in Fig. 6) demonstrate that the thickest section of pure marine sediments (Dark Mudstone Deposits) is where the contact is deepest and a higher proportion of Marginal-Marine Deposits are developed as the top of the Otway Group becomes shallower.

These facts suggest that the Upper Cretaceous seas transgressed up a sloping surface. They also suggest that Upper Cretaceous sedimentation was controlled by the surface configuration of the Otway Group at the time of deposition. It follows that the Upper Cretaceous sediments unconformably overlie the Otway Group.

Outcrop and sub-surface information reveal that the Otway Group has a definite structural configuration. The general structural trend is SW.-NE. This trend is apparent from the exposures in the Otway Ra. (Thomas 1959). A similar trend is noted running NE. from Warrnambool. Some 30 miles NE. of Warrnambool, bores at Glenormiston and L. Bookar pass directly from the Tertiary into Palaeozoic. S. and SW. of these bores, the Otway Group is present below the Tertiary cover and the top of the Otway Group deepens towards Warrnambool, as well as towards Port Campbell. Thus, a line drawn from Glenormiston to Warrnambool appears to be the axis of a SW.-plunging anticline. (The Tectonic Map of Australia shows this structure as a SW.-plunging syncline, due to insufficient sub-surface data at the time of compilation—1958.)

The Upper Cretaceous seas transgressed over the low-lying area between the Otway Ra. structure and the Warrnambool structure, as well as on to the plunging nose of the Warrnambool structure. But the configuration of the top of the Otway Group is not symmetrical about a medial axis between the two anticlinal structures. The greatest vertical displacement of the Otway Group is relatively close to the Otway Ra. structure. The magnitude of this displacement decreases NE. from the coast, until the Warrnambool structure appears to coalesce with the Otway Ra. structure. Maximum development of marine Cretaceous sediments is close to the Otway Ra. structure and the sedimentary trend (of the marine Cretaceous) is from the SE. to the NW., perpendicular to the structural trend. Thus the Upper Cretaceous depositional area is not in a simple syncline.

The explanation of the above is, that the Otway Ra. structure must have been a stable structure, so that movement on the more mobile Warrnambool structure would have caused deformation between the two structures. This deformation would have been in the form of warping and faulting and would be more pronounced closest to the stable structure (i.e. the Otway Ra. structure). Such a mechanism apparently initiated Upper Cretaceous sedimentation and persisted contemporaneously with the deposition, thus explaining the vast differences in the base levels of many horizons of Upper Cretaceous and lower Tertiary sediments.

This area of Upper Cretaceous sedimentation is commonly referred to as the 'Port Campbell Embayment'. (This term has not appeared previously in print, but the author is not its sole user.) W. of the Warrnambool structure, the Upper Cretaceous depositional area could be referred to as the 'Portland Embayment'. The marine Dark Mudstone Deposits at Port Fairy (Belfast No. 4 Bore) are separated from those in the 'Port Campbell Embayment' by the Marginal-Marine Deposits on the Warrnambool structure. During the lower Tertiary, sedimentation was continuous and uninterrupted over the Warrnambool structure, thus the 'Port Campbell Embayment' and the 'Portland Embayment' became one depositional area. This is referred to as the Portland Sunkland (of Boutakoff 1952) or sometimes as the Western District Basin.

Little is known of the structural situation in the 'Portland Embayment', save for the obvious deepening towards Port Fairy (see above). Drilling at Pretty Hill revealed a structural high, as the top of the Otway Group (? Merino Group) was at 2,719 ft. and the bore intersected Cambrian diabase at 7,671 ft. Farther W., in Eumeralla No. 1, the top of the Otway Group was at much the same level (2,940 ft), but the Cambrian was not encountered in 10,000 ft of drilling. In Heywood No. 10, drilling ceased while still in Upper Cretaceous at 5,290 ft. No Mesozoic sediments were encountered in 5,500 ft of drilling at Portland. The exposure of non-marine Mesozoic rocks (Merino Group) and lower Tertiary rocks in the Casterton area indicates that this is a structural high. This feature is referred to by

Boutakoff (1952) as the Dartmoor Ridge. It can only be surmised that similar structural mechanisms existed in the 'Portland Embayment' as probably existed in the 'Port Campbell Embayment'.

The absence of Upper Cretaceous sediments from the Otway Ra. is not surprising if this area was structurally stable and the transgressive sedimentation gradually encroached on to it. Edwards (1962, p. 108) discusses basal marine Tertiary remnants in contact with the Otway Group, well above sea-level, at Cape Paton and Benwerrin. This shows that the Tertiary part of the Wangerrip Group overlapped farther E. than Pebble Point. The extent of the basal Tertiary depositional area is certainly greater than that of the Upper Cretaceous. The suggestion is that an equilibrium of level may have been reached, due to Cretaceous filling of the weaker down-warped (or faulted) area and the erosion of the stable areas.

Edwards (loc. cit., p. 116-118) provides evidence that the Otway Ra. were domed up as a result of fault and fold movements in late Cainozoic times. Structural evidence from the Upper Cretaceous sediments shows that the late Cainozoic structural movements were not the only ones that have affected the Otway Ra. and the region to the W.

Addendum

Since the completion of the preceding text, another marine Cretaceous section has been drilled by the Victorian Mines Department. This section is between 2,954 ft and 3,498 ft in Mepunga No. 7 Bore at Allansford (8 miles E. of Warrnambool). The sediments between 2,954 ft and 3,390 ft are Marginal-Marine Deposits containing mainly arenaceous Foraminifera of Zonule A. These results fit into the framework of marine Cretaceous sedimentation already established in this text.

The interesting feature of the Mepunga section is the presence of Initial Detrital Deposits between 3,390 ft and 3,498 ft. These sediments probably represent the Flaxmans Beds. Sections of a core of sideritic sandstone (3,413 ft to 3,428 ft) revealed arenaceous Foraminifera including *Haplophragmoides* sp. *A*. Therefore, these Initial Detrital Deposits contain Zonule A and, therefore, are younger than those of the Port Campbell No. 2 and Flaxmans section which contained Zonule B faunas.

This information supports the author's views, expressed earlier in this article, that the Initial Detrital Deposits were transgressive and probably diachronous. It is now obvious that the Detrital Deposits and the Flaxmans Beds are represented by the same interval of sediment.

It is also noted that the Flaxmans Beds are reported in Pretty Hill No. 1 (see Table 1) to the W. of Warrnambool. The interval assigned to these beds was not cored and, as contamination was heavy, it is not possible to comment on the biostratigraphic position of this interval.

Fig. 6 has been redrafted to accommodate the Mepunga information and to include the entire interval of the Flaxmans Beds, where recognized, within the Initial Detrital Deposits. No other figure has been amended for this information, as it was felt unnecessary at this stage.

Part B: The Foraminifera

Only 75% of the foraminiferal fauna has been monographed, due to poor preservation of many specimens or not enough available specimens to trace variability within species. Generic reappraisal of many species proved impossible because of poor preservation, lack of specimens, and difficulties of cutting sections.

The species index, which appears later, lists all species recorded in the samples examined. This index includes the indeterminant species as well as the described ones. Apart from Port Campbell No. 2, the faunal distribution charts of all sections examined are not included in this paper, but are available for inspection from the library of the Victorian Geological Survey.

Where a new species is described, a holotype is designated. If variation is recognized within the new species, the range of variation is described and illustrated by selecting 'supplementary specimens', thus dispensing with the typological concept of the paratype. This is in accordance with the views of Simpson (1961), who states that 'populations, not individuals, are the units of systematics and are the things classified'. It should be noted that the selected 'supplementary specimens' may not come from the same sample as the holotype, and some 'supplementary specimens' are selected to illustrate differences in preservation rather than intra-specific variation.

The specimens of described species are illustrated in Pl. LXXIX-LXXXVI. The figures of Pl. LXXIX-LXXXIV are camera lucida drawings by Mrs I. G. Knight. The figures of Pl. LXXXV-LXXXVI are photomicrographs of thin sections. The sections were photographed through a polarizing microscope. Some of the photomicrographs were taken with crossed nicols.

All specimens illustrated are registered and housed in the Geological Survey Museum of the Department of Mines, Melbourne. The registered numbers (e.g. GSM 58699) and the sources of the specimens are given in the appropriate specific description.

Dr M. F. Glaessner allowed the author to examine his collection of Victorian Cretaceous Foraminifera (made on behalf of Frome-Broken Hill Co. Pty Ltd). Any use of this collection is noted in the text.

Genus **Hyperammina** Brady 1878

Hyperammina elongata Brady

(Pl. LXXIX, fig. 1, 2)

1878 *Hyperammina elongata* Brady, *Ann. & Mag. Nat. Hist.* ser. 5, 1: 433, Pl. 20, fig. 2.
1946 *Hyperammina elongata Brady,* Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 15, Pl. 1, fig. 12, 13 (with synonomy).
1958 *Hyperammina elongata Brady,* Pokorný, *Mikropalaontologie,* Berlin, 1: 168, Fig. 57.

The test consists of a long simple cylindrical tube leading from an inflated proloculus, which has partially collapsed in all specimens. The test wall consists of cemented fine quartz grains which are usually clear and white in contrast with the darker material of the arenaceous tests of other species in the sequence. Maximum diameter of proloculus approximates 0·3 mm in all specimens. Maximum length of tube = 0·7 mm.

DISCUSSION: It is unusual to isolate complete specimens as the tube becomes detached easily from the proloculus. A solitary tube can be mistaken as a straight slender *Bathysiphon*, while a detached proloculus resembles *Saccammina* or *Pelosina*. A detached proloculus as well as a complete specimen are illustrated.

DISTRIBUTION: The random distribution of this species lacks stratigraphic significance.

FIGURED SPECIMENS: Pl. LXXIX, fig. 1—GSM 58716 from a core sample at 4,126 ft in Flaxman's No. 1; fig. 2—GSM 58717 from a core sample at 5,231 ft in Port Campbell No. 1.

Genus **Haplophragmoides** Cushman 1910

Haplophragmoides is the most abundant genus of Foraminifera in the Victorian Cretaceous. Specific determination has proved difficult. Numerous Cretaceous species are described in the literature, but the differences between many of them are slight and specific variation is sometimes inferred but seldom discussed. Compression or distortion of the test is prevalent, which adds to the difficulties in specific comparison.

The following features have been used as specific characters in described species:

(1) Size and shape of test: round to flattened (distortion is usually considered).
(2) Form of coiling: involute, partially evolute, wholly evolute. In a loosely coiled species this feature can vary.
(3) Number of chambers: often taken as a characteristic constant. Sometimes it is the only feature that distinguishes between species.
(4) Periphery: rounded or acute; in outline rounded to lobulate.
(5) Nature and depth of umbilicus.
(6) Sutures: straight or curved; width and degree of distinctness; raised, flushed, or depressed.
(7) Composition of test. Regarded as an important character by some authors. Tappan (1957, p. 203) shows that the test composition of *H. toporukensis* varies according to the associated lithology. Similar observations have been made on *Haplophragmoides* in the Victorian sequence. Therefore, this feature is not considered as a specific character in this discussion.

3 definite species have been established in the Victorian sequences. Each species differs from the others in at least 2 of the first 6 features listed above. But each of these 3 species differs from certain described species in only one feature. Classification on a specific level would be simple if each Victorian species had close affinities with only one described species. Formal designation has not been attempted, as the Victorian species have purely local significance. Specific identification, within the sequence, has been achieved by referring to them as *Haplophragmoides* species *A, B,* and *C.*

Haplophragmoides sp. *A*

(Pl. LXXIX, fig. 3)

The bi-umbilicate test is somewhat flattened with an acute periphery, lobulate in outline. There are 8-10 triangular shaped chambers in the outer whorl. This whorl is superimposed on the two earlier whorls, though not completely overlapping them, as the test is partially and irregularly evolute. The sutures are thickened, straight to noticeably curved back and are slightly depressed. The umbilicus is deep with a flattened umbilical margin. The aperture is a sutural slit at the base of the last chamber.

The test is composed of siliceous cement with varying amounts of arenaceous material. Where the siltstone is sandy, higher in the sequence (the Paaratte Formation), the tests have roughened exteriors with a large amount of coarse arenaceous material. In the fine grained Belfast Mudstone the tests are composed of mainly siliceous cement with a small proportion of fine grained arenaceous material. Compression is a common feature, but many specimens from the Belfast Mudstone are infilled with pyritic mud and appear to have resisted deformation.

The maximum diameter of specimens ranges from 0·5 mm to 1·2 mm. The undeformed figured specimen has a thickness of 0·25 mm for a maximum diameter of 0·64 mm.

AFFINITIES: This species has close affinities with the following species, but differs in that:

- *H. gigas* Cushman, has sigmoidally curved, narrow sutures.
- *H. rota* Nauss, has indistinct sutures and the peripheral outline is rounded.
- *H. rudis* Bolin, has narrow sutures.
- *H. excavatus* Cushman & Waters, has raised sutures. (Collapsing of the chambers in some specimens of *H.* sp. *A.* produces close similarities.)

DISTRIBUTION: Common to abundant in Zonule A, though rare at the top of the Zonule. Has not been identified positively in core samples from Zonule B.

FIGURED SPECIMEN: Pl. LXXIX, fig. 3—GSM 58713 from a core sample at 5,231 ft in Port Campbell No. 1.

Haplophragmoides sp. *B*

(Pl. LXXIX, fig. 4)

The bi-umbilicate test has a rounded periphery. It is loosely coiled, the 2 inner whorls being evolute to varying degrees, but never completely evolute. There are 8 chambers in the outer whorl. The straight radial sutures are thickened and the last 2 sutures may be slightly depressed. The umbilicus is broad, deep, and with a rounded umbilical margin. The aperture is a sutural slit at the base of the last chamber.

The amount and coarseness of arenaceous material in the test varies, reflecting the type of sediment as described for *H.* sp. *A*. Test deformation is common.

The maximum diameter varies from 0·4 mm to 0·7 mm and the thickness from 0·15 mm to 0·32 mm.

AFFINITIES: This species has close affinities with the following species, but differs in that—

- *H. atahallpai* Frizzell, has 11 chambers with deeply impressed sutures.
- *H. carlilensis* Fox, has 10 chambers.
- *H. collyra* Nauss, has a lobulate periphery.
- *H. flagleri* Cushman & Hedberg, has 8-10 chambers and the sutures are narrow.
- *H. toporukensis* Tappan, is a species embracing a range of variation which could include *H.* sp. *B*, but the latter species does not exhibit such wide variation.

DISTRIBUTION: Present throughout the Victorian sequence.

FIGURED SPECIMEN: Pl. LXXIX, fig. 4—GSM 58715 from a sample from 5,200 ft to 5,210 ft in Flaxman's No. 1.

Haplophragmoides sp. *C*

(Pl. LXXIX, fig. 5)

The somewhat flattened, bi-convex test has a rounded to sub-rounded periphery and a rounded peripheral outline. The test is completely involute. The whorl consists of 6 chambers. The distinct straight, radial sutures coalesce at the centre of each face. There is no umbilical hollow. The aperture is a sutural slit at the base of the last chamber. The tests are composed of fine grained arenaceous material with a siliceous cement. There is no variation in test composition. Many specimens have an acute periphery but this is due to deformation, as the specimens are not symmetrical in side view.

In undeformed specimens the maximum diameter ranges from 0·5 mm to 0·65 mm, while thickness ranges from 0·2 mm to 0·3 mm.

AFFINITIES: This species shows close affinities with the following species, but differs in that—

H. kirki Wickenden, has depressed sutures and thus a lobulate periphery.

H. dickinsoni Crespin, from the Lower Cretaceous of the Australian Great Artesian Basin, with rounded periphery, slightly lobulate in outline.

H. obesus Takayanagi, has a globular test with a well rounded periphery.

DISTRIBUTION: Associated with *H.* sp. *A* though less frequent.

FIGURED SPECIMEN: Pl. LXXIX, fig. 5—GSM 58714 from core sample at 5,910 ft in Port Campbell No. 2.

Genus **Ammobaculites** Cushman 1910

Ammobaculites cf. **fragmentaria** Cushman

(Pl. LXXIX, fig. 10, 11)

1927 *Ammobaculites fragmentaria* Cushman, *Trans. Roy. Soc. Canada* 3rd ser., 21 (4): 130, Pl. 1, fig. 8.

Long rectilinear, tapering test consists of a small, compressed, planispiral initial portion followed by 6-8 uncoiled chambers. The greatest width is in the final chamber, and the uncoiled chambers are ovoid in cross section. The sutures are straight, depressed and distinct in the uncoiled portion, but are obscured in the coiled portion. The walls are composed of cemented coarse grained quartz. In some specimens the quartz grains are extremely large (up to 0·2 mm in length) and ferromagnesian minerals are incorporated also in the walls. The aperture is elliptical and terminal.

The length of specimens ranges from 0·9 mm to 1·2 mm; maximum width of 0·2 mm to 0·3 mm.

DISCUSSION: The Victorian specimens are typical of the Holotype of *A. fragmentaria* Cushman from the Senonian of Canada, but not of specimens illustrated by Cushman (1946, Pl. 3, fig. 10-16) from the Albian of the Gulf Coast region of America as *A. fragmentarius*. But the Victorian specimens have a roughened exterior and not a surface composed of flat flakes of quartz as in the Canadian material. The external appearance of the test walls appears to have been taken as a specific characteristic so that the Victorian material does not agree entirely with the specific definition. However, composition of arenaceous tests may well be more an environmental than specific feature.

A. cf. *fragmentaria* is distinct from *A. subcretacea* because of the tapering test, relatively small initial coil and more chambers in the uncoiled portion.

DISTRIBUTION: Recognized only in Zonule A of the sequence where the species is associated with the *A. subcretacea* and *A. goodlandensis.*

FIGURED SPECIMENS: Pl. LXXIX, fig. 11—GSM 58673 from a core sample at 4,983 ft in Flaxmans No. 1; fig. 10—GSM 58674 from a core sample at 4,983 ft in Flaxmans No. 1.

Ammobaculites goodlandensis Cushman & Alexander

(Pl. LXXIX, fig. 6)

1930 *Ammobaculites goodlandensis* Cushman & Alexander, *Contr. Cushman Lab.* 6 (1): 8, Pl. 2, fig. 7-8.

1954 *Ammobaculites goodlandensis* Cushman & Alexander, Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 62, Pl. 2, fig. 20.

The robust test consists of a broad initial coil and 2-3 uncoiled chambers. The initial portion is depressed centrally while peripherally the chambers are raised. Sutures are indistinct but are depressed. The uncoiled chambers are irregularly shaped and ovoid in transverse section. The simple aperture is terminal. The arenaceous test walls consist of cemented coarse grains of quartz (up to 0·15 mm long), with small quantities of mica, ferromagnesian minerals, and fragments of calcareous foraminiferal tests. The coarse grained wall composition obscures much detail.

Length of specimens ranges from 0·7 mm to 1 mm; maximum diameter (diameter of coil) from 0·6 mm to 0·38 mm. The maximum thickness is in the uncoiled chambers and is 0·25 mm for all specimens.

DISCUSSION: Victorian specimens are typical of this species which is recorded from sediments of Albian age in the Gulf Coast of America. Some specimens without uncoiled chambers have been assigned to this species.

DISTRIBUTION: Distribution is widespread throughout the Victorian sequence.

FIGURED SPECIMEN: Pl. LXXIX, fig. 6—GSM 58675 from a core sample at 7,403 ft in Port Campbell No. 2.

Ammobaculites subcretacea Cushman & Alexander 1930

(Pl. LXXIX, fig. 7-9)

1930 *Ammobaculites subcretacea* Cushman & Alexander, *Contr. Cushman Lab.* 6 (1): 6, Pl. 2, fig. 9, 10.

1946 *Ammobaculites subcretacea* Cushman & Alexander, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 23, Fig. 18-20.

1952 *Ammobaculites subcretacea* Cushman & Alexander, Brotzen, *Senck.* 33 (4/6): 319, Pl. 1, fig. 8; Pl. 2, fig. 1-9.

The coarse arenaceous test is elongate and compressed laterally. The initial portion consists of 5-7 chambers which are planispirally coiled. The coiled portion is followed by a linear series of 3-4 chambers. The linear chambers are widest immediately after the sutures. The coiled portion is wider than any of the linear chambers. Generally, the linear chambers are flattened in the same plane as the coiling, but in a few specimens the flattening is in the plane perpendicular to that of the coiling. The simple ovoid aperture is terminal, on the tapering neck of the final chamber.

The length in 50 specimens ranges from 0·7 mm to 1 mm.

ADDITIONAL NOTES ON TEST COMPOSITION: The test walls are mainly composed of cemented quartz, with considerable variation in grain size. In some specimens a small amount of mica flakes and a black ferro-magnesian mineral have been incorporated with the test. As can be seen in Pl. LXXIX, fig. 8, the coarser grains in the outer wall of the linear chambers are orientated in the direction of growth, so as to produce a series of ridges and furrows. Although this is not a unique feature in the specimens studied, it is not of specific significance. Other specimens have the same chamber arrangement and shape but the quartz grains are arranged at random, as they are on the type figures of *A. subcretacea.*

OCCURRENCE: This species occurs throughout Zonule A. Only in a core sample from 5,231 ft in Port Campbell No. 1 Well is it an important constituent of the assemblage. Occurs in the Lower Cretaceous in North America, but probably ranges up to the Turonian in Europe (Brotzen).

FIGURED SECIMENS: Pl. LXXIX, fig. 7—GSM 58677 from a core sample at 5,231 ft in Port Campbell No. 1; fig. 8—GSM 58678 from a core sample at 5,231 ft in Port Campbell No. 1; fig. 9—GSM 58676 from a core sample at 5,231 ft in Port Campbell No. 1.

Genus **Textularia** Defrance 1824

Difficulty has been encountered in generically classifying the Victorian Cretaceous textularid forms. Intrinsically, they are all within the genus *Textularia*, but the significance of the initial planispiral coil of some specimens cannot be ignored. It has been shown by Glaessner (1945, p. 98) and others, that the genotype of *Bolivinopsis* Yakovlev 1871 has arenaceous walls. This genus is separated from *Textularia* because the initial coil is equal to or of greater width than the width of the biserial part of the test, at least in the microspheric forms. None of the species described below exhibits this character. However, it is not generally accepted that *Spiroplectammina* Cushman 1927 is a syononym of *Bolivinopsis*. Although *Spiroplectammina* lacks apparent validity, it cannot be ignored because of its use in recent literature. Its generic character is that the initial coil forms a considerable portion of the test in both the microspheric and megalospheric forms. Only one of the species described below, *T. semicomplanata* Carsey, has definitely an initial coil in all specimens, but this coil is but a small portion of the test. Even if *Spiroplectammina* is a valid genus, the Victorian textularids should still be placed within the Genus *Textularia*.

Textularia anceps Reuss 1860

(Pl. LXXIX, fig. 12-15; Pl. LXXXV, fig. 2, 3 (sections))

1860 *Textularia anceps* Reuss, *Sitzber. Akad, Wiss. Wien* 44: 234, Pl. 13, fig. 2.
1957 *Spiroplectammina anceps* (Reuss), Hofker, *Beih. Geol. Jb.* 27: 60, Fig. 56 a-d.

The long wedge-shaped finely arenaceous test is medially thickest. Transversely, the shape is rhomboidal though rounded. The sutures are distinct, depressed, and angled backwards slightly in the biserial part of the test. The narrow slit aperture is at the base of the notch in the final chamber face.

There is considerable diversity within the Victorian specimens of this species. Both microspheric and megalospheric forms are recognized. The larger megalospheric forms have 8-10 pairs of biserial chambers and no indication of initial coiling, while the initially coiled microspheric forms are smaller and have 4-6 pairs of biserial chambers. Some specimens of both forms exhibit inflation of the last pair of chambers and are longitudinally curved. A selection of forms has been illustrated and the dimensions and features are summarized in Table 2.

DISTRIBUTION: In the Victorian Cretaceous sequence this species is found in Zonule A where it is common, although it is not found in the upper part of the Zonule. It is often associated with *Textularia semicomplanata* Carsey. *T. anceps* occurs in the Senonian of Europe.

Textularia semicomplanata Carsey 1926

(Pl. LXXX, fig. 1, 2; Pl. LXXXV, fig. 1 (section))

1926 *Textularia semicomplanata* Carsey, *Texas Univ. Bull.* 2612: 25, Pl. 3, fig. 4.
1931 *Spiroplectammina semicomplanata* (Carsey) Plummer, *Texas Univ. Bull.* 3101: 129, Pl. 8, fig. 7.
1946 *Spiroplectammina semicomplanata* (Carsey) Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 28, Pl. 6, fig. 5-14 (with detailed synonomy).

The fine grained arenaceous tapering test has a maximum width which is always greater than half the length. The test is thicker medially and this thickness increases with chamber addition, while the margin is sharp. The apertural end is rhomboidal.

TABLE 2

Reg. No. GSM	Pl., fig.	Length (mm)	Max. thickness (mm)	Max. width (mm)	Comments	Locality
Microspheric Forms:						
58741	LXXIX, 12	0·52	0·25	0·27		Port Campbell No. 1 core at 5025 ft.
58742	LXXIX, 15	0·51	0·22	0·32	Final chambers inflated.	,,
58802	LXXXV, 2	0·52		0·26	Longitudinal section.	,,
Megalospheric Forms:						
58743	LXXIX, 13	0·8	0·23	0·33		,,
58744	LXXIX, 14	0·72	0·39	0·45	Final chambers greatly inflated.	Port Campbell No. 1 core at 4710 ft.
58801	LXXXV, 3	0·6		0·27	Section last chamber inflated.	,,

Initially 3 or 4 chambers form half a coil round the proloculus. This is followed by 4 to 6 pairs of biserially arranged chambers. The chambers are not inflated although their dimensions increase progressively. The sutures are distinct though slightly depressed, and the biserial chamber sutures curve gently backwards towards the periphery. The terminal face is gently curved. The aperture is a narrow slit-like opening at the base of the apertural face.

The maximum length of the specimens vary from 0·35 mm to 0·45 mm, width from 0·27 to 0·33 mm, thickness from 0·14 mm to 0·16 mm. The width of the coiled portion never exceeds 0·15 mm.

DISCUSSION: The Victorian specimens exhibit little variation. They fit within the range of specific variation illustrated by Cushman (1946), although the Victorian specimens appear to be a little thicker compared to their length.

DISTRIBUTION: Associated with *T. anceps*. Not identified in Zonule B, nor are they present in the upper part of Zonule A. Occurs in the Senonian and Maastrichtian of North America.

FIGURED SPECIMENS: Pl. LXXX, fig. 1—GSM 58745 from a core at 5,025 ft in Port Campbell No. 1; fig. 2—GSM 58746 from a core at 5,025 ft in Port Campbell No. 1; Pl. LXXXV, fig. 1—GSM 58803 from a core at 5,025 ft in Port Campbell No. 1.

Textularia trilobita sp. nov.

(Pl. LXXIX, fig. 16, 17; Pl. LXXXV, fig. 4, 5)

DIAGNOSIS: The robust, fine grained, arenaceous test is of a shiny appearance. The maximum width is greater than half the length. The test is convex on both sides, rising from sharp periphery to a rounded axial ridge. Initially, the margin is rounded, but becomes roughly parallel with serrations where the sutures meet the margins. Transversely, the test is rhomboidal. In the biserial portions of the specimens, the sutures are narrow, depressed, and curve back at 30° to the axis. The terminal chamber overlaps the preceding chambers on one side of the test but not on the other. The abrupt final face has a semi-circular notch with a narrow aperture at the base of the notch.

All specimens exhibit the characters outlined above, but the specimens can be divided into 3 forms.

(a) Microspheric form: has an initial end consisting of half a whorl of 4 chambers with a globular proloculus. The chambers curve in the direction of growth. The initial chambers are followed by 3 to 6 pairs of biserially arranged chambers.

(b) Megalospheric form: is difficult to distinguish on external features. A longitudinal section reveals that there is no initial coil. There are as many as 12 pairs of biserially arranged chambers.

(c) Juvenile form: has only one pair of biserial chambers. The width of the specimens is greater than the length. Only the microspheric form is known for this growth stage.

The length of specimens ranges from 0·25 mm (juvenile form) to 0·9 mm (probably megalospheric form).

HOLOTYPE: GSM 58748, Pl. LXXIX, fig. 16 a-d.

The specimen is from a core sample at 7,093 ft in Port Campbell No. 2.

This is a microspheric specimen. The proloculus and the 4 coiled chambers are prominent. There are 4 pairs of biserial chambers and an unpaired terminal chamber. The test is 0·8 mm long, 0·25 mm thick, 0·54 mm maximum width, and 0·32 mm wide in the coiled portion.

SUPPLEMENTARY SPECIMEN *A*: GSM 58804, Pl. LXXXV, fig. 4.

The specimen is from a rotary cutting sample at 5,540-49 ft in Port Campbell No. 1.

A longitudinal section of a specimen from the same sample and similar in form to the Holotype. The section reveals a circular proloculus around which 4 chambers are arranged in half a whorl before biserially arranged chambers are added. A dark lining is noted on the inside of all chambers; this is most pronounced in the proloculus.

The specimen is 0·73 mm long, 0·51 in maximum width, and 0·3 mm wide in the coiled portion with a proloculus of 0·1 mm in diameter.

SUPPLEMENTARY SPECIMEN *B*: GSM 58805, Pl. LXXXV, fig. 5.

The specimen is from a rotary cutting sample at 5,540-49 ft in Port Campbell No. 2.

A longitudinal section reveals 12 pairs of biserially arranged chambers with an indistinct initial chamber (or chambers). No initial whorl is visible. This is a megalospheric specimen. The initial end is less rounded than in the microspheric specimens. The first 6 pairs of chambers were not visible before sectioning. The specimen is 0·85 mm long and 0·51 mm in maximum width.

SUPPLEMENTARY SPECIMEN *C*: GSM 58747, Pl. LXXIX, fig. 17.

The specimen is from a rotary cutting sample at 6,400-10 ft in Flaxmans No. 1.

A juvenile specimen with one pair of biserial chambers which follows 4 chambers arranged in a half-whorl around a globular proloculus. The specimen is 0·25 mm long, 0·25 mm thick, and 0·32 mm in maximum width.

DISCUSSION: The overlapping, asymetrical terminal chamber is a characteristic feature which differentiates *T. trilobita* from similar species of *Textularia*.

In the higher part of its range, the tests of *T. trilobita* become smaller, but the asymmetrical terminal chamber is retained.

As the microspheric test is reminiscent in shape to the thorax and pygidium of many trilobites, the name *T. trilobita* has been given to this species.

DISTRIBUTION: This species is confined to the upper part of Zonule B. At the top of Zonule B it is replaced by *T. semicomplanata*.

Genus **Dorothia** Plummer 1931

Dorothia conulus (Reuss)

(Pl. LXXX, fig. 3)

1845 *Textularia conulus* Reuss, *Verstein. böhm. Kreide* 1: 34, Pl. 8, fig. 59; Pl. 13, fig. 75.
1937 *Dorothia conula* (Reuss), Cushman, *Spec. Publ. Cushman Lab.* 8: 76, Pl. 8, fig. 11-17 (with synonomy).
1946 *Dorothia conula* (Reuss), Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 44-45, Pl. 12, fig. 12-14.
1954 *Dorothia conulus* (Reuss), Frizzell, *Rep. Inv. Univ. Texas econ. Geol.* 22: 75, Pl. 6, fig. 21.

The arenaceous test is short and stout; maximum width often equals the length. The test tapers and is conical but is compressed so that the transverse section is ovoid. The earliest whorl has 5 chambers but rapidly becomes triserial and then distinctly biserial. The few biserial chambers (2-3 pairs) are inflated. The later sutures are distinctly depressed and straight. The walls are composed of cemented fine grained quartz with an occasional coarser grain. The aperture is a low opening along the inner margin of the terminal chamber. The position of the aperture is marked by a notch in the terminal face. The length of specimens ranges from 0·37 mm to 0·42 mm; the thickness of all specimens is 0·3 mm. The width is not proportional to length. The largest specimen has a length of 0·42 mm and a width of 0·34 mm, while in the smallest specimen both the length and width = 0·37 mm. The thickness of all specimens is 0·3 mm.

DISCUSSION: The specimens are typical of the American material.

DISTRIBUTION: Found only in core samples from 4,974 ft to 4,993 ft in Flaxmans No. 1 Well. From the Senonian of North America and probably from the Senonian of Europe.

FIGURED SPECIMEN: Pl. LXXX, fig. 3—GSM 58698 from a core at 4,983 ft in Flaxmans No. 1.

Dorothia filiformis (Berthelin)

(Pl. LXXX, fig. 4)

1880 *Gaudryina filiformis* Berthelin, *Mem. Geol. France* ser. 3 1: 25, Pl. 1 (24), fig. 8.
1937 *Dorothia filiformis* (Berthelin), Cushman, *Spec. Publ. Cushman Lab.* 8: 73, Pl. 8, fig. 1, 2 (with synonomy).
1954 *Dorothia filiformis* (Berthelin), Bartenstein, *Senck.* 35 (1/2): 39, Pl. 1, fig. 14-15.

The finely arenaceous test is elongate, very narrow and circular in transverse section, although a large percentage of specimens are squashed. The initial end is bluntly pointed, but most of the test is parallel-sided. The earlier whorls have 5 chambers, but the number of chambers decreases rapidly with succeeding whorls. Two-thirds of the test comprises 5-7 pairs of biserial chambers. The biserial portion of the test is often somewhat twisted. The distinct, depressed sutures are horizontal or slightly flexed back. The narrow aperture is sutural along the inner margin of the terminal chamber.

The average length of specimens is 0·5 mm with an extreme of 1 mm. The maximum thickness (not compressed) is 0·1 mm to 0·15 mm.

DISTRIBUTION: Very common species throughout the sequence, although irregular in frequency.

Occurs in the Lower Cretaceous of Europe and Bartenstein states that it probably ranges up to the Turonian.

FIGURED SPECIMEN: Pl. LXXX, fig. 4—GSM 58697 from a core at 4,652 ft in Belfast No. 4.

Genus **Marssonella** Cushman 1933

Marssonella oxycona (Reuss)

(Pl. LXXX, fig. 5-7)

1860 *Gaudryina oxycona* Reuss, *S.B. öst, Akad. Wiss.* 40: 229, Pl. 12, fig. 3.
1937 *Marssonella oxycona* (Reuss) Cushman, *Spec. Publ. Cushman Lab.* 8: 56-59, Pl. 5, fig. 27-29; Pl. 6, fig. 1-17 (with detailed synonomy).
1960 *Marssonella oxycona* (Reuss) Moullade, *Revue de Micropal.* 3 (2): 131-3, Pl. 1, fig. 1-5 (with detailed synonomy).

Conical, fine grained, arenaceous test. At the initial end there is a distinct proloculus then a 4-chambered whorl, but the test rapidly becomes triserial and finally biserial. The sutures are distinct, being flush with the surface. The aperture is a low slit along the marginal suture of the terminal face; it is often accommodated within a curved identation in the terminal face.

The actual shape of the conical test is a variable feature. A range of variation was noted within the Victorian sequence, and it was observed that this range was present in any sample where *Marssonella oxycona* was abundant. For the purpose of studying this variation, a core sample at 5,960 ft in Flaxmans No. 1 was selected and an exhaustive pick yielded 100 specimens. The following features were noted:

(i) Shape of initial end: either distinctly pointed, or bluntly rounded. No intrinsic difference in intial chamber arrangement could be observed. Bartenstein & Brand (1951) attribute this primary variation to dimorphism. It is noted that none of the larger specimens (length $> 0\cdot33$ mm) are intially blunt. Also, the blunt specimens rapidly obtain maximum diameter, so that the ratio of length to diameter equals or approaches 1 : 1.

(ii) Form of cone: the angle of the tapering varies. It can best be expressed in terms of length to diameter, as the specimens which attain maximum diameter gradually are more conical than those which attain it quickly. Therefore, initially pointed specimens, which have a ratio of length to diameter approachin 2 : 1, are more conical than the initially blunt specimens where the ratio approaches 1 : 1.

(iii) Flaring of terminal chamber: this is a factor which appears to contradict the above conclusions. There are a limited number of specimens which have a pointed initial end and are distinctly tapered, yet the ratio of length to maximum diameter = 1 : 1 and the length is well over 0·33 mm. However, these specimens do not attain maximum diameter until the terminal chamber and the width of this chamber is much greater than the width of the preceding chambers, as can be seen in Pl. LXXX, fig. 7.

As already mentioned, these variants intergrade in all features apart from chamber flaring. It would appear that chamber flaring is a random feature. Specimens which exhibit this feature are not comparable with *Textularia trochus* d'Orb, in which the width of the chambers increase gradually and proportionally: Minimum length = 0·2 mm; maximum length = 0·75 mm.

DISTRIBUTION: *Marssonella oxycona* is distributed throughout the Victorian sequence, although it is rare or absent high in the sequence. Even though there is a world-wide break in the distribution of *M. oxycona* during the Aptian, Moullade (1960, p. 131-3) concludes that the forms on either side of this break are analagous and thus, *M. oxycona* is present in both the Lower and Upper Cretaceous.

FIGURED SPECIMENS: Pl. LXXX, fig. 5—GSM 58725 from a core at 5,950 ft in Flaxmans No. 1; fig. 6—GSM 58724 from a cutting sample at 6,010 to 6,017 ft in Port Campbell No. 2; fig. 7—GSM 58723 from a core at 5,950 ft in Flaxmans No. 1.

Genus **Cornuspira** Schultze 1854

Cornuspira involvens (Reuss)

(Pl. LXXX, fig. 8)

1850 *Operculina involvens* Reuss, *K. Akad. Wiss. Wien. Math-Nat.*, Bd. 1: 370, Pl. 46, fig. 20.
1891 *Cornuspira involvens* (Reuss), Chapman, *J. Roy. Micro. Soc.* 11: 574, Pl. 9, fig. 12.
1958 *Cornuspira involvens* (Reuss), Pokorny, *Mikropalaontologie*, Berlin, 1: 249, Fig. 210.

The unornamented test is a long planispirally coiled tube of imperforate calcareous material of a porcellanous appearance, orange in colour. Both surfaces are concave. The tube gradually increases in diameter and the whorls slightly overlap the succeeding whorls. The proloculus is missing in all Victorian specimens. The aperture is a simple opening at the end of the tube where there is some thickening of the wall.

The diameter of specimens ranges from 0·4 mm to 0·65 mm, thickness from 0·1 mm to 0·15 mm.

DISCUSSION: The Victorian specimens are typical of the Lower Cretaceous specimens from Europe. In test shape, this species resembles *Operculina cretacea* Reuss 1845 (*non* Reuss 1862). Cushman (1934) places this species within the genus *Ammodiscus* as its walls are composed of arenaceous material.

DISTRIBUTION: Occurs with *Quinqueloculina* spp., mainly in Zonule A. Reported only from the Lower Cretaceous of Europe.

FIGURED SPECIMEN: Pl. LXXX, fig. 8—GSM 58694 from a core sample at 5,025 ft in Port Campbell No. 1.

Cornuspira subprimitiva Bartenstein & Brand

(Pl. LXXX, fig. 9-10)

1951 *Cornuspira? primitiva* Bartenstein & Brand, *Senckenb. Naturf. Ges.* 485: 279, Pl. 4, fig. 90.
1952 *Cornuspira? subprimitiva* Bartenstein & Brand, *Thalmann, J. Paleont.* 26 (6): 972.

The planispiral discoidal test has calcareous imperforate walls of granular structure and the surface is roughened. One face is flat while the other is slightly convex and the periphery is rounded. There is a globular proloculus followed by a tube-like second chamber of 2-3 volutions. Simple aperture at end of tube.

Diameter of specimens ranges from 0·22 mm to 0·26 mm; thickness is constant at 0·1 mm.

DISCUSSION: The roughened surface veils the chamber structure, so it was found necessary to immerse one specimen in weak acid. The Victorian *C. sub-*

primitiva agrees with the generic diagnosis of *Cornuspira*, as well as with the type description and figures of *C.* ? *subprimitiva* Bartenstein & Brand.

DISTRIBUTION: Rarer than *C. involvens* with which it is associated in the sequence. Reported from the Lower Cretaceous.

FIGURED SPECIMENS: Pl. LXXX, fig. 9 a-b—GSM 58695 from a core sample at 4,757 ft in Port Campbell No. 1; fig. 10—GSM 58693 from a core sample at 4,757 ft in Port Campbell No. 1.

Genus **Quinqueloculina** d'Orbigny 1826

Quinqueloculina sp.

(Pl. LXXX, fig. 11)

The small angular test is a little greater in length than in width and is triangular in transverse section with flat faces and rounded peripheries. The terminal aperture does not protrude, is rounded, and contains a definite tooth plate. The test is of imperforate calcareous material, porcellanous in appearance and orange in colour, but some specimens have fine grained arenaceous material incorporated in the test.

Length of specimens ranges from from 0·33 mm to 0·5 mm, maximum thickness from 0·25 to 0·33 mm.

DISCUSSION: This species of *Quinqueloculina* lacks distinctive characters to the point of being unclassifiable on a specific level. Similar to some living *Quinqueloculina.*

DISTRIBUTION: Occurs mainly in Zonule A, abundant in some samples (e.g. core at 4,757 ft in Port Campbell No. 1), absent in others. Its distribution appears to be facies controlled.

FIGURED SPECIMEN: Pl. LXXX, fig. 11—GSM 58737 from a core at 4,757 ft in Port Campbell No. 1.

Genus **Nodosaria** Lamarck 1812

Nodosaria obscura Reuss

(Pl. LXXX, fig. 12-13)

1845 *Nodosaria obscura* Reuss, Verstein, *bohm. Kreide.* 1: 26, Pl. 13, fig. 7-9.
1936 *Nodosaria obscura* Reuss, Brotzen, *Sver. geol. Unders.* ser. C 396: 84, Pl. 5, fig. 24-25; Fig. 26-27 (with synonymy).
1946 *Nodosaria obscura* Reuss, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 73, Pl. 26, fig. 15, 16.
1960 *Nodosaria obscura* Reuss, Belford, *Bur. Min. Resourc. Aust. Bull.* 57: 36-38, Pl. 11, fig. 1-3; Fig. 1 (with synonomy).

The elongate test comprises a linear series of chambers. The test is widest in the terminal chamber and tapers towards the initial end where it is distinctly pointed. In transverse section the chambers are circular. The chambers progressively increase in length, although this is not a constant feature in the earlier chambers of some specimens. The external test wall is ornamented by 8-10 longitudinal costae which are continuous along the whole length of the test. The costae coalesce at the terminal end where the aperture is simple and surrounded by a distinct collar.

The few Victorian specimens of this species fall into two groups, namely:

(i) A broad 4-chambered form, the length is twice the width, length (mm) to width (mm) in 4 specimens being—0·4 : 0·22, 0·38 : 0·2, 0·35 : 0·19, and 0·28 : 0·14. Typical specimen of this form is illustrated in Pl. LXXX, fig. 13.

(ii) A slender 7-9 chambered form, the proportion of length to width is 5 : 2, these dimensions (mm) in 4 specimens being 0·54 : 0·21, 0·52 : 0·19, 0·51 : 0·19, and 0·47 : 0·18. Typical specimen of this form is illustrated in Pl. LXXX, fig. 12.

DISCUSSION: Both Brotzen (1936) and Bedford (1960) discuss variation within this species and divide their material into a series of types. With so little material available, to assign the described specimens to any of these types is difficult, although the broad form appears to fit Brotzen's Type III. The clear-cut differentiation between the two forms may well indicate megalospheric and microspheric generations, but more material is required to substantiate this.

DISTRIBUTION: Rare in the Victorian sequence. A typically Senonian species from Europe, North America, and Western Australia.

FIGURED SPECIMENS: Pl. LXXX, fig. 12—GSM 58732 from a core at 5,950 ft in Flaxmans No. 1; fig. 13—GSM 58731 from a core at 4,757 ft in Port Campbell No. 1.

Nodosaria cf. **obscura** Reuss

(Pl. LXXX, fig. 14)

Similar to the described 7-9 chambered specimens of *N. obscura*, except that the 8 longitudinal costae bifurcate at the beginning of the last chamber. Only one specimen has been found but its ornamentation is distinctive enough to separate it from the other specimens of this species. No reference to costae bifurcation in *N. obscura* can be found in the literature.

OCCURRENCE: The single specimen GSM 58730 is from a core at 4,710 ft in Port Campbell No. 1 Well.

Nodosaria alternistriata Morrow

(Pl. LXXX, fig. 15-16)

1934 *Nodosaria alternistriata* Morrow, *J. Paleont.* 8: 190, Pl. 29, fig. 1.
1946 *Nodosaria alternistriata* Morrow, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 71, Pl. 26, fig. 3, 4.

The test consists of a linear series of 6-9 cylindrical chambers. The test is circular in transverse section. Progressive increase is not a constant feature in chamber width and height, as the last chamber may not be as wide as the preceding one, and often a long narrow chamber is between the shorter, broader ones. Sutures are depressed, earlier sutures often obscured by surface ornamentation. The external surface is covered by numerous costae (16-20) which vary in intensity. The costae reach almost to the distinct collar which surrounds the aperture.

The lengths of specimens vary from 0·6 mm to 0·8 mm, maximum width from 0·25 mm to 0·3 mm.

DISCUSSION: Whether *N. alternistriata* is a synonym of *N. fusula* Reuss 1872 is not considered, although it is implied by Cushman (1946). The Victorian specimens agree in all features with the description of the former species but differ from the latter in not having a drawn out apertural neck.

DISTRIBUTION: Fairly rare in the Victorian sequence. From the lower Senonian in North America.

FIGURED SPECIMENS: Pl. LXXX, fig. 15—GSM 58727 from a core at 5,025 ft in Port Campbell No. 1; fig. 16—GSM 58726 from a core at 5,950 ft in Flaxmans No. 1.

Nodosaria navarroana Cushman

(Pl. LXXX, fig. 17-18)

1937 *Nodosaria navarroana* Cushman, *Cushman Lab. Contr.* 13 (4): Pl. 15, fig. 11.
1946 *Nodosaria navarroana* Cushman, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 73, Pl. 26, fig. 23-24.
1954 *Nodosaria navarroana* Cushman, Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 62, Pl. 2, fig. 20.

The elongate test tapers at the initial end but the final 3-4 chambers are of the same diameter. In transverse section the test is 5-sided with each side slightly concave. The angles of the test are marked by 5 longitudinal costae which extend from the initial end to the apertural collar where they coalesce. Each of the 7-8 chambers partially embrace the preceding chamber, and the increase in chamber length is not always progressive. The distinct sutures are straight to slightly curved but form a backwardly directed 'V' along the costae. The terminal end tapers up to the simple aperture which is surrounded by a definite collar.

The length of specimens ranges from 0·3 mm to 0·5 mm, while the maximum diameter ranges from 0·11 mm to 0·2 mm.

Discussion: The few Victorian specimens assignable to this species show some variation in degree of ornamentation and the degree of initial tapering. Despite the fact that the type description of *N. navarroana* states that 4 longitudinal costae are present, the type figure clearly shows 5 costae. *N. orthopleura* is a very similar species but is much larger (Holotype = 3 mm in length).

Distribution: Very rare, found only in Zonule A. From the Campanian and probably Maastrichtian in North America.

Figured Specimens: Pl. LXXX, fig. 17—GSM 58729 from a core at 4,652 ft in Belfast No. 4; fig. 18—GSM 58728 from a core at 5,950 ft in Flaxmans No. 1.

Genus **Dentalina** d'Orbigny 1826

Dentalina cf. **intrasegma** (Carsey)

(Pl. LXXX, fig. 19)

1926 *Nodosaria intrasegma* Carsey, *Univ. Texas Bull.* 2612: 33, Pl. 4, fig. 10.
1938 *Dentalina solvata* Cushman, *Contr. Cushman Lab.* 14 (2): 39-40, Pl. 6, fig. 9-14.
1946 *Dentalina solvata* Cushman, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 68, Pl. 24, fig. 13-17, 22.
1954 *Dentalina intrasegma* (Carsey), Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 88, Pl. 9, fig. 52-54.

None of the available specimens is complete; the initial ends are missing and the terminal chambers may not be present. The test is a linear series of slender, elongate, bead-like chambers which increase progressively in length and are circular in transverse section. The test is indented at the sutures which are thickened. The surface of some of the larger chambers is smooth, while on others there are fine longitudinal costae. These costae persist across all the sutures. The simple aperture is terminal and central and appears to have been on a neck.

The length of the largest specimen (figured specimen: 4 chambers intact) is 0·68 mm with a maximum width of 0·15 mm.

Discussion: The fragmentary nature of the specimens does not permit a confident determination. However, the persistence of the costae over the sutures is a specific character of *D. intrasegma.*

Distribution: Fairly rare, but difficult to identify positively. *D. introsegma* is described from the Senonian of North America.

Figured Specimen: Pl. LXXX, fig. 19—GSM 58696 from a core at 5,025 ft in Port Campbell No. 1.

Genus **Lenticulina** Lamarck 1804

Representatives of the genus *Lenticulina* are a fairly constant feature of the fauna, though by no means abundant. Intergradation has made specific determinations difficult. Only 3 distinct species have been described, 2 of which are regarded to be of local stratigraphic importance. The undescribed forms of this genus are listed as *Lenticulina* spp. in the distribution charts.

Closely related genera to *Lenticulina* have been erected, but have been relegated to sub-generic status by some authors, including Pokorný (1958, p. 277-9). This procedure has been followed in the belief that *Marginulinopsis* Silvestra 1904, *Saracenaria* Defrance 1824, *Robulus* Montfort 1808, etc. are not generically distinct from *Lenticulina.*

Subgenus **Robulus** Montfort 1808

Lenticulina (Robulus) navarroensis (Plummer)

(Pl. LXXXI, fig. 1-3)

1927 *Cristellaria navarroensis* Plummer, *Texas Univ. Bull.* 2644: 39, fig. 4.
1946 *Robulus navarroensis* (Plummer) Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 51-2, Pl. 16, fig. 6-8 (with synonomy).
1954 *Robulus navarroensis* (Plummer) var. *navarroensis* Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 81, Pl. 8, fig. 6.
1936 *Robulus navarroensis* (Plummer) var. *extruatus* Cushman, *Contr. Cushman Lab.* 14: 31, Pl. 5, fig. 1.
1946 *Robulus navarroensis* (Plummer) var. *extruatus* Cushman, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 52, Pl. 16, fig. 9, 10; pl. 17, fig. 2 (with synonomy).
1954 *Robulus navarroensis* (Plummer) var. *extruatus* Cushman, Frizzell, *Rep. Inv. Texas Bur. econ. Geol.* 22: 81, Pl. 8, fig. 6.

A test of 7 to 12 chambers around a distinct central boss. The sutures are limbate, slightly to distinctly raised and fuse with the central boss. The periphery has a broad thin keel.

This is the largest species in the Victorian sequence as it obtains a maximum diameter of 2·2 mm. The maximum thickness (thickness of central boss) is one-third of the diameter.

Discussion: Typical of the American representatives of this species, although some Victorian specimens have as few as 7 chambers, while the American species have from 10 to 12 chambers. It is impossible to separate the specimens with distinctly raised sutures from those with slightly raised sutures. For this reason, *R. navarroensis* var. *extruatus* is not recognized.

Distribution; Rarely and sporadically distributed throughout the sequence. Occurs in the upper Senonian in North America.

Figured Specimens: Pl. LXXXI, fig. 1—GSM 58738 from a core at 5,025 ft in Port Campbell No. 1; fig. 2—GSM 58739 from a core at 5,910 ft in Port Campbell No. 2; fig. 3—GSM 58740 from a cutting sample at 5,400-10 ft in Port Campbell No. 1.

Subgenus **Marginulinopsis** Silvestri 1904

Lenticulina (Marginulinopsis) jarvisi (Cushman)

(Pl. LXXXI, fig. 6)

1938 *Marginulina jarvisi* Cushman, *Contr. Cushman Lab.* 14: 35, Pl. 5, fig. 17-18.
1946 *Marginulina jarvisi* Cushman, Cushman, *Prof. Pap. U.S. Geol. Surv.* 207: 63, fig. 18-20.

The smooth walled elongate test is ovoid in cross section and has a rounded periphery. The early portion is coiled with 4 chambers and there are 3-5 linear chambers. All curved sutures are distinct; the earlier ones are limbate while the later are narrower but depressed. The radiate aperture is peripheral. The linear chambers are parallel-sided, except in the terminal chamber where the terminal face slopes steeply for two-thirds of the chamber length. The coiled portion does not project laterally beyond the sides of the linear chambers. Maximum length is 0·9 mm, and maximum diameter is 0·35 mm.

DISCUSSION: The steep terminal face and limbate early sutures distinguish this species from other smooth walled members of the sub-genus.

DISTRIBUTION: Restricted to the bottom part of the sequence. Usually confined to Zonule B, but has been recorded several hundred feet above this Zonule. Is not an abundant form. Occurs in the Upper Cretaceous, probably upper Senonian.

FIGURED SPECIMEN: Pl. LXXXI, fig. 6—GSM 58722 from a core sample at 7,093 ft in Port Campbell No. 2.

Lenticulina (Marginulinopsis) curvisepta (Cushman & Goudkoff)

(Pl. LXXXI, fig. 4-5)

1944 *Marginulina curvisepta* Cushman & Goudkoff, *Contr. Cushman Lab. Foram. Res.* 20: 57, Pl. 9, fig. 12-13.

The roughened, elongate test has a planispirally coiled early portion which is somewhat depressed with a distinct keel. The chambers in the coiled portion are indistinct though distinct in the uncoiled portion as the sutures are depressed. The uncoiled chambers are ovoid to circular in cross section and are parallel-sided with the terminal face flat to faintly angled. The coiled portion projects laterally on one side beyond the uncoiled chamber. The test is ornamented by many distinct, longitudinal costae which extend from the coiled portion to the radiate peripheral aperture.

DISCUSSION: The inflated linear chambers and the complete ornamentation of the test distinguishes this species from other ornamented species of *L.* (*Marginulinopsis*) in the sequence.

DISTRIBUTION: Occurs rarely throughout the sequence, yet it is of importance as it appears high in the sequence and helps confirm the highest recognitions of Cretaceous sediment in well sequences. Upper Cretaceous, but exact range is not known.

FIGURED SPECIMENS: Pl. LXXXI, fig. 4—GSM 58720 from a cutting sample at 5,600 to 5,610 ft in Port Campbell No. 2; fig. 5—GSM 58721 from a cutting sample at 5,600 to 5,610 ft in Port Campbell No. 2.

Genus **Marginulina** d'Orbigny 1826

Marginulina inaequalis Reuss

(Pl. LXXXI, fig. 7-8)

1860 *Marginulina inaequalis* Reuss, Sitzber, *Akad. Wiss. Wien.* 44: 207, Pl. 5, fig. 3.
1936 *Marginulina inaequalis* Reuss, Brotzen, *Sver. Geol. Unders., Ser. C* 396: 63-4, Pl. 4, fig. 3 (with detailed synonomy).

The smooth calcareous test consists of a linear series of 5 to 6 chambers. In outline it is straight or slightly curved and is circular in transverse section. The initial end of the test is rounded with a globular transparent area which appears to be the proloculus. The chambers increase gradually in diameter so that the sides of the test are not parallel. There is little increase in the height of chambers apart from the terminal chamber which is twice as high as the preceding one. The final face slopes obliquely away from the aperture to half way down the terminal chamber. The distinct, depressed sutures slope down from the apertural side. The simple aperture with its grooved neck is on one side of the test.

Length of specimens ranges from 0·5 mm to 0·65 mm, maximum diameter of last chamber ranges from 0·15 mm to 0·22 mm.

Distribution: Rare in the sequence. Occurs in the Lower Cretaceous and throughout the Upper Cretaceous.

Figured Specimens: Pl. LXXXI, fig. 7—GSM 58718 from a core at 4,757 ft in Port Campbell No. 1; fig. 8—GSM 58719 from a core at 5,950 ft in Flaxmans No. 1.

Genus **Citharina** d'Orbigny 1839

Citharina geisendoerferi (Franke)

(Pl. LXXXI, fig. 10)

1928 *Vaginulina geisendörferi* Franke, *Abh. preuss. geol. Landesanst.* N.S. 11: 80, Pl. 7, fig. 18.
1954 *Citharina geisendörferi* (Franke), Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 94, Pl. 11, fig. 5.
1960 *Citharina geisendörferi* (Franke), Belford, *Bur. Min. Resour. Aust. Bull.* 57: 40, Pl. 11, fig. 14-15.

The smooth calcareous test consists of 2 ovoid chambers with low convex faces. The base of the proloculus is rounded but the two sides are parallel; in the later chamber the apertural side remains straight while the other side converges with it at the aperture. The suture is broad and depressed and is higher on the apertural side. The periphery of the test is bicarinate throughout. The terminal aperture is a simple protruding tube covered by the clear peripheral material.

The dimensions of the 4 available specimens approximate to those of the figured specimen which are: length = 0·45 mm, maximum width = 0·2 mm, and maximum thickness (= thickness of proloculus) = 0·16 mm.

Distribution: Very rare. Occurs in the Turonian of Europe, but Belford records it from lower Senonian of Western Australia.

Figured Specimen: Pl. LXXXI, fig. 10—GSM 58687 from a core at 4,757 ft in Port Campbell No. 1.

Citharina whangaia (Finlay)

(Pl. LXXXI, fig. 9)

1939 *Planularia whangaia* Finlay, *Trans. Roy. Soc. N.Z.* 69 (3): 317, Pl. 26, g. 63-65.

The test is triangular in outline and wedge-shaped in side view, as each chamber is higher aperturally than initially and the chamber height increases progressively.

The proloculus is elongate, but forms a curve in the base of the straight apertural side of the test. 6-9 chambers are present. The periphery of the ultimate chamber is concave with a ridge on both edges. Fine longitudinal costae are present on all chambers including the proloculus, but these costae do not appear to cross the prominent sutures.

The length of specimens ranges from 0·55 mm to 0·88 mm.

DISCUSSION: Although Finlay does not describe variation in chamber height (both individually and collectively), the Victorian specimens exhibit close similarity to *C. whangaia* and the ornamentation pattern is identical. Similarities are also noted with the Western Australian and Victorian Paleocene species *C. subplumoides* (Parr), but in this species the sutures are not so distinct and the ornamentation crosses them.

None of the author's specimens was complete, so Dr Glaessner kindly lent the few specimens from his collection.

DISTRIBUTION: Very rare. Probably confined to Zonule A. This species was described from the New Zealand Campanian.

FIGURED SPECIMEN: Pl. LXXXI, fig. 9—GSM 58688 from a core sample 5,910 ft in Port Campbell No. 2.

Genus **Frondicularia** Defrance 1826

Frondicularia cf. **mucronata** Reuss

(Pl. LXXXI, fig. 11-12)

1845 *Frondicularia mucronata* Reuss, *Verstein bohm. Kreide* 1: 31, Pl. 13, fig. 43-44.
1939 *Frondicularia mucronata* Reuss, Finlay, *Trans. Roy. Soc. N.Z.* 69 (3): 316, Pl. 26, fig. 58.
1946 *Frondicularia mucronata* Reuss, Cushman, *Prof. Pap. Geol. Surv.* 206: 87, Pl. 34, fig. 14-17.
1954 *Frondicularia mucronata* Reuss, Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 99, Pl. 12, fig. 36-37.
1957 *Frondicularia mucronata* Reuss, Hofker, *Beih. geol. Jb.* 27: 153 (reference only).
1960 *Frondicularia mucronata* Reuss, Belford, *Bur. Min. Resur. Aust. Bull.* 57: 46, Pl. 12, fig. 10-11 (with detailed synonymy).

No complete tests of this species were isolated, so only fragments can be described. All the fragments are of smooth, calcareous, thick walled tests which are broad, though compressed laterally.

(i) Initial end: Has a very elongate proloculus with a raised central ridge, and protrudes as a basal spine. The proloculus is in part parallel-sided, but the sides then converge towards the terminal end. Each of the 7 embracing chambers appear to have the same outline as the proloculus. The sutures are clear but not depressed. There is a peripheral flange of transparent test material which is the same thickness as the chambers.

(ii) Apertural end: Each chamber converges to a parallel-sided apertural neck which has a simple aperture.

In these fragments the maximum width is 0·6 mm and the length of the proloculus is 0·3 mm. The length of a complete test is expected to be 1·5 mm approximately.

DISCUSSION: The elongate, ridged proloculus and the partial parallelism of chamber outlines are characters of *F. guestphalica* Reuss and *F. mucronata* Reuss. The chamber walls of the former species are ornamented with grooves, which is not a feature of the Victorian material. Close affinities with *F. mucronata* are evident, but a precise specific determination is not justified with the fragmentary material available.

Distribution: Very rare and occurs only in Zonule A. A Senonian form, though Hofker mentions it as a Turonian species.

Figured Specimens: Pl. LXXXI, fig. 11—GSM 58699 from a cutting sample at 6,010 to 6,017 ft in Port Campbell No. 2; fig. 12—GSM 58700 from a cutting sample at 6,010 to 6,017 ft in Port Campbell No. 2.

Frondicularia sp.

(Pl. LXXXI, fig. 13)

The single specimen is broken at the terminal end. The elongate operculus is inflated with a single, longitudinal costae on both sides and a terminal spine. The only other chamber embraces most of the proloculus though not its base. This second chamber is slightly convex but not as thick as the proloculus. The outer margin is bi-carinate while the inner margin is marked by a distinct limbate suture. The test tapers towards the apertural end with the greatest width at a third of the length from the terminal spine.

The length of the specimen = 0·3 mm, maximum width = 0·18 mm, maximum thickness (= thickness of proloculus) = 0·11 mm.

Discussion: The incompleteness of this specimen makes specific identity difficult, especially as the mode of chamber addition is not known. The elongate, costate proloculus with terminal spine is similar to specimens here described as *F.* cf. *mucronata* Reuss. However, both chambers of this specimen are inflated. Also, it is suspected that chamber addition is of elongate and not lateral pattern as in *F. mucronata.* No other described species shows the essential features of this specimen which may represent a new species.

Distribution: The single specimen GSM 58701 was found in a core sample from 4,652 ft in Belfast No. 4.

Genus **Globulina** d'Orbigny 1826

Globulina lacrima Reuss

(Pl. LXXXI, fig. 14)

1845 *Polymorphina* (*Globulina*) *lacrima* Reuss, *Verstein. bohm. Kreide* 1: 20, Pl. 12, fig. 6; Pl. 13, fig. 83.
1946 *Globulina lacrima* Reuss, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 96, Pl. 40, fig. 8-10 (with detailed synonymy).
1957 *Globulina lacrima* Reuss, Hofker, *Beih. geol. Jb.* 27: 107-8, Fig. 212-3 (with detailed synonymy).

The smooth, finely perforate test is subglobular with a broadly rounded base. Each chamber has a hemispherical outline on the test surface and partially overlaps the preceding chambers. 4 chambers are visible, the earliest chamber is only visible at the base, but the later 3 extend to the base. The curved sutures are distinct and depressed. The terminal chamber is produced up to the radiate aperture. The length of specimens is from 0·35 mm to 0·4 mm, the maximum width from 0·3 to 0·35 mm, and maximum thickness from 0·25 m to 0·3 mm.

Discussion: This form may be referable to *G. lacrima subsphaerica* (Berthelin), as the maximum width is a little greater than the maximum thickness.

Distribution: Found rarely in cores from Zonule A. This is a wide ranging species.

Figured Specimen: Pl. LXXXI, fig. 4—GSM 58703 from a core at 5,900 ft in Port Campbell No. 2.

Genus **Praebulimina** Hofker 1953

Praebulimina ovulum (Reuss)

(Pl. LXXXI, fig. 15)

1844 *Bulimina ovulum* Reuss (non *ovula* d'Orbigny), *Geog. Skizzen Bohm.* 2: 215.
1934 *Bulimina reussi* Morrow, new name. Morrow, *J. Paleont.* 8: 195, Pl. 29, fig. 12.
1946 *Bulimina reussi* Morrow, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 120, Pl. 51, fig. 1-5 (with synonomy).
1951 *Praebulimina ovula* (Reuss), Hofker, *Siboga Exped., Mongr. 4a, Leiden*, p. 123, Fig. 73, 74.
1954 *Bulimina ovulum* Reuss ver. *ovulum* Reuss, Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 115, Pl. 17, fig. 2.
1957 *Praebulimina ovulum* (Reuss), Hofker, *Beih. Geol. Jb.* 27: 184.
1960 *Praebulimina ovulum* (Reuss), Belford, *Bur. Min. Resour. Aust. Bull.* 57: 64-5, Pl. 16, fig. 7-9 (with synonomy).

The small, smooth walled, finely perforate test is globular being sub-circular in transverse section. The chambers rapidly increase in size so that the test tapers to a rounded initial end. Initial chambers are indistinct but later ones are triserially arranged. The sutures are narrow and flush with surface. The virguline aperture is sub-terminal.

Maximum length of specimens ranges from 0·15 mm to 0·2 mm with maximum width from 0·1 mm to 0·15 mm.

Discussion: The belief that *B. ovulum* Reuss 1844 was a homonym of *B. ovula* d'Orbigny 1839 led to the erection of *B. reussi* Morrow 1934 for Reuss's species. But subsequent authors show that *B. ovulum* Reuss is valid, and that this species is taxonomically distinct from *B. ovula* d'Orbigny (refer Belford 1960, p. 64).

Distribution: The distribution of this species is sporadic, even within the one core. Appears to be confined to the dark mudstones of Zonule A. Widely distributed in Santonian and Campanian deposits.

Figured Specimen: Pl. LXXXI, fig. 15—GSM 58736 from a core at 4,757 ft in Port Campbell No. 1.

Genus **Buliminella** Cushman 1911

Buliminella cf. **parvula** Brotzen

(Pl. LXXXI, fig. 16)

1948 *Buliminella parvula* Brotzen, *Sver. Geol. Unders. C.* 443: 57, Pl. 10, fig. 3, 4.
1957 *Praebulimina parvula* (Brotzen), Hofker, *Beih. geol. Jb.* 27: 193, Fig. 238.

The very small test is 1½ times as long as broad, though some specimens are more elongate. There are at least 3 whorls with 4 chambers to the whorl. The earlier chambers are indistinct. The later sutures are narrow and slightly depressed. The initial end is bluntly rounded. The loop-shaped aperture extends from the final suture into the final chamber face. The test is finely perforate and smooth.

The dimensions of specimens range from 0·13 mm long and 0·07 mm wide, to 0·23 mm long and 0·1 mm wide.

Discussion: The Victorian material is more elongate than typical specimens of *B. parvula*, but otherwise is closely comparable. Some specimens from Dr Glaessner's material are markedly elongate and are regarded by him as having close affinities to *B. westraliensis* Parr from the Australian Paleocene. The author believes that there are forms (within the one sample) which are intermediary between that considered as *B.* cf. *parvula* and *B.* aff. *westraliensis*. At present, all specimens are assigned to *B.* cf. *parvula*, although further material may clearly show a new species should be erected.

DISTRIBUTION: Sporadic, found only in Zonule A. *B. parvula* occurs in the European Maastrichtian.

FIGURED SPECIMEN: Pl. LXXXI, fig. 16—GSM 58679 from a core at 4,652 ft in Belfast No. 4 Bore.

Genus **Allomorphina** Reuss 1850

Allomorphina pyriformis sp. nov.

(Pl. LXXXII, fig. 5)

DESCRIPTION OF HOLOTYPE: GSM 58673, Pl. LXXXII, fig. 5.

The smooth walled test is pear shaped. It has a depressed spire on one side and is bi-convex with a rounded periphery. 4 whorls are visible on the spiral side with 3 chambers to the whorl. The terminal chamber of each whorl is distinctly elongate, its length being ⅔ of the total length of the whorl. The sutures are distinct though only slightly depressed. Only 3 chambers are visible on the umbilical side. There is a straight marginal suture between the terminal chamber and both the preceding chambers. The apertural slit occupies ⅔ of this suture but does not reach the periphery. There is a broad apertural lip which slightly overlaps both the preceding chambers.

The test is 0·5 mm long, 0·4 mm in maximum width, and 0·33 mm in maximum height. (Both the maximum width and height are those of the first 2 chambers of the last whorl, as the terminal chamber tapers away from the marginal suture.

The specimen is from a core sample at 4,974 ft in Flaxmans No. 1 Well.

UNFIGURED SPECIMENS: All other specimens are poorly preserved. The pear-shape of the whorls and the straight marginal suture on the ventral side are constant features. The length of specimens ranges from 0·25 mm to 0·53 mm, while the width from 0·25 mm to 0·42 mm.

DISCUSSION: The straight marginal suture with the apertural lip overlapping both preceding chambers, makes this species distinct from other Cretaceous *Allomorphina*. But these features are exhibited in the Paleocene form *A. halli* Jennings 1936 and *A. paleocenica* Cushman 1948. Neither of these species has such radially elongate and tapering terminal chambers.

The specific name of *A. pyriformis* alludes to its pear-shaped whorls.

DISTRIBUTION: This is an extremely rare species.

Genus **Pallaimorphina** Tappan 1957

Pallaimorphina heliciformis sp. nov.

(Pl. LXXXII, fig. 6-7)

DESCRIPTION OF HOLOTYPE: GSM 58734. Pl. LXXXII, fig. 6.

The small, finely perforate test is trochospiral with the spiral side being slightly turretted and the umbilical side flattened. There are 2 whorls visible on the spiral side with 5 chambers in the outer whorl. The chambers increase gradually in both height and length, so there is little inflation and none of the chambers is radially elongate. The sutures are curved and depressed on the spiral side. On the umbilical side there is only one whorl visible which has straight sutures radiating out from the shallow umbilical hollow. The aperture is a small sutural slit extending from one side of the umbilicus to the periphery, bordered above by a narrow lip. The lip does not extend over the umbilical area.

The maximum diameter is 0·19 mm, the maximum height of the test is 0·1 mm, and the height of the last chamber is 0·09 mm.

The specimen is from a core sample at 5025 ft in Port Campbell No. 1 Well.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN: GSM 58733, Pl. LXXXII, fig. 7. The compressed test may be a little distorted. General features characteristic of the holotype.

Maximum diameter is 0·2 mm, the maximum height is 0·11 mm, and the height of the last chamber is 0·1 mm.

The specimen is from a core sample at 4,710 ft in Port Campbell No. 1 Well.

The maximum diameters of specimens range from 0·15 mm to 0·25 mm.

DISCUSSION: The chamber shape and especially the apertural features make this species generically distinct from *Quadromorphina* Finlay and *Allomorphina* Reuss. This species is generically similar to the genotype of *Pallaimorphina, P. ruckerae* Tappan 1957, but differs in that it is more noticeably trochospiral, and that the aperture and the lip extend to the periphery.

The specific name of *P. heliciformis* refers to the gastropod like shape of the test in side view, with the terminal chamber resembling a protruding 'foot' of a gastropod.

DISTRIBUTION: Confined to Zonule A. This is the highest reported occurrence of this genus, which has been recorded from the Albian to the Turonian.

Genus **Stilostomella** Guppy 1894

Stilostomella alexanderi (Cushman)

(Pl. LXXXII, fig. 8)

1936 *Ellipsonodosaria alexanderi* Cushman, *Contr. Cushman Lab.* 12 (3): 52, Pl. 9, fig. 6-9.
1946 *Ellipsonodosaria alexanderi* Cushman Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 135, Pl. 56, fig. 12-15.
1954 *Stilostomella alexanderi* Cushman var. *alexanderi* Cushman, Frizzell, *Univ. Texas Bur. econ. Geol. Rep.* 22, Pl. 18, fig. 13-14 (amended from *E. alexanderi* on p. 121).

An elongate series of slightly inflated chambers. The sutures are depressed. The test is ornamented by backwardly directed pointed spines which originate from a ring on each chamber. The apertural area is missing.

Length of specimen = 0·75 mm; maximum diameter = 0·15 mm.

DISCUSSION: This specimen has the distinctive ornamentation of *S. alexanderi.*

DISTRIBUTION: One specimen only GSM 58752 from a core sample at 4,652 ft in Belfast No. 4.

This species is reported from the upper Senonian of North America.

Genus **Pleurostomella** Reuss 1860

Pleurostomella subnodosa Reuss

(Pl. LXXXII, fig. 9)

1860 *Pleurostomella subnodosa* Reuss, *S.B. öst, Akad. Wiss. Wien.* 40: 204, Pl. 8, fig. 2.
1946 *Pleurostomella subnodosa* Reuss, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 132, Pl. 55, fig. 1-9 (with synonomy).
1954 *Pleurostomella subnodosa* Reuss, Frizzell, *Rep. Inv. Univ. Texas, Bur. econ. Geol.* 22: 120, Pl. 18, fig. 6.
1960 *Pleurostomella subnodosa* Reuss, Belford, *Bur. Min. Resour. Aust.* 57: 70, Pl. 19, fig. 3-5 (with synonymy).

The elongate test tapers at the initial end. The early chambers are biserial but later chambers become irregularly uniserial and are wedge-shaped. The distinct, depressed sutures are olique. The arched apertural depression is on one side of the terminal chamber with an over-hanging lip. A longitudinal section parallel to the apertural face reveals a funnel-like structure tapering down from the aperture to the preceding chamer. The test is finely perforate and smooth walled.

The dimensions of the figured specimen are: length = 0·64 mm, maximum width = 0·15 mm.

Discussion: Only one complete specimen has been isolated and the apertural features are not clear; a tooth plate cannot be observed. The funnel-shaped internal tube and the chamber arrangement suggests either *Pleurostomella* Reuss, or *Ellipsoidella* Heron-Allen & Earland 1910 (refer Belford 1960, p. 72-73). The apertural depression is much wider than would be expected in *Ellipsoidella*, thus the specimens can be placed within the genus *Pleurostomella*. The external features of test shape and chamber arrangement agree with those of *P. subnodosa* Reuss.

Occurrence: Very rare; found in Zonule A in Port Campbell No. 2 Well and Flaxmans No. 1 Well. This species is well known from Senonian deposits.

Figured Specimen: Pl. LXXXII, fig. 9—GSM 58735 from a core sample at 5,950 ft in Port Campbell No. 2.

The sectioned specimen (GSM 58735 from 5,950 ft in Flaxmans No. 1) has not been figured.

Genus **Valvulineria** Cushman 1926

Valvulineria lenticula (Reuss)

(Pl. LXXXII, fig. 10)

1845 *Rotalina lenticula* Reuss. *Verstein böhm. Kreide* p. 35, Pl. 12, fig. 17.
1936 *Valvulineria lenticula* (Reuss) Brotzen, *Sver. Geol. Unders.* C.396: 151-3, Pl. 11, fig. 5; Fig. 54-5 (with synonomy).
1957 *Valculineria lenticula* (Reuss) Hofker, *Beih. geol. Jb.* 27: 380-1, Fig. 425.
1960 *Valvulineria lenticula* (Reuss) Belford, *Bur. Min. Resour. Aust. Bull.* 57: 75, Pl. 20, fig. 3-10.

The smooth, finely perforate test is trochoid. The spiral surface is flat, umbilical surface convex, and the periphery rounded. The spiral surface is evolute with 2 whorls visible and there are 7-8 chambers in the outer whorl. On the spiral surface the sutures are strongly curved, distinct, and the final suture is depressed. On the umbilical surface the sutures are slightly curved, being limbate earlier but later becoming narrower and depressed. The umbilicus is covered by a flap protruding from the terminal chamber. This flap is produeed narrowly above the aperture.

The narrow aperture extends from the umbilicus for ⅔ of the length of the basal suture of the final chamber on the umbilieal surface. The terminal face is rounded. The dimensions of the Victorian specimens are: maximum diameter = 0·2 mm to 0·4 mm, maximum height = 0·1 mm to 0·15 mm.

Reference has been omitted to the variant American material discussed and described by Harris & McNaulty (1956) as *V. lenticula* (Reuss) in order to demonstrate closer similarities with the described European and Western Australian specimens of *V. lenticula*.

DISTRIBUTION: Fairly rare in the Victorian sequence. Its sporadic occurrence is limited to Zonule A. This species has a widespread distribution in the Upper Cretaceous.

FIGURED SPECIMEN: Pl. LXXXII, fig. 10—GSM 58751 from a core at 4.757 ft in Port Campbell No. 1.

Valvulineria erugata Belford

(Pl. LXXXII, fig. 12)

1960 *Valvulineria erugata* Belford, *Bur. Min. Resour. Aust. Bull.* 57: 76, Pl. 20, fig. 11-18.

The calcareous test is granular in structure yet finely perforate. The trochoid test has a rounded periphery and is plano-convex; the spiral side is flat, although it may exhibit a slight degree of concavity or convexity. 2½ whorls are visible on the spiral side with 8 chambers in the outer whorl. On the spiral side, the sutures are narrow, distinct and curved backwards, while the later sutures are slightly depressed. The strongly convex umbilical surface has curved slightly depressed sutures. The wide umbilicus is covered by a thin flap extending from the terminal chamber. The narrow aperture extends from the umbilicus along the basal suture of the terminal chamber, but does not reach the periphery.

The diameter of specimens ranges from 0·25 mm to 0·3 mm while the height ranges from 0·13 mm to 0·15 mm.

DISCUSSION: The spiral face is not perfectly flat in all the Victorian specimens but is obviously a variant feature with several specimens closely resembling the described type material. The Victorian material has only 8 chambers to the whorl compared with 9-10 chambers in the Western Australian specimens.

DISTRIBUTION: Rare, only recorded in Zonule A. Occurs in the Santonian and lower Campanian in Western Australia.

FIGURED SPECIMEN: Pl. LXXXII, fig. 12—GSM 58749 from a core at 4,652 ft in Belfast No. 4.

Valvulineria undulata Belford

(Pl. LXXXII, fig. 11)

1960 *Valvulineria undulata* Belford, *Bur. Min. Resour. Aust. Bull.* 57: 67-8, Pl. 20, fig. 19-24.

The trochoid test is unequally biconvex, the umbilical surface being more convex. The periphery is rounded. The evolute spiral surface has 2½ whorls with 8 chambers in the outer whorl. The narrow, distinct, smooth sutures are flexed backwards towards the outer margin and they are sinuous in the later chambers. The umbilical surface is involute with narrow radial sutures. The umbilicus is covered by a distinct plate. The apertural face is rhombic in outline. The calcareous test wells are granular and finely perforate.

The maximum diameter of specimens is 0·25 mm and the maximum height is 0·1 mm.

DISCUSSION: The illustrated specimen shows a greater trochospiral tendency than that illustrated for the type material. Apart from this and smaller size the Victorian material corresponds to *V. undulata*.

DISTRIBUTION: Found only in a core sample from 4,652 ft in Belfast No. 4 Bore, where it is associated with *V. erugata* Belford. Figured specimen, GSM 58750. The species occurs in the Santonian of Western Australia.

Genus **Gyroidinoides** Brotzen 1942

Gyroidinoides nitida (Reuss)

(Pl. LXXXIII, fig. 1)

1845 *Rotalina nitida* Reuss, *Verstein bohm. Kreide* 1: 35, Pl. 7, fig. 8 & 20; Pl. 8, fig. 52.
1942 *Gyroidinoides nitida* (Reuss) Brotzen, *Sver. Geol. Unders. C.* 396: 19, Fig. 6, 3.
1946 *Gyroidina nitida* (Reuss) Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 140, Pl. 58, fig. 5.
1957 *Gyroidinoides nitida* (Reuss) Hofker, *Beih. geol. Jb.* 27: 393-4, Fig. 437-440.

The perforate, smooth, shiny calcareous test is trocho-spirally coiled, circular in outline, though appears conical in side view. The spiral surface is flat, but this surface on the last chamber may be below the surface of the earlier chambers. On the spiral surface there are 3 whorls visible with 7 chambers in the outer whorl. The chambers increase gradually in size. The faintly curved, radial sutures are depressed. The periphery is rounded. The umbilical surface is involute, with a small umbilicus which may be partially covered by apertural lip and relic lips. The aperture is a narrow slit which reaches from the umbilicus towards the spiral surface. The aperture does not reach the spiral surface and its termination is marked by a distinct bulge in the terminal face. Below this bulge the terminal face is flat with a lip overhanging the umbilicus. The diameter of specimens ranges from 0·3 mm to 0·35 mm; the height from 0·2 mm to 0·24 mm.

Distribution: Common to abundant in Assemblages 2 & 4 of Port Campbell No. 2 section, though it occurs rarely and sporadically in the rest of the sequence. A well-known species ranging from the Turonian to the Danian.

Figured Specimen: Pl. LXXXIII, fig. 1—GSM 58707 from a core at 5,025 ft in Port Campbell No. 2.

Gyroidinoides cruachin sp. nov.

(Pl. LXXXIII, fig. 2)

Description of Holotype: Pl. LXXXIII, fig. 2. GSM 58708.

The finely perforate smooth test is somewhat compressed as the diameter is twice the height. The dorsal surface is only slightly convex, as the chamber surfaces are flat but the spiralling is not horizontal and the later chambers are on a lower plane than the earlier ones. 3 whorls are visible dorsally with 12 chambers in the outer whorl. The sutures on both surfaces are radial, straight to slightly curved, and the last 2 sutures are depressed. The periphery is rounded. The convex ventral surface is involute with a wide open umbilicus which is filled by a clear calcite plug. The terminal chamber protrudes a little over the umbilicus and along the base of this chamber there is a very narrow convex flap. The slit-like aperture extends from the umbilicus almost to the periphery.

The diameter of the test is 0·3 mm, while the height is 0·15 mm. The Holotype is from a core sample at 4,710 ft in Port Campbell No. 1 Well.

Observations of Other Specimens: All resemble the holotype. The diameter ranges from 0·2 mm to 0·3 mm while the height from 0·1 mm to 0·15 mm.

Discussion: This form is not as compressed as *G. depressa* (Alth) and also appears to differ in umbilical detail. The test of this form is less conical, has more chambers, and the umbilical flap is less developed than *G. nitida* (Reuss) with which it is often associated in the Victorian sequence. However, this species is very similar to the Upper Cretaceous form *G. pontoni* Brotzen, as described by Hofker (1957, p. 399-400), but *G. pontoni* has curved septae which are strongly flexed towards the inner margin of the whorl.

The specific name of *G. cruachin* is from the Gaelic; Crauchin being the place of origin and the rallying cry of the Clan Campbell. Thus, the specific name records its occurrence in the Cretaceous sequence of the Port Campbell wells.

OCCURRENCE: Fairly rare. Never recorded in cores below Zonule A.

Genus **Alabamina** Toulmin 1941

Alabamina australis Belford

(Pl. LXXXIII, fig. 3-4; Pl. LXXXVI, fig. 6)

1960 *Alabamina australis australis* Belford, *Bur. Min. Resour. Aust. Bull.* 57: 84-86, Pl. 23, fig. 13-20; Fig. 4, 5.

1960 *Alabamina australis obscura* Belford, ibid., p. 86, Pl. 24, fig. 1-8; Fig. 5.

The finely perforate smooth test is trochoid and plano-convex with a rounded periphery. The flat spiral side is evolute with 2-3 whorls visible and 5-6 chambers in the last whorl. The distinct sutures on the spiral surface are straight to faintly curved and are reflexed; the later sutures are slightly depressed. The convex umbilical surface is completely involute, and the sutures are radial, straight and converge. The narrow aperture is at the base of the terminal chamber, extending from the umbilicus to the periphery, with a distinct groove into the final face just below and parallel to the periphery. In horizontal section, a tooth plate is visible in each chamber.

The diameter of specimens ranges from 0·15 mm to 0·3 mm and the ratio of diameter to height is 3:2 in all specimens.

Several specimens have been isolated in which the spiral surface is partially involute.

DISCUSSION: The spirally evolute forms are identical with the type description of *A. australis australis*, except that the Victorian specimens are of smaller size and the spiral sutures are not so strongly curved, though this factor may relate to size.

The few specimens that are partially involute on the spiral side could be assigned to *A. australis obscura*. But the two forms appear to intergrade in the Victorian material.

DISTRIBUTION: Apart from at the base of the sequence (Assemblage 5 in Port Campbell No. 2) this species occurs in both Zonules. The species is described from the Santonian of Western Australia, but its range could extend down to the Turonian.

FIGURED SPECIMENS: Pl. LXXXIII, fig. 3—GSM 58670 from a core sample at 4,757 ft in Port Campbell No. 1; fig. 4—GSM 58671 from a rotary cutting sample at 5,200-10 ft in Flaxmans No. 1 (partially involute specimen); Pl. LXXXVI, fig. 6—GSM 58790 from a core at 5,950 ft in Flaxmans No. 1.

Genus **Cibicides** Montfort 1808

Cibicides excavatus Brotzen 1936

(Pl. LXXXIII, fig. 5-6; Pl. LXXXVI, fig. 4-5)

1936 *Cibicides excavatus* Brotzen, *Sver. geol. Unders.* C. 396: 189, Pl. 13, fig. 7, 8 (with synonomy).

1957 *Cibicides excavatus* Brotzen, Hofker, *Beih. geol. Jb.* 27: 84-94, Fig. 96.

1960 *Cibicides excavatus* Brotzen, Belford, *Bur. Min. Resour. Aust. Bull.* 57: 111, Pl. 34, fig. 12-16.

1962 *Cibivides excavatus* Brotzen, Ebensberger, *Palaeontographica* 120 (A): 96, Pl. 9, fig. 10.

The closely coiled planispiral tests are formed of coarse to medium grained calcium carbonate and are perforate on both sides. The 6 to 7 chambers in the outer whorl become increasingly inflated. This is apparent on the spiral dorsal surface where the earlier chambers are flat faced, while the later ones form a convex face. The degree of chamber inflation may be interpreted as a growth factor, as the smallest specimens have flat dorsal surfaces. The dorsal surface is wholly or partially involute, while the convex umbilical (ventral) surface is completely involute. The periphery is round, though the margin is angular where there is dorsal flattening. The half-moon shaped aperture is along the marginal suture and is sometimes covered by a lip. The septae and test walls appear to be monolamellid.

DIMENSIONS: The smallest specimen has a diameter of 0·22 mm with a last chamber 0·11 mm high. The largest specimen has a diameter of 0·6 mm with a last chamber 0·45 mm high. These dimensional extremes illustrate the relationship between size and chamber inflation.

DISTRIBUTION: This species is restricted to Zonule A. It has been reported from the Santonian and lower Campanian of Europe and Western Australia, though Brotzen shows it to range into the Turonian, while Ebensberger records it from the Maastrichtian of Germany.

FIGURED SPECIMENS: Pl. LXXXIII, fig. 5—GSM 58685 from a core at 5,025 ft in Port Campbell No. 1; fig. 6—GSM 58684 from a core at 5,910 ft in Port Campbell No. 2. Pl. LXXXVI, fig. 4—GSM 58791 from a core at 5,910 ft in Port Campbell No. 2; fig. 5—GSM 58870 from a core at 5,950 ft in Flaxmans No. 1.

Cibicides ribbingi Brotzen

(Pl. LXXXIII, fig. 7)

1936 *Cibicides ribbingi* Brotzen, *Sver. Geol. Unders.* C. 396: 186, Pl. 13, fig. 5, 6; Fig. 67, 68.
1960 *Cibicides ribbingi* Brotzen, Belford, *Bur. Min. Resour. Aust. Bull.* 57: 111-2, Pl. 34, fig. 17-20.

The test is sub-round in outline and plano-convex in side view. The margin is acute with a narrow thickened keel in the earlier chambers. The flat to slightly concave spiral surface is partially evolute with 9 chambers in the outer whorl. The convex umbilical surface is completely involute and the umbilicus is covered. The low apertural arch extends from the periphery along the inner margin of the last few chambers on the spiral surface.

The granular calcareous test is perforate, although the granular structure is not as coarse grained as *C. excavata* of the Victorian sequence.

The figured specimen has a maximum diameter of 0·6 mm and a maximum height of 0·25 mm.

DISTRIBUTION: Occurs only in a core sample from 4,652 ft in Belfast No. 4, and rotary cutting sample from 4,695 ft in Port Campbell No. 1. Occurs in the Santonian of Europe and Western Australia.

FIGURED SPECIMEN: Pl. LXXXIII, fig. 7—GSM 58682 from a core sample at 4,652 ft in Belfast No. 4.

Genus **Hanzawaia** Asano 1944

Hanzawaia californica (Bandy)

(Pl. LXXXIII, fig. 8; Pl. LXXXVI, fig. 7)

1951 *Cibicidina californica* Bandy, *J. Paleont.* 25: 505-6, Pl. 74, fig. 7.

The small, delicate test is circular in outline and plano-convex in side view. The flat to slightly concave dorsal surface is partially evolute. The convex ventral side is usually involute although one specimen exhibits slight evolution of the ventral surface. There is a central umbo on both sides. There are 9-11 chambers in the final whorl, with only 1½ whorls in the test. The sutures are distinct, thickened and curved backwards, with dorsal re-entrants at the inner margin of the outer whorl. The low arched aperture extends from the periphery along the inner margin of the last 2 chambers on the dorsal surface (spiral surface). In some specimens the aperture is covered by a narrow lip. The calcareous test is hyaline with perforate walls. The umbilical plug is composed of cloudy imperforate calcite. The septal walls are monolamellid, although the chamber walls appear to be lined with dark substance (refer Pl. LXXXVI, fig. 7). The diameter of most specimens is 0·2 mm with a height of 0·1 mm.

DISCUSSION: The Victorian specimens compare closely with *H. californica* Bandy, although the holotype is twice their size.

DISTRIBUTION: Fairly rare. Occurs only in Zonule A. The species is reported only from the Campanian of California.

FIGURED SPECIMENS: Pl. LXXXIII, fig. 8—GSM 58686 from a core at 5,025 ft in Port Campbell No. 1. Pl. LXXXVI, fig. 7—GSM 58792 from a core at 4,974 ft in Port Campbell No. 1.

Genus **Gavelinopsis** Hofker 1951

Gavelinopsis cenomanica (Brotzen)

(Pl. LXXXIII, fig. 9; Pl. LXXXVI, fig. 8-9)

1945 *Cibicidoides* (*Cibicides*) *cenomanica* Brotzen, *Sver. Geol. Unders.* C. 465, Pl. 2, fig. 2.
1957 *Gavelinopsis cenomanica* (Brotzen) Hofker, *Beih. geol. Jb.* 28: 321-2, Fig. 370.

The bi-convex test has an acute margin with a keel in the earlier chambers, but the margin is rounded and without a keel in the later chambers. 2 whorls visible on dorsal surface, although some of the chambers in the first whorl are partially obscured by the secondary calcite which covers the inner whorl. 9-10 chambers are visible in the outer whorl with the earlier chambers flattened dorsally while the later chambers are more inflated. The sutures curve backwards on both surfaces, dorsally they are limbate in the earlier portion but become narrower and depressed, ventrally the sutures are depressed but are infilled with clear secondary calcite to the extent of appearing raised. The ventral surface is almost completely involute with all chambers convex. The umbilicus is deep, although it is infilled with secondary calcite. The narrow apertural lip can be seen to extend halfway round the inner margin of the whorl, overhanging the umbilical surface. The apertural face extends farther on the ventral surface than on the dorsal. The apertural slit is basal and is only ventral.

The bi-lamellid test walls and septa are finely perforate. The secondary calcite veneer is imperforate and its extent is illustrated by the areas lacking pores on the figures. As is illustrated and already described, the secondary calcite is not confined to the umbilical hollow on both surfaces. The term umbilical boss or plug is not used, for veneer is regarded as more applicable.

Maximum diameter of specimens varies from 0·45 mm to 0·65 mm while the height from 0·18 mm to 0·24 mm.

DISCUSSION: The Victorian material compares closely with that described by Hofker (1957) from the Cenomanian of Holland and NW. Germany. In the original description, Brotzen (1945) states that the sutures are raised, but Hofker (loc. cit.) indicates that the sutures may not appear raised, due to secondary calcite infilling; this is verified in the Victorian material.

Belford (1960, p. 101-3) and other authors doubt the generic validity of

Gavelinopsis. Hofker's generic determination of *G. cenomanica* has been accepted by the author and Hofker's designation of dorsal and ventral surfaces has been followed in order to achieve descriptive uniformity. The Victorian material, though determinant, is too poorly preserved for close generic study.

Distribution: This species is confined to Zonule B of which it is characteristic, although it does not extend to the lower horizons of the Zonule as does *Textularia trilobita*. *G. cenomanica* is often associated with a smaller form of *Gavelinopsis* so poorly preserved as to be indeterminate. Was originally reported from the upper Albian and Cenomanian, Hofker has extended its range to the Turonian.

Figured Specimens: Pl. LXXXIII, fig. 9—GSM 58702 from a core at 7,000 ft from Port Campbell No. 2. Pl. LXXXVI, fig. 8—GSM 58797 from a core at 7,000 ft from Port Campbell No. 2; fig. 9—GSM 58796 from a cutting sample at 7,650-7,660 ft in Port Campbell No. 2.

Gavelinopsis cf. **eriksdalensis** (Brotzen)

(Pl. LXXXIII, fig. 10)

1936 *Cibicides* (*Cibicidoides*) *eriksdalensis* Brotzen, *Sver. Geol. Unders.* 396: 193, Pl. 14, fig. 5; Fig. 69.
1957 *Gavelinopsis eriksdalensis* (Brotzen) Hofker, *Beih. geol. Jb.* 27: 322-4; Fig. 371, 372.
1960 *Anomalinoides eriksdalensis* (Brotzen) Belford, *Bur. Min. Resour. Aust. Bull.* 57: 108-9, Pl. 34, fig. 1-11.

The bi-convex test has an acute margin with a narrow thickened keel in the earlier chambers. The ventral surface is partially evolute with 2 whorls visible and with 8-10 chambers in the outer whorl. The dorsal surface is involute with a prominent umbilical plug. The sutures are indistinct, narrow, and curve slightly backwards. The narrow aperture extends ventrally from the periphery to halfway along the inner margin of the outer whorl. The test is composed of coarsely perforate, granular calcite. The calcite of the umbilical plug is particularly coarse grained and is opaque. The septal walls are bi-lamellid.

The mximum diameter of specimens ranges from 0·33 mm to 0·4 mm, and the thickness from 0·15 mm to 0·2 mm.

Discussion: This Victorian form differs from *G. eriksdalensis* in that the umbilical plug is larger and the ventral surface is more involute. Brotzen (1945) notes an increase in size of the umbilical plug, but this increase in size is accompanied by a surface flattening of the plug, which is not a feature of the Victorian form.

Distribution: Rare, but occurs throughout the sequence. This species is present in the Santonian and Campanian of Europe.

Figured Specimen: Pl. LXXXIII, fig. 10—GSM 58705 from a cutting sample at 5,650 to 5,660 ft in Flaxmans No. 1.

A vertical section of specimen GSM 58799 has not been figured.

Genus **Ceratobulimina** Toula 1920

Ceratobulimina kremnoides sp. nov.

(Pl. LXXXIV, fig. 1-2)

Description of Holotype: GSM 58680. Pl. LXXXIV, fig. 1.

The smooth, perforate, calcareous test is flatly coiled and its length is greater than its width (ratio = 4:3). The periphery is rounded, while both faces are somewhat flattened. 2½ whorls are visible on the spiral side with 6 chambers in the outer whorl. The sutures are distinct, being limbate, especially on the spiral side, and depressed on the umbilical side. The involute umbilical face slopes into the deltaic shaped umbilicus. The apex of this 'delta' is the apertural slit which extends into the umbilical face of the terminal chamber. There are also indentations into the test where the sutures meet the umbilicus. In edge view, the terminal face is abrupt, being steep though slightly curved.

The test is 0·45 mm long, 0·32 mm wide, and 0·2 mm thick.

The specimen is from a rotary cutting sample at 6,500-10 ft in Flaxmans No. 1 Well.

Description of Supplementary Specimen: GSM 58681. Pl. LXXXIV, fig. 2.

The test is more circular and convex in outline and the terminal face is more abrupt in edge view than in the Holotype. There are 7 chambers in the outer whorl. The terminal chamber is infilled with pyritic mud, which is a common feature in other specimens of this species.

The test is 0·45 mm long, 0·38 mm wide, and 0·25 mm thick.

The specimen is from a core sample at 5,910 ft in Port Campbell No. 2 Well.

The length of unfigured specimens ranges from 0·2 mm to 0·45 mm.

Discussion: The abrupt terminal face and the delta shape of the umbilicus are the major features that differentiate this species from other Cretaceous *Ceratobulimina*. Apart from these characters, the Albian species, *C. gaultina* ten Dam 1947 and *C. woodi* Khan 1950, are flatter and more elongate, while the Upper Cretaceous *C. cretacea* Cushman & Harris 1927 is more elongate and the sutures more distinctly limbate.

However, *C. kremnoides* compares closely with the Paleocene species *C. westraliensis* Parr 1938, but the examination of topotype and other material of this species (including specimens from the Paleocene at Pebble Point, Victoria) has shown that, in *C. westraliensis*, the terminal face is gently sloping and the umbilicus tends to be elongate rather than deltaic. The specific name of *C. kremnoides* refers to the abrupt terminal face of the test (Kremnos (Gk), cliff or precipice).

Distribution: This species is very rare in the sequence.

Ceratobulimina cretacea Cushman & Harris

(Pl. LXXXIV, fig. 3)

1927 *Ceratobulimina cretacea* Cushman & Harris, *Contr. Cushman Lab.* 3: 173, Pl. 29, fig. 1; Pl. 30, fig. 11.

1946 *Ceratobulimina cretacea* Cushman & Harris, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 143, Pl. 59, fig. 6-7 (with synonomy).

1951 *Ceratobulimina cretacea* Cushman & Harris, Bandy, *J. Paleont.* 25 (4): 507, Pl. 73, fig. 20.

1954 *Ceratobulimina cretacea* Cushman & Harris, Frizzell, *Rep. Inv. Univ. Texas econ. Geol.* 22: 125, Pl. 19, fig. 13.

The smooth walled, finely perforate test is ovoid, bi-convex in side view, and the periphery is rounded. The spiral, dorsal surface is evolute with 2 whorls, and with 6 chambers in the outer whorl; the chambers increase rapidly in size. The sutures are slightly limbate on both surfaces, dorsally they are curved, ventrally nearly straight and radial. The evolute ventral surface has a well developed umbilicus. The aperture is a narrow cleft in the terminal face and leads into the umbilicus. The only complete specimen has a length of 0·3 mm, a width of 0·2 mm, and a thickness of 0·15 mm.

DISCUSSION: The differences between this species and *C. kremnoides* sp. nov. are obvious on comparing the specimens. The former is more elongate and all sutures more distinct. The aperture is visible in edge view in *C. cretacea*, while it is only visible on the umbilical face of *C. kremnoides*.

DISTRIBUTION: Isolated only in a core sample from 4,757 ft in Port Campbell No. 1 Well. GSM 58682. Commonly reported in the Campanian of North America.

Genus **Hedbergella** Bronnimann & Brown 1958

Considerable revision of the Cretaceous globigerinids has taken place during the last 7 years. This has especially affected the non-keeled forms in which the apertures are interiomarginal extraumbilical-umbilical arches, and have open umbilici. Bronnimann & Brown (1956) proposed the genus *Hedbergina* to include such forms, but the proposed genotype *Globigerina seminolensis* Harlton 1927, was shown not to be acceptable. Bolli, Loeblich and Tappan (1957) included such forms within the genus *Praeglobotruncana* Bermudez 1952, together with keeled forms with similar apertural and umbilical features as shown in the genotype *Globorotalia delrioensis* Plummer 1931. The genus *Hedbergella* was then established by Bronnimann & Brown (1958) with *Anomalina lorneiana* d'Orbigny var. *trocidea* Gandolfi 1942, as the Genetype. Banner & Blow (1959) gave *Hedbergella* subgeneric status within the genus *Praeglobotruncana.* In a study of globigerinids in the 'Complexe schisteux intermediare', Klaus (1959) was satisfied with the status of *Hedbergella.* He described only the genotypic species *H. trocoidea* (Gandolfi) from the Albian to Turonian stages, although he mentions stratigraphic variation in size, chamber arrangement, and height of spire. In a recent study, Loeblich & Tappan (1961) have separated *Hedbergella* from *Praeglobotruncana*, mainly on the presence or absence of a peripheral keel. They have described 8 species of *Hedbergella* (5 of the species are generically redefined) which are designated on size, shape, chamber arrangement, number of chambers, and height of spire. From the descriptions and figures it is difficult to distinguish between some of the species so, with reference to the work of Klaus (loc. cit), one cannot dismiss the possibility that some of Loeblich & Tappan's species are conspecific variants due to vertical distribution, environment or even population differences.

Hofker (1961) refuses to recognize current taxonomic findings, as he places the non-keeled members of *Praeglobotruncana* (= *Hedbergella*) within his *Globigerina cretacea* 'gens' and illustrates traceable variation in size, chamber arrangement and number, height of spire and ornamentation. But Hofker includes in his 'gens' forms which do not have interiomarginal, extraumbilical-umbilical arched apertures, and he also includes a form with an umbilical covering plate. Hofker believes that these two features are artificial generic characters, yet they are features which are clearly either present or absent. They can hardly be described as variable features. Therefore, I am of the opinion that Hofker's 'gens' includes 3 genera, namely *Globigerina, Hedbergella*, and *Rugoglobigerina*. Hofker's study on NW. European material clearly shows that there is a traceable stratigraphic variation of specimens which can be included in the genus *Hedbergella*, namely his Pl. 1, fig. 5-14.

Upon this review of the literature the generic status of *Hedbergella* is accepted for the purpose of this study. It has clearly distinguishable features from the following superficially similar genera:

(1) *Globigerina* d'Orbigny 1826—which has an arched umbilical aperture which does not extend to the margin.

(2) *Praeglobotruncana* Bermudez 1952—which has a peripheral keel which is often better developed in the early stages.

(3) *Ticinella* Reichel 1950 and *Rugoglobigerina* Bronnimann 1952—which have secondary apertures on the umbilical side. The latter genus has an umbilical cover plate.

Loeblich and Tappan (1961) have elevated *Clavihedbergella* to generic rank after Banner & Blow (1959) had designated it as a sub-genus of *Praeglobotruncana*. Its radially elongate chambers distinguish it from *Hedbergella*. Loeblich & Tappan's figures on Pl. 3 seem to show that chamber elongation is not a clear-cut generic feature, as *H. amabilis* Loeblich & Tappan blend with *C. simplex* (Morrow) (fig. 5 & 14 appear to be the two extremes). Thus, the generic status of *Clavihedbergella* is dubious.

Hedbergella trocoidea (Gandolfi)

(Pl. LXXXIV, fig. 4-7)

1942 *Anomalina lorneiana* var. *trocoidea* Gandolfi, *Riv. Ital. Pal.* 48 (4): 99, Pl. 2, fig. 1; Pl. 4, fig. 2, 3; Pl. 13, fig. 2-5.

1942 *Anomalina lorneiana* Gandolfi (non d'Orbigny), *Riv. Ital. Pal.* 48 (4): 98, Pl. 4, fig. 1, 19; Pl. 8, fig. 2; Pl. 13, fig. 1, 4.

1956 *Hedbergina seminolensis* Bronnimann & Brown (non Harlton), *Eclog. Geol. Helv.* 48 (2): 529, Pl. 20, fig. 4-6.

1958 *Hedbergella trocoidea* (Gandolfi), Bronnimann & Brown, *Washington Acad. Sci.* 48 (1): 16, Fig. 1.

1959 *Praeglobotruncana* (*Hedbergella*) *trocoidea* (Gandolfi), Banner & Blow, *Palaeontology* 2 (1): p. 18 (no figure).

1959 *Hedbergella trocoidea* (Gandolfi), Klaus, *Eclog. Geol. Helv.* 52 (2): 792, Pl. 1, fig. 1.

1961 *Globigerina cretacea* d'Orbigny, Hofker (in part), *Micropaleontology* 7 (1): 96-98, Pl. 1, fig. 5-15 only.

1961 *Hedbergella trocoidea* (Gandolfi), Loeblich & Tappan, *Micropaleontology* 7 (3): 277-8, Pl. 5, fig. 1-2.

1961 *Hedbergella amabilis* Loeblich & Tappan, *Micropaleontology* 7 (3): 274, Pl. 3, fig. 2, 3, 5, 7.

The small, perforate, trochoidal test is flat to slightly convex on the spiral side and convex on the umbilical side. It is sub-round to sub-angular in peripheral outline. The chambers are ovoid to globular in shape, increasing rapidly in size as added; 5 to 6 chambers to the whorl with 2 to 3 whorls visible on the spiral side. Some of the chambers are radially elongate, but this is not a persistent feature in any one specimen. The radial sutures are straight, distinct, and depressed on both sides. The margin lacks a keel and is indented at the sutures. The degree of identation depends on the degree of radial elongation of the chambers. Only the last whorl is visible on the umbilical side, where the umbilicus is narrow, deep, and open, though sometimes fringed with relic apertural lips. The aperture is an interiomarginal, extraumbilical to umbilical arch partially covered by a lip which flares out over the umbilicus.

The maximum diameter ranges up to 0·28 mm; the terminal chamber is as high as 0·15 mm, with a height of 0·05 mm for the first chamber in the last whorl.

Discussion: The Victorian specimens show variation in chamber shape but morphologically intergrade within the one sample. As already mentioned, both Klaus (1959) and Hofker (1961) show variation in form within a species assignable to *H. trocoidea*. Some of the Victorian specimens could be assignable to *H. amabilis* Loeblich & Tappan 1961 if they were specifically finite from the other specimens in the sample. Morphological intergradations have been observed in living populations of globigerinids, as discussed by Bé (1959, p. 84). The Victorian specimens of *H. trocoidea* are smaller than those described by other authors. The study of recent globigerinids has shown that size variation within a species may be influenced by the environment, especially temperature, as is suggested by Bradshaw (1959, p. 57-59). (The Victorian fauna is believed to be a cold water fauna.)

PRESERVATION: Most of the Victorian specimens were partially covered by matrix. The only satisfactory method of cleaning was found to be in the alteration of calcium carbonate test material to calcium fluoride by the method described by Sohn (1956). This eliminated any siliceous material adhering to the test, but the only specimens successfully treated were those free from cracks or pyrite. The treatment cleans out the pores in the test walls, so treated specimens appear to be different in texture from untreated ones.

DISTRIBUTION: This species has not been found in any core sample below Zonule A, where it is usually rare, though common in some samples. The presence of several specimens at 5,540-49 ft in Zonule A in Port Campbell No. 1 is unreliable as the sample is from rotary cuttings.

The restricted range of *H. trocoidea* in the Victorian sequence is regarded as an environmental factor rather than a stratigraphic one. The species is reported from Albian to Turonian, but the generic range may be higher.

FIGURED SPECIMENS: Pl. LXXXIV, fig. 4—GSM 58709 (fluoride replacement) from a core at 5,025 ft in Port Campbell No. 1; fig. 5—GSM 58711 from a core at 4,757 ft in Port Campbell No. 1; fig. 6—GSM 58712 (calcite mould) from a cutting sample at 5,540 ft to 5,549 ft in Port Campbell No. 1; fig. 7—GSM 58710 (fluoride replacement) from a core at 5,025 ft in Port Campbell No. 1.

Genus **Guembelina** Egger 1899

Guembelina reussi Cushman

(Pl. LXXXIV, fig. 8)

1938 *Gümbelina reussi* Cushman, *Contr. Cushman Lab.* 14: 11, Pl. 2, fig. 6-9.
1946 *Gümbelina reussi* Cushman, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 104, Pl. 44, fig. 18, 19 (with synonomy).
1954 *Gümbelina reussi* Cushman, Frizzell, *Rep. Inv. Univ. Texas econ. Geol.* 22: 110, Pl. 15, fig. 38.

The smooth, finely perforate, bi-serial test is 1½ times as long as wide. The periphery is straight in the earlier portion but later it is indented at the sutures. There are 6-8 pairs of chambers which are globular. The sutures are distinct, depressed, and angled slightly (10°) back. There is an indented triangular area between any 3 of the later chambers. The aperture is high and semicircular in the terminal face reaching down to the marginal suture. The test wall is thickened round the aperture and projects as a lip in some specimens. The length of specimens ranges from 0·2 mm to 0·45 mm, width from 0·15 mm to 0·28 mm, thickness from 0·1 mm to 0·2 mm.

DISCUSSION: The Victorian specimens are characterized by the high semicircular aperture and the indented area between the chambers which do not appear to overlap. These are features which differentiate this species from the more widespread *G. globulosa* (Ehrenberg).

DISTRIBUTION: Always associated with *Hedbergella trocoidea*. Reported from the Senonian of North America.

FIGURED SPECIMEN: Pl. LXXXIV, fig. 8—GSM 58706 from a core at 5,910 ft in Port Campbell No. 2.

Genus **Hoeglundina** Brotzen 1948

Hoeglundina subcretacea (ten Dam)

(Pl. LXXXIV, fig. 9)

1925 *Epistomina caracolla* Franke (not Roemer), *Geol. Pal. Inst. Univ. Greifswald Abh.* t. 6: 88, Pl. 8, fig. 10.

1946 *Epistomina caracolla* Franke (not Roemer), Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 142-3, Pl. 59, fig. 2.

1948 *Epistomina supracretacea* ten Dam, *Revue de L'Institut Francais et Annales des Combustibles Liquides* 111 (6): 163, Pl. 1, fig. 8.

1951 *Höglundina supracretacea* (ten Dam), Bandy, *J. Paleont.* 25 (4): 507-8, Pl. 74, fig. 3 (with synonomy).

1960 *Höglundina supracretacea* (ten Dam), Takayanagi, *Sci. Reps. Tohoku Univ.* 2nd series (Geology), 32 (1): 127-8, Pl. 9, fig. 2.

The calcareous test is almost circular, and is unequally bi-convex. The margin is acute with a slight keel. The less convex dorsal side is evolute with 2-3 whorls visible and with 7-8 chambers in the outer whorl. The sutures are limbate, dorsally they are flexed backwards and are faintly curved, ventrally they are straight radiating out from the central umbo. The aperture is indistinct but appears to be a narrow slit along the basal suture of the terminal chamber on the ventral side. Diameter of specimens ranges from 0·3 mm to 0·51 mm, thickness from 0·15 mm to 0·32 mm.

Discussion: Although all the Victorian specimens are poorly preserved (some replaced by pyrite), they appear to be fairly typical of this species.

Distribution: Occurs rarely and sporadically in the sequence. Reported from the Senonian.

Figured Specimen: Pl. LXXXIV, fig. 9—GSM 58704 from a cutting sample at 6,200 to 6,210 ft in Flaxmans No. 1.

Genus **Colomia** Cushman & Bermudez 1948

Colomia austrotrochus sp. nov.

(Pl. LXXXII, fig. 1-4; Pl. LXXXVI, fig. 1-3)

Diagnosis: The test is circular in transverse section; conical in the early portion with an initial apiculate end; conical, cylindrical, or bulbous later. The calcareous test is bi-lamellid and finely perforate. The exterior walls are hispid to varying degrees. The initial chambers are trochospirally coiled with a proloculus. The later 3 chambers are uniserial, though the trochospiral tendency is still apparent. The narrow, distinct sutures are flush with the surface or slightly depressed. The sutures are oblique, the angle alternates so that the chambers are wedge-shaped, the obliqueness may decrease with chamber addition. The terminal aperture is an elongate narrow opening, slightly curved at both ends. There is a thin apertural lip on one side of the opening. Often in the terminal face, there is a hollow which contains the aperture. A thin section, cut perpendicular to the aperture, reveals 2 vertical columns extending from the aperture towards, but not reaching, the preceding septal wall. The distance between the columns is greater than the width of the aperture so that the apertural lip covers most of this opening. The apertural columns may be missing in every second chamber, which suggests that the position and orientation of the aperture must alternate.

Length of specimens ranges from 0·3 mm to 0·45 mm, maximum diameter from 0·22 mm to 0·3 mm.

Description of Holotype: Pl. LXXXII, fig. 1. GSM 58691.

A conical specimen with a sloping terminal face. Apertural detail a little indistinct. The initial chamber arrangement is distinctly trochospiral.

Length = 0·38 mm, maximum diameter = 0·27 mm.

The specimen is from rotary cutting samples from 5,460-70 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN A: Pl. LXXXII, fig. 2. GSM 58690.

The test is conical with a small apical angle. The exterior surface is distinctly hispid. The uniserial sutures are only slightly oblique. The terminal chamber has been removed so as to reveal clear apertural detail. There is a definite apertural lip on one side of the aperture.

Length = 0·44 mm, maximum diameter = 0·3 mm.

The specimen is from rotary cutting samples at 5,400-10 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN B: Pl. LXXXII, fig. 3. GSM 58692.

The final portion of the test is cylindrical in shape with very oblique depressed sutures and a steep final face. The aperture is within an elongate hollow open at the margin where the chamber is thinnest. The exterior surface is finely hispid.

Length = 0·37 mm, maximum diameter = 0·2 mm.

The specimen is from a rotary cutting sample at 5,400-10 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN C: Pl. LXXXII, fig. 4. GSM 58689.

The test is slightly bulbous with a conical initial end. The uniserial sutures are extremely oblique. The terminal chamber is small and 3-sided, as if the test was reverting to the initial bi-serial, trochospiral chamber arrangement. The typical aperture is in an elongate hollow which runs down the steep terminal face and meets the suture of the preceding chamber.

Length = 0·38 mm, maximum diameter = 0·23 mm.

Specimen from rotary cuttings at 5,460-70 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN D: Pl. LXXXVI, fig. 1. GSM 58793.

The longitudinal section cut perpendicular to the direction of the aperture. Clearly shows the apertural columns and the covering lip of the aperture in the third last chamber.

Length = 0·4 mm, maximum diameter = 0·28 mm.

The specimen is from 5,400-10 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN E: Pl. LXXXVI, fig. 2. GSM 58794.

Longitudinal section cut parallel to the direction of the aperture. Shows 2 chambers to the whorl in the initial portion and the proloculus.

Length = 0·36 mm, maximum diameter = 0·25 mm.

Specimen from rotary cutting sample at 5,400-10 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN F: Pl. LXXXVI, fig. 3. GSM 58795.

Transverse section of initial end above the proloculus. The section has been left thick so as to illustrate the spiral nature of the chamber wall. The chamber wall curves into the centre of the test where it joins a small ovoid area suggestive of an umbilicus.

Diameter = 0·13 mm.

Specimen from rotary cutting sample at 5,400-10 ft in Port Campbell No. 1.

DISCUSSION: The conical, hispid test with the linear, uniserial arrangement of the later chambers are external characters of the Genus *Colomia*. Moreover, section reveals internal apertural structures similar to those described in the genotype, *C. cretacea* Cushman & Bermudez 1948. In a thorough taxonomic study of the genotype, Hofker (1958) shows many features which are described here in *C. austrotrochus*. This evidence fully confirms the generic identity of the Victorian form.

The author concurs with Hofker (loc. cit) in that *Colomia* shows an apparent relationship with the Genus *Conorboides*, rather than being a member of the Buliminidae, as suggested by Cushman & Bermudez (1948). Furthermore, the author suggests that *C. austrotrochus* may be an intermediary form in the supposed lineage between *Conorboides* and the other 3 described species of *Colomia*. This opinion is based on the fact that the Victorian form is more noticeably trochospiral than the other members of the genus, the trochospiral tendency being still apparent in the uniserial chambers. In fact, in some specimens, the uniserial chambers almost revert to a trochospiral arrangement, as in Supplementary Specimen C (Pl. LXXXII, fig. 4.). It should also be noted that *C. austrotrochus* is the oldest species of the genus as yet recorded. *C. californica* Bandy is from the Campanian, while the genotype and *C. orthostoma* Klasz are recorded from the Maastrichtian. The Victorian species is restricted to Zonule B which the author places within the Turonian Stage.

The external shape of *C. austrotrochus* is a variant feature. The shape appears to depend on the degree of trochospirality in the test, which is expressed by the sutural angle of the terminal chambers. With a low sutural angle, the test is conical (e.g. Holotype and Supplementary Specimen A); with a high sutural angle it is cylindrical (Supplementary Specimen B); and with a more acute sutural angle it is bulbous (Supplementary Specimen C).

Hofker (loc. cit.) shows that *C. cretacea* is a dimorphic form. This could well be the explanation to the variation with the Victorian species, the conical form being megalospheric, and the more trochospiral, cylindrical to bulbous form being microspheric. With the available material, this assumption cannot be confirmed. Bandy (1951) differentiates his species, *C. californica*, into 2 varieties on whether they are conical or cylindrical. It is noteworthy that Bandy's figures suggest that the cylindrical form, *C. californica californica*, shows more trochospirality than the conical form, *C. californica mundula*.

The specific name of *C. austrotrochus* relates to its noticeable trocoid nature and is geographic occurrence.

DISTRIBUTION: A characteristic species of Zonule B, to which it is confined.

Bibliography

References for foraminiferal taxonomy are given in the synonmy with the species concerned and are not included here.

BAAS BECKING, L. G. M., GAPLAN, I. R., and MOORE, D., 1960. Limits of natural environment in terms of pH and oxidation-reduction potentials. *J. Geol.* 68 (3): 243-284.

BAIN, J. S., and MCQUEEN, A. F. New formation names. Appendix to completion reports of Port Campbell No. 1 and No. 2 wells. *Commonwealth Petroleum Search Subsidy Acts Publication* (in press).

Baker, G., 1943. Eocene deposits south east of Princetown, Victoria. *Proc. Roy. Soc. Vict.* 55: 237-256.

———, 1950. The geology and physiology of the Moolight Head district, Victoria. ibid. 60: 17-43.

———, 1953. The relationships of the *Cyclammina*-bearing sediments to the older Tertiary deposits south east of Princetown, Victoria. *Mem. Nat. Mus. (Melbourne)* 18: 125-134.

———, 1961. Studies of Nelson Bore sediments, Western Victoria. *Geol. Surv. Vict. Bull.* 58.

———, 1963. Oil well samples from Mesozoic sediments in the region west of the Otway Ranges, south west Victoria. *CSIRO Mineragraphic Investigations Rep.* 860.

Baker, G., and Cookson, I. C., 1955. The age of the Nelson Bore sediments. *Aust. J. Sci.* 17 (4): 133-134.

Bandy, O. L., 1951. Upper Cretaceous Foraminifera from the Carlsbad area, San Diego County, California. *J. Paleont.* 25 (4): 488-513.

Banner, F. T., and Blow, W. H., 1959. The classification and stratigraphic distribution of the Globigerinaceae. *Palaeontology* 2 (1): 1-27.

Bartenstein, H., and Brand, E., 1951. Mikropalaontologische Untersuchungen zur Stratigraphie des nordwestdeutschen Valendis. *Abh. Senck. Naturf. Ges.* 485: 239-336.

Bē, A. W. H., 1960. Ecology of recent planktonic Foraminifera: Part 2—Bathymetric and seasonal distributions in the Sargasso Sea off Bermuda. *Micropalaeontology* 6 (4): 373-392.

Belford, D. J., 1958. The stratigraphy and micropalaeontology of the Upper Cretaceous of Western Australia. *Geol. Rdsch.* 47 (2): 629-647.

———, 1960. Upper Cretaceous Foraminifera from the Toolonga Calcilutite and Gingin Chalk, Western Australia. *Bur. Min. Resour. Aust. Bull.* 57.

Bolli, H. M., Loeblich, A. R., and Tappan, H., 1957. Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotalidae and Globotruncanidae. *Bull. U.S. Nat. Mus.* 215: 3-50.

Boutakoff, N. A., 1952. The structural pattern of south west Victoria. *Vict. Min. & Geol. J.* 4 (6): 21-29.

Bradshaw, J. A., 1959. Ecology of living planktonic Foraminifera of the North and Equatorial Pacific Ocean. *Contr. Cushman Fdn.* 10 (2): 25-64.

Bronnimann, P., and Brown, N. K., 1956. Taxonomy of the Globotruncanidae. *Ecol. Geol. Helv.* 48 (2): 503-561.

———, and ———, 1958. *Hedbergella*, a new name for a Cretaceous foraminiferal genus. *Washington Acad. Sci. J.* 48 (1): 15-17.

Brotzen, F., 1936. Foraminiferen us dem Schwedischen untersten Senon von Eriksdal in Schonen. *Sver. Geol. Unders. Ser. C* (396).

———, 1945. De Geologiska resultaten fran Borrningara vid Höllviken. *Sver. Geol. Unders. Ser. C* (465).

Burnaby, T. P., 1962. Palaeoecology of the Foraminifera of the Chalk Marl. *Palaeontology* 4 (4): 599-608.

Cookson, I. C., and Balme, B. E., 1962. *Amosopollis cruciformis* gen. et. sp. nov., a pollen tetrad from the Cretaceous of Western Australia. *J. Roy. Soc. West. Aust.* 45 (4): 97-99.

Cookson, I. C., and Dettmann, M. E., 1958. Some trilete spores from upper Mesozoic deposits in the eastern Australian region. *Proc. Roy. Soc. Vict.* 70 (2): 95-128.

Cookson, I. C. and Eisenack, A., 1961. Upper Cretaceous microplankton from Belfast No. 4 Bore, south western Victoria. ibid. 74 (1): 69-76.

Crespin, I., 1954. The Nelson Bore, south western Victoria, micro-palaeontology and stratigraphic succession. *Bur. Min. Resour. Aust. Rept.* 11.

Cushman, J. A., 1934. The generic position of '*Cornuspira cretacea* Reuss'. *Contr. Cushman Lab.* 10 (2): 44-47.

———, 1946. Upper Cretaceous Foraminifera of the Gulf Coast region of the United States and adjacent areas. *Prof. Pap. U.S. Geol. Surv.* 206: 1-241.

———, 1950. *Foraminifera; their Classification and Economic Use*—4th ed., Harvard Uni. Press, 605 p.

Cushman, J. A., and Bermudez, P. J., 1948. *Colomia*, a new genus from the Upper Cretaceous of Cuba. *Contr. Cushman Lab.* 24 (1): 12-13.

Douglas, J. G., 1960. Microplankton of the Deflandreidae group in Western District sediments. *Vict. Mining & Geol. J.* 6 (4): 17-33.

Edwards, A. B., 1962. Notes on the geology of the Lorne district, Victoria. *Proc. Roy. Soc. Vict.* 75 (1): 101-119.

Fenton, C. L., and Fenton, M. A., 1928. Ecologic interpretation of some biostratigraphic terms. *Am. Midland Nat.* 11: 1-40.

Glaessner, M. F., 1945. *Principles of Micropalaeontology*. Melbourne Uni. Press. 296 p.

———, 1955. Taxonomic, stratigraphic and ecologic studies of Foraminifera and their interrelations. *Micropalaeontology* 1 (1): 3-8.

———, 1959. Tertiary stratigraphic correlation in the Indo-Pacific region and Australia. *J. Geol. Soc. India* 1: 53-69.

———, 1962. Isolation and Communication in the geological history of the Australian fauna. p. 242-249 in *The Evolution of Living Organisms*, ed. G. W. Leeper, Melbourne Uni. Press.

Glenie, R. C., and Reed, K. J., 1960. Bores 2 and 3, Portland, Victoria. Subsurface geology and engineering data. *Vict. Mining and Geol. J.* 6 (4): 37-43.

Harris, R. W., and McNulty, C. L., 1956. Notes concerning a Senonian valvulinerian. *J. Paleont.* 30 (4): 865-868.

Hofker, J, 1957. Foraminiferen der Oberkreide von Nordwestdeutschland und Holland. *Beih. geol. Jb.* 27: 1-464.

———, 1958. Taxonomic position of the Genus *Colomia* Cushman & Bermudez, 1948. *Contr. Cushman Fdn.* 9 (2): 34-35.

———, 1961. The gens *Globigerina cretacea* in north-western Europe. *Micropaleontology* 7 (1): 95-100.

Jefferies, R. P. S., 1962. Palaeoecology of the *Actinocamax plenus* subzone (lowest Turonian) in the Anglo-Paris Basin. *Palaeontology* 4 (4): 609-647.

Kenley, P. R., 1951. Marine Eocene sediments near Casterton, Victoria. *Aust. J. Sci.* 14 (3): 19.

———, 1954. The occurrence of Cretaceous sediments in southwestern Victoria. *Proc. Roy. Soc. Vict.* 66: 1-16.

———, 1959. The occurrence of marine Cretaceous sediments in the Belfast No. 4 Bore, Port Fairy. *Vict. Mining & Geol. J.* 6 (3): 55-56.

Klaus, J., 1959. Le 'Complex schisteux intermediare' dans le synclinal de la Gruyere (Pre Alpes Medianes). Stratigraphie et micropaleontologie avec l'etude speciale des Globotruncanides de l'Albien, du Cenomanien et du Turonien. *Ecol. Geol. Helv.* 52 (2).

Kleinpell, R. M., 1938. Miocene stratigraphy of California. *Am. Assoc. Pet. Geol.* 450 p.

Loeblich, A. R., and Tappan, H., 1961. Cretaceous planktonic Foraminifera: Part I, Cenomanian. *Micropalaeontology* 7 (3): 257-304.

Lowenstam, H. A., and Epstein, S., 1959. Cretaceous paleo-temperatures as determined by oxygen isotope methods; their relation to, and the nature of rudistid reefs. *20th Congresso geol. Internat. Mexico, El Sistema Cretacico* 1: 65-76.

Lowman, S. W., 1949. Sedimentary facies in Gulf Coast. *Bull. Am. Assoc. Petrol. Geol.* 33 (12): 1939.

Macfadyen, W. A., 1933. Fossil Foraminifera from the Burwood Bank and their geologic significance. *Discovery Rept. 7.*

McQueen, A. F., 1961. The Geology of the Otway Basin. *Aust. Oil & Gas. J.* 8 (2): 8-13.

Moullade, M., 1960. Foraminiferes du Cretace inferieur de la Drome. *Revue de Micropal.* 3 (2): 131-142.

Muller, S. M., and Schenck, H. G., 1943. Standard of the Cretaceous System. *Bull. Am. Assoc. Petrol. Geol.* 27 (3): 262-278.

Phleger, F. B., 1960. *Ecology and Distribution of Recent Foraminifera*. John Hopkins Press, Baltimore.

Pokorný, V., 1958. *Grundzüge der Zoologischen Mikropaläontologie Band.* I, D.V.W. Berlin.

Simpson, G. G., 1961. *Principles of Animal Taxonomy*. Columbia Univ. Press, New York.

Sohn, I. G., 1956. The transformation of opaque calcium carbonate to translucent calcium fluoride in fossil Ostracoda. *J. Palont.* 30 (1): 113-114.

Stainforth, R. M., 1952. Ecology of arenaceous Foraminifera. *The Micropaleontologist* 6 (1): 42-44.

Stelck, C. R., and Wall, J. H., 1954. Kaskapau Foraminifera from Peace River area, western Canada. *Research Counc. Alberta, Rept.* 68.

Takayanagi, Y., 1960. Cretaceous Foraminifera from Hokkaido, Japan. *Sci. Repts. Tohoku Uni., Japan, 2nd Ser.* (*Geology*) 32 (1).

Tappan, H., 1957. New Cretaceous index Foraminifera from Northern Alaska. *U.S. Nat. Mus. Bull.* 215: 201-222.

———, 1960. Cretaceous biostratigraphy from Northern Alaska. *Bull. Am. Assoc. Petrol. Geol.* 44 (3): 273-297.

Teichert, C., 1958a. Some biostratigraphic concepts. *Bull. Geol. Soc. Am.* 69 (1): 99-120.

———, 1958b. Concepts of facies. *Bull. Am. Assoc. Petrol. Geol.* 42 (11): 2718-2744.

THOMAS, D. E., 1959. The geological structure of Victoria. *J. & Proc. Roy. Soc. N.S.W.* 92: 182-190.

WELLMAN, W. H., 1959. Divisions of the New Zealand Cretaceous. *Trans. Roy. Soc. N.Z.* 87 (1 & 2): 99-163.

Explanation of Plates

PLATE LXXIX

Fig. 1-2—*Hyperammina elongata* Brady. (1) GSM 58716, complete specimen, × 33; (2) GSM 58717, usual preservation, × 48.

Fig. 3—*Haplophragmoides* sp. *A*. GSM 58713, 3a, side view; 3b, edge view; × 33.

Fig. 4—*Haplophragmoides* sp. *B*. GSM 58715, 4a, side view; 4b edge view; × 33.

Fig. 5—*Haplophragmoides* sp. *C*. GSM 58714, 5a, side view; 5b, edge view; × 33.

Fig. 6—*Ammobaculites goodlandensis* Cushman & Alexander. GSM 58675, side view, × 33.

Fig. 7-9—*Ammobaculites subcretacea* Cushman & Alexander. (7) GSM 58676, side view, × 33; (8) GSM 58677, side view, × 33; (9) GSM 58678, side view—abnormal specimen, × 33.

Fig. 10-11—*Ammobaculites* cf. *fragmentaria* Cushman. (10) GSM 58674, side view, × 33; (11) GSM 58673, side view, × 23.

Fig. 12-15—*Textularia anceps* Reuss. (12) GSM 58741, microspheric form; 12a, side view; 12b, edge view; 12c, apertural view; × 48. (13) GSM 58743, megalospheric form; 13a, side view; 13b, apertural view; × 33. (14) GSM 58744, megalospheric form; 14a, side view; 14b, edge view; 14c, apertural view; × 33. (15) GSM 58742, microspheric form; 15a, side view; 15b, apertural view; × 48.

Fig. 16-17—*Textularia trilobita* sp. nov. (16) GSM 58748, Holotype; 16a, side view with terminal chamber overlapping; 16b, opposite side view; 16c, edge view; 16d, apertural view; × 33. (17) GSM 58747, supplementary specimen C—juvenile; 17a, side view; 17b, apertural view; × 48.

PLATE LXXX

Fig. 1-2—*Textularia semicomplanata* Carsey. (1) GSM 58745, side view, × 48; (2) GSM 58746, 2a, side view; 2b, apertural view; × 48.

Fig. 3—*Dorothia conulus* (Reuss). GSM 58698, 3a, side view; 3 b, apertural view; × 48.

Fig. 4—*Dorothia filiformis* (Berthelin). GSM 58697, 4a, side view; 4b, apertural view; % 48.

Fig. 5-7—*Marssonella oxycona* (Reuss). (5) GSM 58725, 5a, side view; 5b, apertural view; × 48; (6) GSM 58724, 6a, side view, × 33; (7) GSM 58723, 7a, side view; 7b, end view; × 48.

Fig. 8—*Cornuspira involvens* (Reuss). GSM 58694, side view, × 48.

Fig. 9-10—*Cornuspira subprimitiva* Bartenstien & Brand. (9) GSM 58695, 9a, side view; 9b, edge view; × 73; (10) GSM 58693, acidized specimen, side view, × 73.

Fig. 11—*Quinqueloculina* sp. GSM 58737, 11a, edge view; 11b, side view; 11c, apertural view; × 48.

Fig. 12-13—*Nodosaria obscurra* Reuss. (12) GSM 58732, slender form, side view; (13) GSM 58731, broad form, 13a, side view; 13b, apertural view; × 48.

Fig. 14—*Nodosaria* cf. *obscurra* Reuss. GSM 58730, side view, × 73.

Fig. 15-16—*Nodosaria alternistriata* Morrow. (15) GSM 58727, 15a, side view; 15b, apertural view; × 48; (16) GSM 58726, side view, × 60.

Fig. 17-18—*Nodosaria navorroana* Cushman. (17) GSM 58729, 17a, side view; 17b. apertural view; × 48; (18) GSM 58728, side view, × 48.

Fig. 19—*Dentalina* cf. *intrasegma* (Carsey). GSM 58696, side view, × 48.

PLATE LXXXI

Fig. 1-3—*Lenticulina* (*Robulus*) *navarroensis* (Plummer). (1) GSM 58738, 1a, side view; 1b, edge view; × 17; (2) GSM 58739, side view, × 9; (3) GSM 58740, 3a, side view; 3b, edge view; × 17.

Fig. 4-5—*Lenticulina* (*Marginulinopsis*) *curvisepta* Cushman & Goudkoff. (4) GSM 58720, side view, × 33; (5) GSM 58721, 5a, side view; 5b, apertural view; × 33.

Fig. 6—*Lenticulina* (*Marginulinopsis*) *jarvisi* (Cushman). GSM 58722, 6a, side view; 6b, apertural view; × 33.

Fig. 7-8—*Marginulina inaequalis* Reuss. (7) GSM 58718, 7a, side view; 7b, edge view; × 48; (8) GSM 58719, 8a, side view; 8b, edge view; × 48.

Fig. 9—*Citharina whangaia*. GSM 58688, 9a, side view; 9b, apertural margin; 9c, outer margin; × 33.

Fig. 10—*Citharina geisendoerferi* (Franke). GSM 58687, 10a, side view; 10b, edge view; × 73.

Fig. 11-12—*Frondicularina* cf. *mucronata* Reuss. (11) GSM 58699, fragment-apertural end, × 33; (12) GSM 58700, fragment-basal end, × 33.

Fig. 13—*Frondicularia* sp. GSM 58701, 13a, edge view; 13b, side view; × 73.

Fig. 14—*Globulina lacrima* Reuss. GSM 58703, 14a, edge view; 14b, side view; 14c, basal view; × 48.

Fig. 15—*Praebulimina ovulum* (Reuss). GSM 58736, 15a, side view; 15b, apertural view; × 120.

Fig. 16—*Buliminella* cf. *parvula* Brotzen. GSM 58679, 16a, side view; 16b, front view; × 120.

Plate LXXXII

Fig. 1-4—*Colomia austrotrochus* sp. nov. (1) GSM 58691, holotype; 1a, front view; 1b, opposite side view; × 73; (2) GSM 58690, supplementary specimen A; 2a, side view; 2b, apertural view; × 48; (3) GSM 58692, supplementary specimen B; 3a, side view; 3b, apertural view; × 73; (4) GSM 58689, supplementary specimen C; 4a, front view; 4b, side view; × 73.

Fig. 5—*Allomorphina pyriformis* sp. nov. GSM 58673, Holotype; 5a, spiral view; 5 b, umbilical view; 5c, edge view; × 48.

Fig. 6-7—*Pallaimorphina heliciformis* sp. nov. (6) GSM 58734, Holotype; 6a, spiral view; 6b, umbilical view; 6e, edge view; × 105; (7) GSM 58733, supplementary specimen; 7a, spiral view; 7b, umbilieal view; 7c, edge view; × 105.

Fig. 8—*Stilostomella alexanderi* (Cushman). GSM 58752, side view, × 48.

Fig. 9—*Pleurostomella subnodosa* Reuss. GSM 58753, 9a, front view; 9b, side view; × 42.

Fig. 10—*Valvulineria lenticula* (Reuss). GSM 58751, 10a, spiral view; 10b, umibilical view; 10c, edge view; × 105.

Fig. 11—*Valvulineria undulata* Belford. GSM 58750, 11a, spiral view; 11b, umbilical view; 11c, edge view; × 105.

Fig. 12—*Valvulineria erugata* Belford. GSM 58749, 12a, spiral view; 12b, umbilical view; 12e, edge view; × 105.

Plate LXXXIII

Fig. 1—*Gyroidinoides nitida* (Reuss). GSM 58707, 1a, spiral view; 1b, umbilical view; 1e, edge view; × 73.

Fig. 2—*Gyroidinoides cruachin* sp. nov. GSM 58708, Holotype; 2a, spiral view; 2b, umbilical view; 2c, edge view; × 73.

Fig. 3-4—*Alabamina australis* Belford. (3) GSM 58670, 4a, spiral view; 4b, umbilical view; 4c, edge view; × 105; (4) GSM 58671, 4a, spiral view; 4b, umbilical view; 4c, edge view; × 120.

Fig.5-6—*Cibicides excavatus* Brotzen. (5) GSM 58684, 5a, spiral view; 5b, umbilical view; 5c, edge view; × 48; (6) GSM 58685, spiral view, × 48.

Fig. 7—*Cibicides ribbingi* Brotzen. GSM 58682, 7a, spiral view; 7b, umbilieal view; 7c, edge view; × 33.

Fig. 8—*Hanzawaia californica* (Bandy). GSM 58686, 8a, spiral view; 8b, umbilical view; 8c, edge view; × 105.

Fig. 9—*Gavelinopsis cenomanica* (Brotzen). GSM 58702, 9a, dorsal view; 9b, ventral view; 9c, edge view; × 48.

Fig. 10—*Gavelinopsis* cf. *eriksdalensis* Brotzen. GSM 58705, 10a, dorsal view; 10b, ventral view; 10c, edge view; × 73.

Plate LXXXIV

Fig. 1-2—*Ceratobulimina kremnoides* sp. nov. (1) GSM 58680, Holotype; 1a, spiral view; 1b, umbilical view; 1e, edge view; × 48; (2) GSM 58681, supplementary specimen; 2a, spiral view; 2b, umbilical view; 2e, edge view; × 48.

Fig. 3—*Ceratobulimina cretacea* Cushman & Harris. GSM 58682, 3a, spiral view; 3b, umbilical view; 3e, edge view; × 73.

Fig. 4-7—*Hedbergella trocoidea* (Gandolfi). (4) GSM 58709 (fluorite replacement); 4a, spiral view; 4b, umbilieal view; 4c, edge view; × 105; (5) GSM 58711, 5a, spiral view; 5b, umbilical view; 5c, edge view; × 73; (6) GSM 58712 (calcite mould); 6a, spiral view; 6b, umbilieal view; 6e, edge view; × 73; (7) GSM 58710 (flourite replacement); spiral view; × 105.

Fig. 8—*Guembelina reussi* Cushman. GSM 58706, 8a, side view; 8b, edge view; × 73.

Fig. 9—*Hoeglundina supracretacea* (ten Dam). GSM 58704, 9a, spiral view; 9b, umbilical view; 9c, edge view; × 73.

PLATE LXXXV

(Photomicrographs of thin sections)

Fig. 1—*Textularia semicomplanata* Carsey. GSM 58803, longitudinal section—under crossed nicols, × 80.

Fig. 2-3—*Textularia anceps* Reuss. (2) GSM 58802, microspheric specimen, longitudinal section —under crossed nicols, × 80; (3) GSM 58801, megalospheric specimen, longitudinal section—under crossed nicols, × 80.

Fig. 4-5—*Textularia trilobita* sp. nov. (4) GSM 58804, supplementary specimen A—microspheric form, longitudinal section, 4a, under crossed nicols; 4b, normal; × 50; (5) GSM 58805, supplementary specimen B—megalospheric specimen, longitudinal section—under crossed nicols, × 50.

PLATE LXXXVI

(Photomicrographs of thin sections)

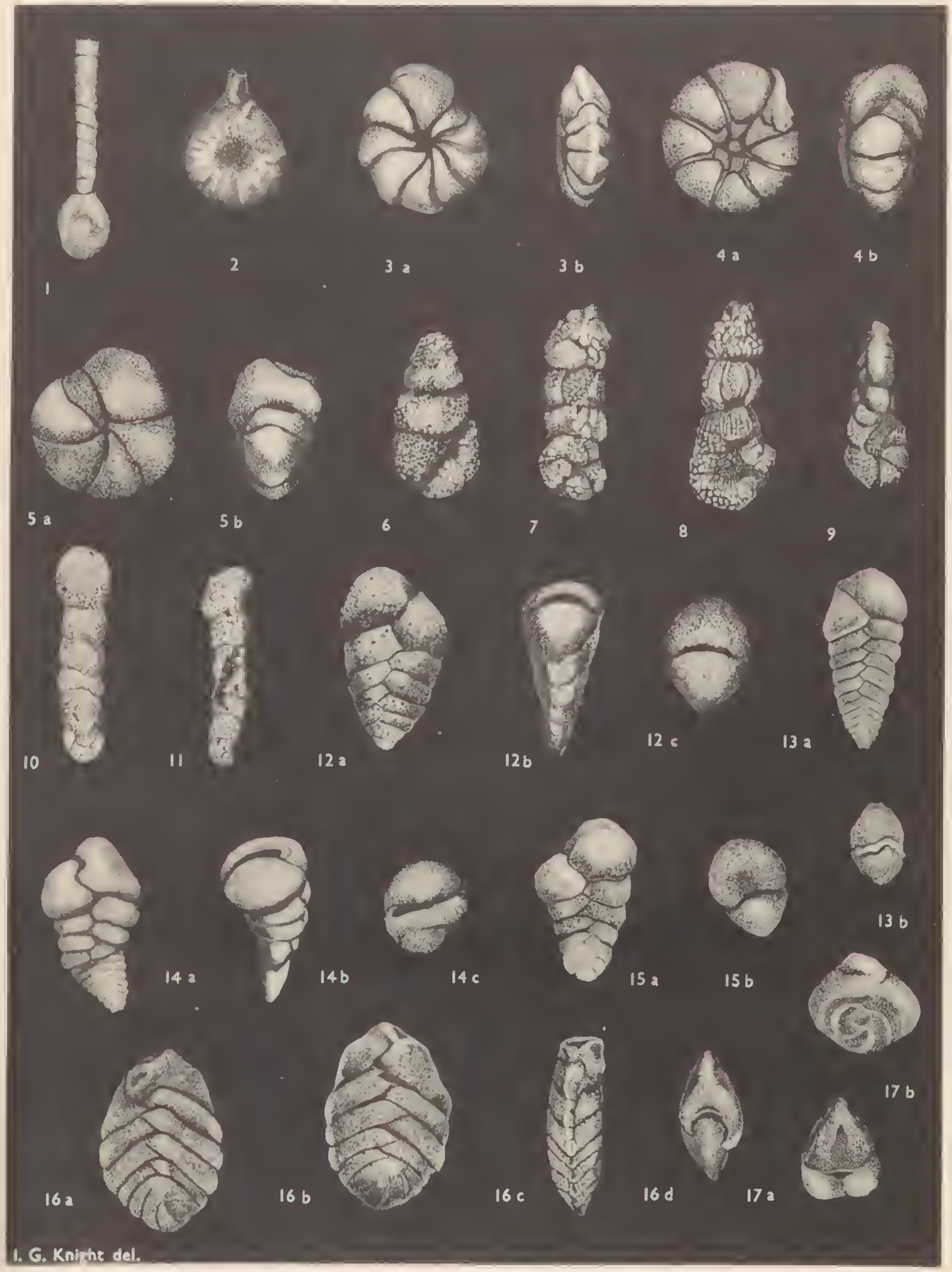
Fig. 1-3—*Colomia austrotrochus* sp. nov. (1) GSM 58793, supplementary specimen D, longitudinal section, 1a, normal; 1b, under crossed nicols; × 80; (2) GSM 58794, supplementary specimen E, longitudinal section—under crossed nicols, × 80; (3) GSM 58795, supplementary specimen F, thick transverse section towards initial end, × 215.

Fig. 4-5—*Cibicides excavatus* Brotzen. (4) GSM 58791, horizontal section—under crossed nicols, × 80; (5) GSM 58870, vertical section, × 80.

Fig. 6—*Alabamina australis* Belford. GSM 58790, horizontal section, × 160.

Fig. 7—*Hanzawaia californica* Bandy. GSM 58792, horizontal section, × 200.

Fig. 8-9—*Gavelinopsis cenomanica* Brotzen. (8) GSM 58797, vertical section, × 80; (9) GSM 58796, horizontal section, × 80.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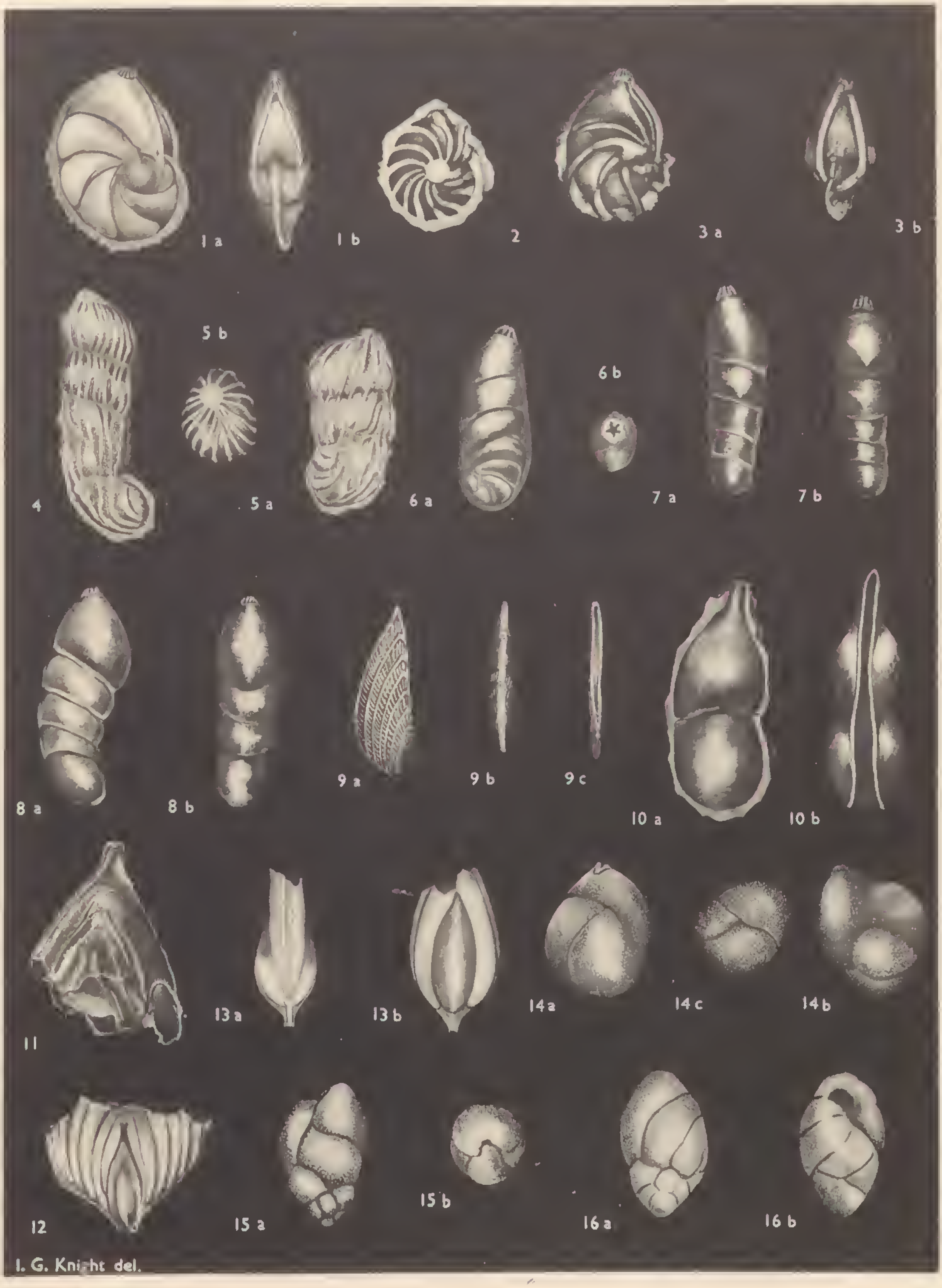

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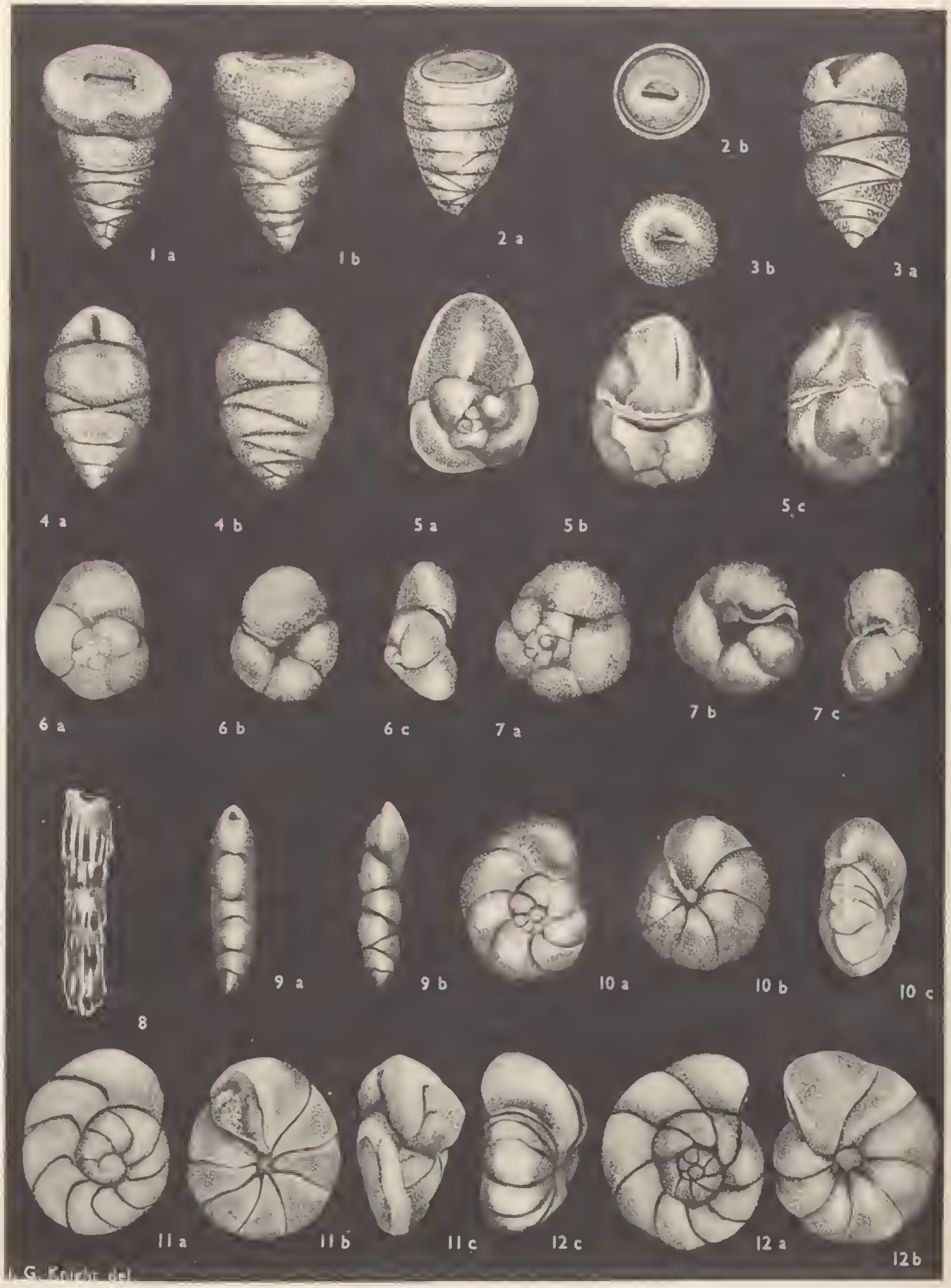

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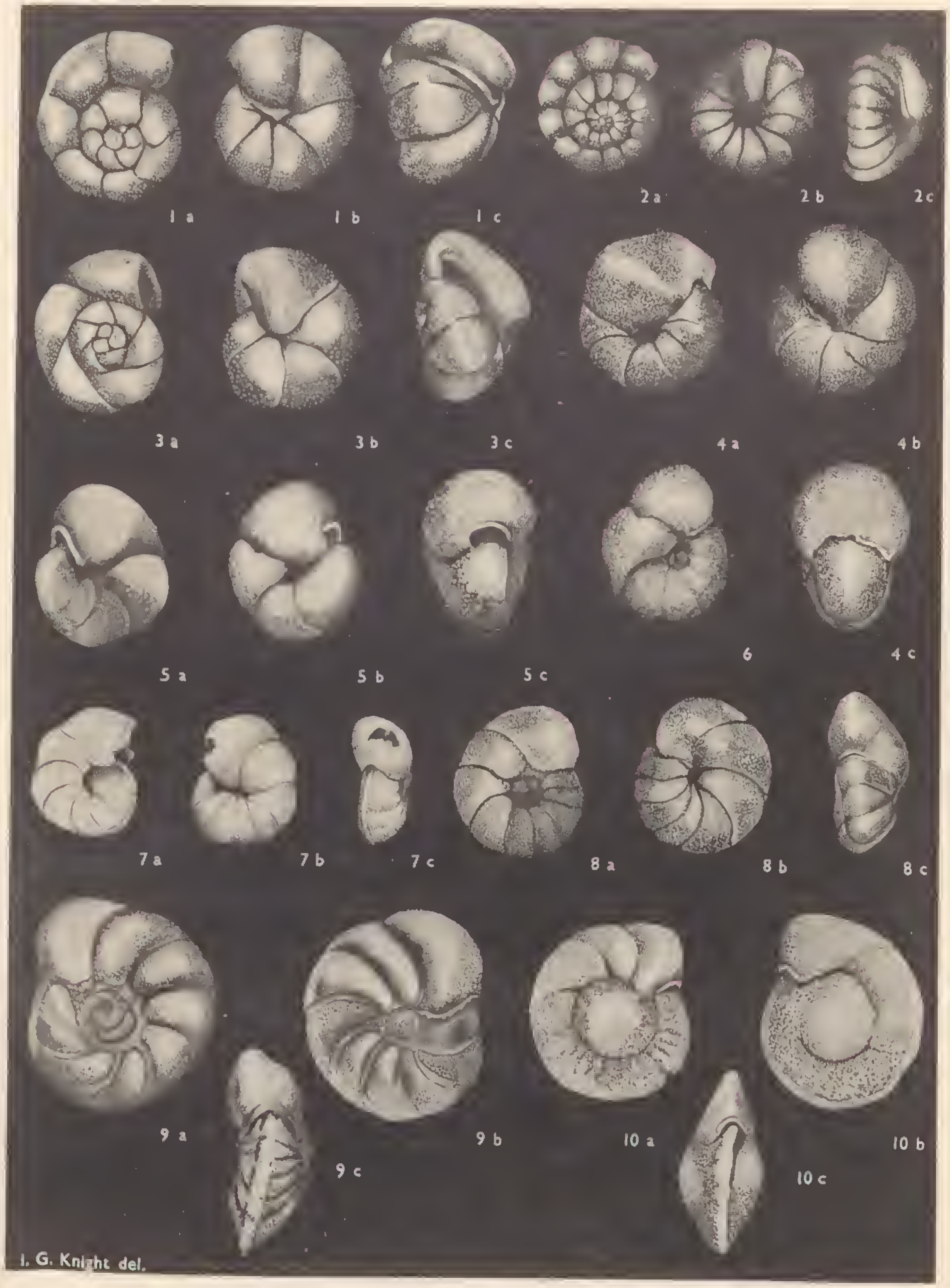
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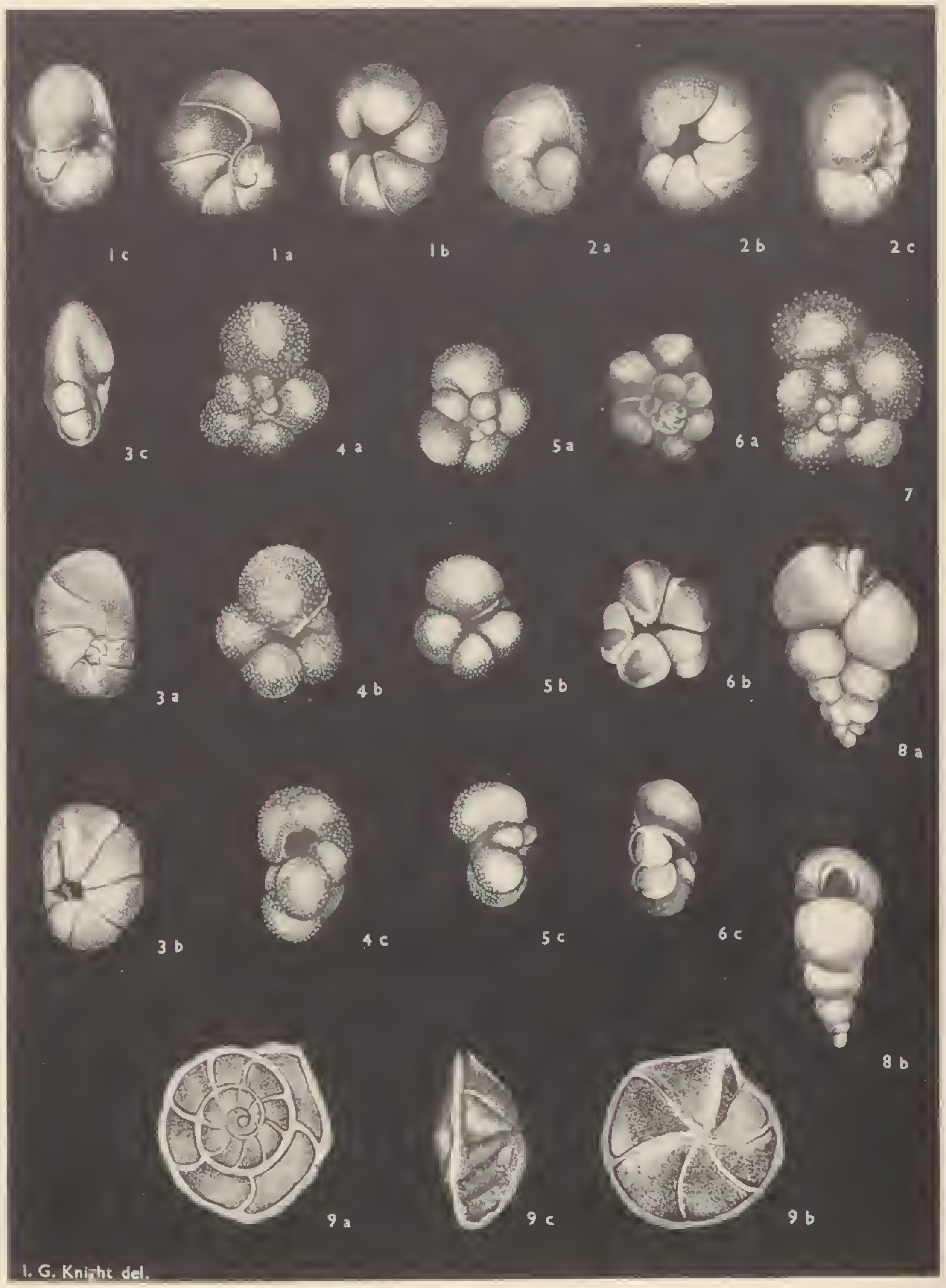

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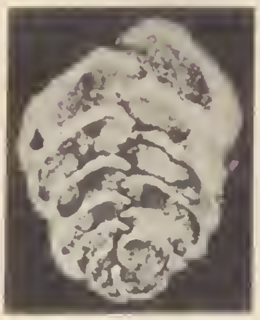
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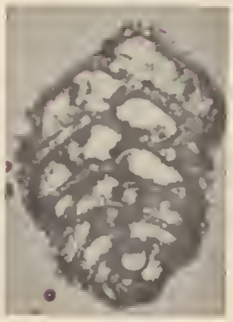
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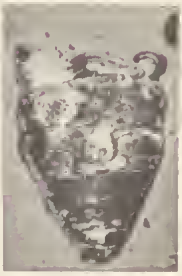

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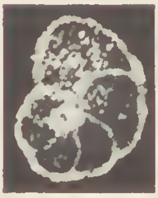

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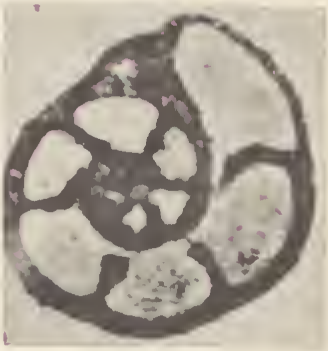

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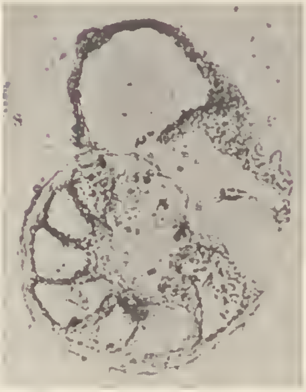

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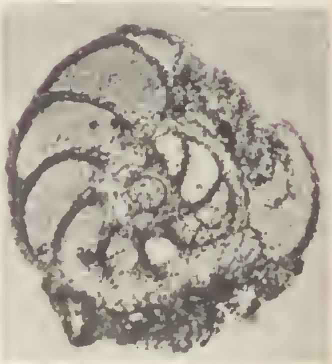

9

Species Index

SPECIES DESCRIBED IN TEXT:

SPECIES RECORDED BUT NOT DESCRIBED OR FIGURED:

(C = common; other species extremely rare)

Ammodiscus sp. C
Bathysiphon sp. C
Bolivina ? sp.
Conorbina ? sp.
Cymbalopora ? sp.
Dentalina spp. C
Gavelinopsis sp.
Globorotalites sp.
Hastigerinella ? sp.
Lagena spp. C
Lenticulina spp. C
Nodosaria sp.
Osangularia ? sp.
Pullenia sp.
Reophax sp. C
Trochammina sp. C

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1964

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Wark, I. W., CBE, PhD DSc, FAA, CSIRO, 314 Albert St, E. Melbourne, C2	1961
Warren, J. W., MA PhD, Zoology and Comparative Physiology Dept, Monash University, Clayton	1963
Watson, Mrs Jeanette E., 74 Nimmo St, Essendon, W5	1961
Weickhardt, L. W., MSc, FRACI, 125 Canterbury Rd, Canterbury, E7	1959
Wettenhall, H. N. B., MD BS, MRCP FRACP, 41 Spring St, Melbourne, C1	1959
White, Prof. M. J. D., DSc *Lond.*, FRS FAA, Zoology Dept, University, Parkville, N2	1958
White, R. K., FIPAA, 360 Collins St, Melbourne, C1	1958
Whiting, R. G., BME, 7 Barkly Ter., Mitcham	1959
Whitelaw, J. J., BME, 286 Huntingdale Rd, Chadstone, SE10	1963
Wickens, T. W., 27 Narrak Rd, Balwyn, E8	1957
Wilcock, A. A., BSc BEd, Geography Dept, University, Parkville, N2	1934
Williams, W. D., BSc PhD, FZS, Monash University, Clayton	1961

Willis, A. G., MSc, Zoology Dept, University, Parkville, N2	1949
Wilson, D., BSc, 46 Hoddle St, Essendon, W5	1961
Wiltshire, A. R. L., CMG DSO MC VD, 35 Evans Ct, Toorak, SE2	1955
Woodford, E. R., Flat 3, 'Winton', Linton Ct, E. Hawthorn, E3	1963

COUNTRY MEMBERS

Adams, H. G. C., 'Danedite', Weerite	1945
Baldwin, J. G., BSc BAgrSc, 33 Walnut Av., Mildura	1949
Bishop, J. J., BA. High School, Moe	1950
Burn, R., 3 Nantes St, Newtown, Geelong	1956
Casey, Mrs D. A., 'Willimi', Cheniston Rd, Mt Macedon	1953
Condon, M. A., MSc, Bureau of Mineral Resources, Canberra, ACT	1937
Conley, W. R., 2 Lillian St, Nunawading	1956
Corney, Mrs A. D., BSc, 17 Ratho St, New Town, T.	1945
Dawes, L. F., BSc, 43 Hopetoun Gr., Ivanhoe, N21	1954
Dickins, J. MacG., MSc PhD, Bureau of Mineral Resources, Canberra, ACT	1952
Forrest, J. M., Metropolitan Farm, PO, Werribee	1954
Glaessner, M. F., PhD DSc, FAA, Geology Dept, University of Adelaide, S.A.	1939
Hill, Prof. Dorothy, DSc PhD, FAA, Geology Dept, University of Queensland, St Lucia, Q.	1939
Hope, G. B., BME, 'Carrical', Hermitage Rd, Newtown, Geelong	1918
Kershaw, R. C., BSc, 'Manorama', c/o Lyetta PO, W. Tamar, T.	1956
Lindholm, J. D. E., c/o High School, Shepparton	1952
Massey, C. H., 11 Church St, Ashfield, N.S.W.	1957
McWhae, Mrs J. R. H., c/o California Standard Co., Medical Arts Bldgs, 329A 6th Ave SW, Calgary, Canada	1948
Murphy, H. D., Mornington	1950
Netherway, G. C., 606 Dana St, Ballarat	1958
Payne, T. E. N., 'Woodburn', Kilmore	1945
Searle, S. S., Metropolitan Farm, PO, Werribee	1954
Yates, H., MSc, School of Mines, Ballarat	1943

ASSOCIATES

Anderson, R. E., BA, 20 Hudson St, Moonee Ponds, W4	1964
Autry, W. C., BSc, 8402 Flalon St, Whittier, California, U.S.A.	1957
Baker, A. A., 53 Carlisle St, Preston, N18	1946
Bamford, W. E., BE (Hons), 55 Park Hill Rd, Kew, E4	1963
Bell, G., BSc, 62 Athol St, Surrey Hills, E10	1955
Bird, R. G., 'Hoana', Saltpan Bay, Prince Alfred Pde, Newport, Sydney, N.S.W.	1962
Boardman, Miss V. M., 24 Shannon Av, N. Geelong	1962
Boch, P. E., BSc, 32 Swayfield Rd, Mt Waverley	1957
Bollen, P. W., BSc, Flat 16, 21 Bruce St, Toorak, SE2	1957
Bowler, J. M., MSc, Geology Dept, University, Parkville, N2	1960
Brunn, Mrs T. H., 605 Malvern Rd, Toorak, SE2	1960
Burns, D., 11 Robertson St, Colac	1960
Buttery, S. H., 146 Highfield Rd, Camberwell, E6	1952
Carr, Mrs D. J., MSc, Queen's University, Belfast, N. Ireland	1937
Carter, A. N., MSc PhD, 8 Scott St, Maroubra Bay, N.S.W.	1947
Clarke, W. G., BE BSc, DipEd, 67 Willis St, Hampton, S7	1957
Clifford, H. T., MSc PhD, Botany Dept, University of Queensland, St Lucia, Q.	1949
Coats, R. P., BSc, South Australian Dept of Mines, 168 Rundle St, Adelaide, S.A.	1951
Cobbett, A. M., Oxford Close, Moorabbin, S20	1951
Cochrane, G. W., MSc, 320 Lane St, Broken Hill, N.S.W.	1945
Cormak, M. G., Lower Crawford, Private Bag 39, PO, Heywood	1961
Court, A. B., MSc, National Herbarium, Royal Botanic Gardens, South Yarra, SE1	1949
Crawford, T. W., 1 Belgrave Av., Balwyn, E8	1964

Darragh, T. A., BSc, DipEd, 46 The Esplanade, Clifton Hill, N8	1963
Dempster, Miss P. B., BSc, c/o 751 Canterbury Rd, Surrey Hills, E10	1957
Elford, F. G., BSc BEd, 76 New St, Brighton, S5	1929
English, J. R., 302 Lower Heidelberg Rd, E. Ivanhoe, N21	1956
Esplan, W. A., BSc, 37 Barnes Av., Burwood, E13	1951
Finlay, Miss C. F., BSc, Geology Dept, University, Parkville, N2	1950
Fisher, Eileen E., PhD, 1 Balwyn Rd, Canterbury, E7	1949
Frostick, A. C., 9 Pentland St, N. Williamstown, W16	1933
Gale, J. C., 154 Mont Albert Rd, Canterbury, E7	1959
Gamble, D. S., Ormond College, College Cr., Parkville, N2	1964
Gostin, V. A., BSc, 92 Marlborough St, E. Bentleigh, SE15	1963
Hewett, D. C., BSc, DipEd, 77 Agg St, Newport, W15	1959
Holdaway, E. A., BSc BEd, 9 Bardolph St, Burwood, E13	1957
Hounslow, A. W., BSc, 28 Georgiana St, Sandringham, S8	1958
Johns, M. W., BSc, 355 Upper Heidelberg Rd, Ivanhoe, N21	1958
Kenley, P. R., BSc, 14 Yarrabee Ct, Mt Waverley	1948
Lawrence, C. R., BSc, 3 Wright St, Bentleigh, SE14	1958
Learmonth, A. P., BSc, 12 Cornwall Rd, Sunshine, W20	1955
Lord, E. E., GPO Box 5278, Melbourne, C1	1950
McLaurin, A. N., Couangalt, via Gisborne	1963
McLennan, Assoc. Prof. Ethel, DSc, Botany Dept, University, Parkville, N2	1915
Marsden, M. A. H., BSc, 17 Oak St, Beaumaris, S10	1952
Matthaei, Mrs G., 146 Gatehouse St, Parkville, N2	1959
Moir, Mrs Marion M., MA, DipEd, 434 Elgar Rd, Box Hill, E11	1960
Mooney, M. J., 'Beann Nhairi', Yarra Junction	1963
Moore, B. R., BSc, Peter St, Eltham	1957
Morris, P. F., 6 Mandeville Cr., Toorak, SE2	1921
Neilson, J. L., BSc, 1 Fordham Av., Camberwell, E6	1952
Nicholas, T., Bureau of Mineral Resources, Canberra, ACT	1958
Nicholson, B. M., BAgrSc, Soil Conservation Authority, Box 187 PO, Bairnsdale	1963
Passioura, J. B., MSc PhD, 28 Meredith St, Elwood, S3	1961
Pinches, Mrs M., 140 Churchill Highway, Braybrook, W19	1943
Pretty, R. B., MSc, Private Bag, Cobargo, N.S.W.	1922
Pringle, J. V., 422 Waverley Rd, E. Malvern, SE5	1961
Rash, K. E., 75 Humffray St S., Ballarat	1960
Rawlins, R. J., BSc, c/o PO, Cloncurry, Q.	1957
Reed, K. J., BSc, Dept of Geology, McGraw Hall, Cornell University, Ithaca, N.Y., U.S.A.	1958
Richards, S. M., BSc (Hons), PhD, CSIRO Mineragraphic Invest. Section, University, Parkville, N2	1964
Rimington, K. N., BSc, 15 Yuille St, Brighton, S5	1948
Shaw, H., 18 Normanby Rd, E. Bentleigh, SE15	1956
Sherrard, Mrs H. M., MSc, 43 Robertson Rd, Centennial Park, N.S.W.	1918
Simpson, B., 3 Knutford St, Balwyn, E8	1959
Singleton, O. P., MSc PhD, Geology Dept, University, Parkville, N2	1943
Sinnott, P. J., 17 Normdale Rd, E. Bentleigh, SE15	1959
Squance, G. J., 14 Rupert St, E. Brunswick, N11	1963
Stubbs, D., 2 Coleridge St, Elwood, S3	1960
Taylor, T. W., 22 Jellicoe St, Box Hill, E11	1963
Tuddenham, W. G., BSc, DipEd, Geography Dept, University of Sydney, N.S.W.	1963
Valiullah, M., MSc, Geology Dept, University, Parkville, N2	1962
Vasey, G. H., BCE, University, Parkville, N2	1936
Walker, A. L., Chemistry Dept, University, Parkville, N2	1961
Walsh, Mrs A., 64 Brown St, Heidelberg, N22	1964
Watts, H. A., 15 Tower Hill Rd, Glen Iris, SE6	1954
White, O. L., BSc MASc, Dept of Civil Engineering, University of Waterloo, Waterloo, Ontario, Canada	1955

Whitehead, Mrs R., MSc, 58 Invermay Gr., Rosanna	1942
Wilkins, R. W. T., MSc, Dept Mineralogy and Petrology, University of Cambridge, U.K.	1961
Wilkinson, H. E., National Museum of Victoria, Russell St, Melbourne, C1	1963
Williams, G. E., MSc, Sedimentology Research Laboratory, Whiteknights Park, Reading, Berks, U.K.	1962
Wymond, A. P., MSc, CSIRO Division of Forest Products, PO Box 18, S. Melbourne, SC4	1951

Royal Society of Victoria

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR 1963

The President and Council present to members of the Society the Annual Report with Financial Statement for the year 1963.

The following meetings of the Society were held:

MARCH 14—ANNUAL MEETING. The following office-bearers were elected:

President—Mr R. T. M. Pescott.
Vice-Presidents—Dr D. E. Thomas, Mr J. H. Chinner.
Honorary Treasurer—Mr L. Adams.
Honorary Secretary—Mr E. D. Gill.
Honorary Librarian—Associate Professor C. M. Tattam.
Honorary Editor—Professor G. W. Leeper.

The following members of Council were elected:

Mr V. G. Anderson, Dr B. D. Cuming, Capt. J. K. Davis, Dr R. R. Garran, Professor G. W. Leeper and Professor J. S. Turner.

The following members of Council continued in office:

Mr H. C. Chipman, Dr J. D. Morrison, Dr C. E. Resch and Mr A. G. Willis.

The Annual Report with Financial Statement for 1962 was received and adopted.

Upon conclusion of the Annual Meeting, an ORDINARY MEETING was held when Mr John Thomson introduced discussion on 'What, if anything, is a species?'

APRIL 11—Professor J. Andrews and Dr P. G. Law were elected members of Council and Dr Spencer-Jones Assistant Secretary. The Society's RESEARCH MEDAL for 1962 was presented to Professor J. M. Cowley, who then gave a LECTURE on 'The use of electrons in the study of crystals'.

MAY 9—RESEARCH PAPER. Dr Mary Dettmann outlined her work at Cambridge University on the Upper Mesozoic microfloras of Australia.

JUNE 13—It was announced that the new Governor of Victoria, Sir Rohan Delacombe, had become Patron of the Society, and that the former Patron, Sir Dallas Brooks, had become an Honorary Member. Mrs P. G. Law, deputizing for Dr Law, gave a LECTURE on 'The exploration of Oates Land'.

JULY 11—RESEARCH PAPERS by Mr N. W. Schleiger, Dr G. P. Briner, Dr J. A. Talent, Mr G. Ross Cochrane and Mr Robin J. Pryor, Dr Donald Thomson and Mr W. Hosmer, Professor and Mrs D. J. Carr, Mr J. G. Douglas, Dr F. Beavis, and Mr E. D. Gill and Mr T. A. Darragh were presented.

AUGUST 8—LECTURE by Professor D. C. Blood on 'Livestock conservation in Australia'.

SEPTEMBER 12—SYMPOSIUM—'The basalt plains of Western Victoria'. The early afternoon session was chaired by Professor G. W. Leeper and papers were given by Mr C. E. Hounam and Mr E. A. Powell, Mr J. H. Willis, Mr R. H. Groves, Mr N. A. Wakefield, and Mr F. R. Gibbons and the Hon. Secretary.

The late afternoon session was chaired by Professor C. M. Tattam and papers were presented by Mr D. T. Currey, Mr A. Baker, Mr E. D. Gill, and Mr P. E. Bock and Mr R. Glennie.

The evening session was chaired by the President and papers were given by Mr C. D. Ollier, Mr D. J. Mulvaney, and Dr P. S. Lang.

OCTOBER 10—LECTURE by Mr N. C. Manning on 'The control of drugs in the community'.

NOVEMBER 14—SOIREE: reception, exhibits, films and supper.

DECEMBER 12—The Society's RESEARCH MEDAL for 1963 was presented to Mr D. J. Mulvaney. RESEARCH PAPERS were then presented by Mr D. J. Mulvaney, Dr Isabel Cookson and Dr S. Manum, Dr F. C. Beavis, Mr A. R. Berger, Mr G. E. Williams, Dr M. F. Glaessner, Dr G. M. Philip, Mr J. A. Mahoney and Mr D. J. Taylor.

The number of members at 31 December 1963 was: Honorary 3, Life Members 22, Members 299, Associates 70 and Country Members 21, making a total of 415. This is a record figure for membership. During the year 2485 volumes and parts were added to the library.

Attendances at Council meetings were: Mr Adams 3, Mr Anderson 8, Professor Andrews 4, Mr Chinner 1, Mr Chipman 2, Dr Cuming 5, Capt. Davis 3, Dr Garran 10, Mr Gill 10, Dr Law 5, Professor Leeper 10, Dr Morrison 8, Mr Pescott 9, Dr Resch 7, Dr Spencer Jones 10, Professor Tattam 9, Dr Thomas 0, Professor Turner 2, Mr Willis 3. Leave of absence was granted during the year to Mr Chinner, Mr Chipman, Capt. Davis and Dr Thomas.

The Society deeply regrets the loss during the year of the following members:

GEORGE MACK was born in Scotland in 1899 and died on 24 October 1963. On coming to Australia after the war of 1914-18 he joined the staff of the National Museum of Victoria as ornithologist, and completed a science course at the University. He published many articles, generally on taxonomy, between 1930 and 1945. In 1946 he was appointed Director of the Queensland Museum, a post that he held till his death. He became a member of the Royal Society of Victoria in 1943 and remained a country member on leaving Victoria in 1946.

RONALD REAY MACKAY, FInstRE FAIM, was born in Melbourne on 22 December 1905 and died on 4 December 1963. He was head of the Radio School, Melbourne Technical College, for some years, and became Principal of Royal Melbourne Institute of Technology in 1952. He was associated with the Flying Doctor Service of Australia since 1936 as an honorary adviser on radio matters. He was concerned in many committees on technical education and was a member of the Commonwealth Committee on the Future of Technical Education. He had been a member of the Royal Society of Victoria since 1958.

STANLEY ROBERT MITCHELL was born in St Kilda on 12 February 1881, and died in Melbourne on 22 March 1963. His father, James Davidson Mitchell, was a bookseller and stationer in Smith Street, Collingwood, his hobby being mineralogy. Under his influence the son became interested in minerals and accompanied his father on collecting trips, thereby acquiring a love for and continuing interest in this and allied subjects. He was trained at the Working Men's College (now the Royal Melbourne Institute of Technology) where he completed courses in mineralogy, metallurgy, chemistry and geology. He embarked on a metallurgical career which culminated in his founding the business of Mitchell's Abrasives Pty Ltd.

Mitchell's interest in anthropology began in the early 1890's when he found an aboriginal axe whilst on a geological excursion. From this time on he systematically searched for aboriginal implements, and eventually accumulated a magnificent private collection. He published a large number of articles and papers in leading anthropological journals. His *Stone Age Craftsmen*, published in 1949, has become a textbook on the stone implements of the Victorian aborigines.

JOHN NORRIS MONTGOMERY was born at Wedderburn, Victoria, in 1891 and died in Melbourne on 3 November 1963. After graduating in mining engineering and geology at the Ballarat School of Mines he taught at the Bairnsdale School of Mines until 1917, when he joined the Commonwealth Government's oil exploration party in Papua under Dr Arthur Wade. For the next quarter-century he worked with various oil companies, some of the time in other continents but mostly in Papua and New Guinea. During the war he continued geological work partly in the office of Australasian Petroleum Company and partly as a technical adviser to the United States Army. From 1946 until retirement in 1959 he was geological adviser to the management of Australasian Petroleum Company in Melbourne. He was joint author of two important publications on Papua and New Guinea. He was elected a Member in 1945.

FRANK LESLIE STILLWELL, OBE, DSc, FAA, was born in 1888, and died on 8 February 1963. He took his first degree in science at the University of Melbourne in 1911 and was awarded the doctorate of science in 1916 for his work in metamorphic differentiation, developed during his visit to Antarctica, where he was a member of Mawson's 1911-13 Expedition. He was a pioneer in mineragraphy in Australia, and his 63 scientific papers were centred on the mineragraphy of Australian ores, especially in the fields of Kalgoorlie, Broken Hill and Bendigo. He was appointed to C.S.I.R. in 1927 and was in charge of its mineragraphic investigations until he retired in 1953. He was awarded the Syme Research Prize in 1919 for his work on the origin of gold in quartz reefs and the Clarke Memorial Medal of the Royal Society of New South Wales in 1951. He was a foundation fellow of the Australian Academy of Science. He was on the Council of the Royal Society of Victoria from 1929 till the time of his death, being Honorary Secretary from 1929 to 1947, President in 1953 and 1954, and Honorary Editor from 1956 until his death.

Dr Stillwell bequeathed £4,000 to the Royal Society of Victoria.

HERBERT ST JOHN SUMMERS died on 15 August 1963, after an almost lifelong association with the University of Melbourne. He was born at Benalla in 1876 and came to the Geology Department as a Caroline Kay Scholar in 1906. He was appointed lecturer in 1909 and Associate Professor in 1920, and, on the retirement of Professor E. W. Skeats in 1940, he succeeded to the Chair of Geology and Mineralogy at the age of 64. After his retirement from the Chair at the age of 68 he continued to work for the University on administrative matters until 1950, and from then until his death he maintained his association with the Geology Department through his work in technical school and forestry examinations.

In addition to his teaching duties he was active in research, chiefly in petrology and experimental tectonic geology, obtaining his DSc degree in 1913. He also played an active part in University affairs, representing the sub-professorial staff on Council from 1922 to 1935.

Herbert Summers was one of the true founders of the Geology Department of the University, and is remembered as a man who was ever ready to help and advise the many hundreds of young people with whom he was associated. He was President of the Royal Society of Victoria in 1931-2, and a member of the Council of the Society from 1914 to 1949.

ROBERT MILNE WISHART, MB ChB *NZ.*, FRACS FRMS, was born on 2 October 1895 at Dunedin, New Zealand, and graduated in Medicine and Surgery at the University of Otago in 1917. He served in the Medical Corps in Egypt in the First World War. Upon his return he practised as a physician and surgeon in Hawthorn, Victoria. He became a Fellow of the Royal Australian College of Surgeons in 1938 and for the last 20 years of his life was an Honorary Surgeon at Prince Henry's Hospital.

A keen student of natural history, he contributed several papers on birds and on botany to the *Victorian Naturalist*, and on diatoms and human blood to the *Journal of Microscopy*. He became a Fellow of the Royal Microscopical Society of Great Britain in 1962. Ethnology was his hobby and gradually he amassed a large collection of ethnographical objects, most of the stone implements having been collected by himself from aboriginal camping sites in south-east Australia. He was a foundation member of the Anthropological Society of Victoria, a member of its Committee for 20 years, and its president in 1954-56 and again in 1957-58.

Dr Wishart died in Melbourne on 28 April 1963.

TREASURER'S REPORT

It will be seen that total receipts and payments were much higher than usual. This was mainly due to an expedited rate of publication. The building was also painted during the year.

Costs of publication are rising and further maintenance will be necessary.

The Society expresses its appreciation to the State Government for its grant and also to the generous support of those shown in the financial statement. After the books closed, the following further donations were received towards the publication of the monograph by Dr Mary Playford—Mobil Oil Australia Ltd £50, Delhi Australian Petroleum Ltd £10.

We are much indebted to the late Dr F. L. Stillwell for his generous bequest of £4,000.

SUMMARY FOR YEAR ENDED 31 DECEMBER 1963

		£	s.	d.
Balance from 1962		£727	14	2
Total Receipts		7,539	7	0
		£8,267	1	2
Total Payments		6,877	10	10
	Cr.	£1,389	10	4

INVESTMENTS HELD AS AT 31 DECEMBER 1963

Australian Guarantee Corporation Limited— 7% Debenture Stock	£1,000
Australian Aluminium Company Limited— 7% Debenture Stock	800
Bitumen & Oil— 8% Registered Unsecured Notes	100
	£1,900

FINANCIAL STATEMENT FOR YEAR ENDED 31 DECEMBER 1963

RECEIPTS

Balance brought forward 1/1/63		£727 14 2
Subscriptions		1,501 10 11
Rents		1,017 9 6
Sale of Publications		1,218 4 5
Interest—		
Investments	£162 15 5	
Benefactions	272 10 0	435 5 5
Grants and Donations—		
Government of Victoria—		
1962	£500 0 0	
1963	500 0 0	
University of Melbourne	300 0 0	
Commonwealth of Australia	600 0 0	
Woodside Oil Company*	50 0 0	
Mid-Eastern Oil Co.*	50 0 0	
Alliance Oil Development*	50 0 0	
Alliance Petroleum*	50 0 0	
Ampol Exploration*	25 0 0	
B.H.P.*	100 0 0	
Union Oil Development*	50 0 0	
University of New England	154 10 0	
Exoil No Liability*	25 0 0	
Frome Broken Hill No Liability*	100 0 0	
American Overseas Petroleum*	50 0 0	
British Petroleum*	50 0 0	
Albion Quarrying Company*	50 0 0	
Interstate Oil Ltd.*	50 0 0	2,754 10 0
		£7,654 14 5

* Donations towards publication of monograph by Dr Mary Playford (*P.R.S.V.* 77: 1-148)

PAYMENTS

Salaries—			
Assistant Editor		£70 12 2	
Assistant Librarian		189 14 5	
Clerical		106 12 3	
Hallkeeping	£475 8 8		
Less Refunds	89 13 6	385 15 2	£752 14 0
Publishing Proceedings 75 (2) 76 (1 and 2)			4,253 16 5
Stationery			184 16 1
Telephones		£45 19 1	
Less Refunds		9 15 4	36 3 9
Electricity		£401 7 10	
Less Refunds		28 3 4	373 4 6
Rates			73 14 6
Repairs and Maintenance			871 6 11
Postages			127 9 0
Sundries—			
Journals		£5 6 5	
Insurance		55 19 4	
Engraving		5 0 0	
Projector Lamps		3 17 9	70 3 6
			£6,743 8 8
Less received from R.C.O.G.			478 4 7
			£6,265 4 1
Balance carried forward, 31/12/63			1,389 10 4
			£7,654 14 5

L. ADAMS, *Hon. Treasurer*

Audited and found correct—
S. M. WADHAM } *Hon.*
CARL E. RESCH } *Auditors*

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