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DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
PALYNOLOGY SECTION

S.A.G. COOTANOORINA NO. 1 WELL

UPPER PALAEOZOIC AND LOWER CRETACEOUS MICROPALAEONTOLOGY

Grid G/3

by

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and

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DM.1510/68

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CONTENTS — PAGE

PLATES

FIGURES

TABLE

Rept.Bk.No. 66/33
G.S. No. 3895
D.M. 1510/67
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ABSTRACT

Microfossils (spores, pollen, microplankton, foraminifera) from the section intersected in Cootanoorina No. 1 Well have been analysed biostratigraphically and environmentally.

Age determinations include: Unit 3 (2925 - 3111ft.), Devonian; Units 2 and 1 (1695-2925ft.), Lower Permian; Mount Toondina Beds (615-1595ft.), Lower Permian; Algebuckina Sandstone (467-615ft.), no fossil evidence; Cadna-Owie Formation (370 - 467ft.), Lower Cretaceous (Valanginian to Aptian); Bulldog Shale (0 - 370ft.), Lower Cretaceous (Valanginian to Aptian).

The presence of foraminifera and organic-walled microplankton indicates marine influence during the deposition of Unit 1 in the Lower Permian. Below 2200ft. in Unit 2, the foraminiferal fauna is diverse though entirely arenaceous, and microplankton occur consistently. It is suggested that deposition occurred in a barred basin with rising temperatures and salinity. Anhydritic sediment above 2200ft. coincides with the sudden disappearance of foraminifera. Fossil evidence indicates that during deposition of the black-shale facies above 1745ft. bottom conditions were stagnant and saline, with a surface layer of fresher water. The Mount Toondina Beds are a paludal, fluviatile and lacustrine complex; no marine fossils were found.

INTRODUCTION

This report summarizes an investigation of microfossils from the sequence encountered in Cootanoorina No. 1 Well, drilled by the South Australian Department of Mines in the Arckaringa Sub-Basin (Latitude 28°00'30" South, Longitude 135°20' East).

Text-figure 1, showing the position of the well in relation to other subsurface sections and the approximate limits of Permian subcrop, is taken from Wopfner (1964, fig. 1). It is seen that Cootanoorina No. 1 is further north, and further "offshore", than any other section, with the exception of the (stratigraphically restricted) section at Mt. Toondina (Freytag 1965). Thus, it could be expected that study of the section would be quite rewarding; and this has been justified. Wopfner and Allchurch (1967) have already discussed the significance of this well relative to the petroleum potential of the Arckaringa Sub-Basin.

Most attention was devoted to the Palaeozoic and particularly the Permian part of the sequence, and the fossil groups considered are pollen, spores, organic walled microplankton and foraminifera.

The aims of the study were correlation and age determination of the various rock units and an analysis of the Permian depositional environments.

Upper Palaeozoic biostratigraphy in South Australia is still in its infancy. That Devonian is here proven for the first time, is an indication of this. Since Permian in this region was first recognized on fossil evidence a decade ago (Balme 1957) there have been some advances palynologically, but a major attack on the many problems has still to be made. Foraminiferal studies have been taken further by Ludbrook (1967b), but study of the local restricted faunas is hampered by a lack of detailed comparative criteria from regions of greater faunal diversity.

Santos Oodnadatta No. 1 Well, about 50 miles northeast of Cootanoorina (Fig. 1), has been used as primary reference for the Mesozoic section. Dettman (1963) has studied the microfloras and Ludbrook (1966) the foraminifera from the Oodnadatta section. In the case of microfloras and microplankton, further comparisons are made with the type sections of Mesozoic formations and also the sections drilled near Mt. Toondina.

W.K. Harris carried out the palynological and B. McGowran the foraminiferal investigations.

METHODS

Although rotary cuttings had to be used extensively, particularly for the foraminiferal studies, there are some indications that contamination has not significantly distorted the recovered assemblages. Depths given are uncorrected; corrections are insignificant. Bit samples were taken at 1580, 1736 and 1902ft. for palynological examination. For the details of drilling and the lithological sequence reference is made to the Well Completion Report by Allchurch and Wopfner (1967, unpub.).

Foraminifera and megaspores were recovered by standard methods of sample disintegration and washing. Selected megaspores were bleached with a mixture of sodium hypochlorite and concentrated by hydrochloric acid followed by a short treatment with 10% ammonium hydroxide. Smaller pollens and spores were recovered by a method similar to that described by Balme and Hassell (1962).

Representative specimens of the larger microfossils, foraminifera and megaspores, were photographed in reflected light using a Leitz Utropak Lighting unit and objectives mounted on a Leitz Laborlux microscope. Bleached megaspores, smaller palynomorphs and thin sections of foraminifera were photographed with conventional objectives on the Laborlux. Photomicrographs were recorded on 35mm. Adox KB14 film.

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DEVONIAN

Unit 3 (2925-3111ft.)

A microflora from a grey clay shale at 3010ft. contains Geminospora lemurata, Granulatisporites cf. G.phillipsi, Convolutispora fromensis, Emphanisporites sp., Retusotriletes sp., Reticulatisporites textilis, ?Diaphanospora sp. and ?Leiozonotriletes.

No other fossils were recovered from this interval.

de Jersey (1966) has most recently summarised and compared Australian Devonian microfloras. Assemblages of this age have been described from the Canning Basin (Balme and Hassell 1962), the Carnarvon Basin (Balme 1960), the Amadeus Basin (Hodgson 1964 unpub.) and the Adavale Basin (de Jersey 1966).

Whilst the Cootanoorina assemblage is small and poorly preserved, it does have affinities with the described Devonian microfloras. In particular, it closely resembles those from the Gneudna correlatives in the Carnarvon Basin and the Parke Siltstone in the Amadeus Basin. For the present the age of the unit can be regarded as middle to upper Devonian.

PERMIAN

The following units, distinguished on their lithological and geophysical characteristics (Allchurch and Wopfner, 1967 unpublished; Wopfner and Allchurch 1967), have been dated biostratigraphically as Permian:

Mount Toondina Beds (615-1695ft.)

Unit 1 (1695-2550ft.)
Unit 2 (2550-1925ft.)

DISTRIBUTION OF FOSSILS

Foraminifera

The distribution of Permian foraminifera is summarised in text - fig. 1 and more fully in table 1.

Foraminifera were not found below 2750ft. Occasional specimens of six species were found in cuttings samples between 2600 and 2750ft. It is possible that they represent caving from 2300-2400ft., but this is thought unlikely even though none were found in core 6 at 2697ft. Three cuttings samples between 2420 and 2600ft. yielded no fauna.

Foraminifera occur consistently in cuttings between 2420 and 2200ft. However, two samples from core 5 between 2356 and 2359ft. appear to be barren. The specimen count drops from a maximum at 2200ft. to zero at 2190ft.

Occasional, poorly preserved specimens of <u>Lagenammina</u> and <u>Thuramminoides</u> were found in two samples from core 4, between 1745 and 1750ft., and in cuttings from 1730 and 1980ft. No fauna was found in the Mt. Toondina Beds which were examined at 50ft. intervals.

<u>Note on Foraminiferal Systematics</u>: The systematics of Permian foraminifera from South Australia recently have been studied by Ludbrook (1967b). Identification of the Cootanoorina faunas is made primarily with reference to this work; comparative material from the Australian Permian as a whole (Crespin 1958) has not been available.

Preservation of the Cootanoorina faunas is rather poor, due to flattening, breakage and strongly adherent sapropelic matrix, especially above 2300ft. Consequently, identification is often tentative and sometimes impossible. The discrimination of species and genera at present is based largely on gross form of the test (shape, direction of growth) with wall structure subordinate. When wall structure is analysed more thoroughly, using numerous thin sections, the information content of distorted and fragmented specimens is expected to increase.

Examples of probable confusion include: *Glomospirella nyei* with *Hemidiscus balmei*; *Hyperammina hebdenensis* with *H. acicula* and *H. coleyi*; *Digitina recurvata* with *Textularia bookeri* and *Recurvoides wilsoni*. The latter example is important because *Digitina recurvata* is much more common than in other Permian assemblages from this State (see below); furthermore, its morphological aspect at Cootanoorina (pl. figs. 15-20) differs from previous records (Crespin 1958, Ludbrook 1967b).

The identifications on text-fig. 2 and table 1 should be considered with these points in mind. It is felt, however, that the charts are quite accurate as to species numbers and general faunal trends.

Characteristics of Foraminiferal Fauna: Relative abundances (table 1) are based on an exhaustive search of approximately the same amount of each washed cuttings sample. Counts of specimens and species between 2450ft. and 2190ft. are graphed, on this quasi-statistical basis, in text-fig. 3. The specimen trend would be accentuated if significant contamination has occurred. That it has not, is suggested by a distinct change in preservation between 2280ft. and 2300ft. This change matches the lithological change from uniform dark grey, silty sapropelic shale downwards to an interbedding of this sediment type with light grey, sandy, plastic shale.

The richer samples have been plotted percentagewise for the four higher taxa distinguished here (text-fig. 3) following Loeblich and Tappan (1964). The superfamily Lituolacea includes the multichambered genera *Digitina*, *Textularia*, *Recurvoides*, *Reophax* and *Ammobaculites*.

The family Ammodiscidae includes *Ammodiscus*, *Hemidiscus*, *Tolypammina*, *Glomospira*, *Ammovertella* and *Ammovertellina*. The family Astrorhizidae includes *Hippocrepinella* and *Hyperammina*. Use of these family-group taxa avoids two taxonomic problems. One concerns the identification of species, as discussed above. The other is that certain genera, particularly among the Ammodiscids, are based on rather doubtful criteria.

The important characteristics of the fauna are:

1. Its entirely arenaceous (agglutinated) character.
2. An increase upward in species and specimen numbers to 2300ft., with continued increase in specimens but decrease in species to 2200ft.
3. General decrease in Astrorhizidae numbers and increase in Lituolacea, the Ammodiscidae and Saccamminidae changing less. However, *Ammodiscus ɔonahensis* makes up 30% of the assemblage at 2200ft.
4. The Lituolacea are dominated by *Digitina recurvata* which makes up 58% of the total assemblage at 2250ft. and 52% at 2200ft.
5. Other variations in distribution and abundance (table 1) are relatively minor. There is no convenient criterion for recognizing more than one successional assemblage.

Microplankton

Organic walled microplankton referable to the Acritarcha (Downie et.al 1963, Segroves, 1967) were recovered from most samples in both Units 1 and 2. Species of *Leiosphaera* occur most consistently and abundantly in some samples together with *Quadrisporites horridus.* The upper limit of *Q. horridus* is in core 4 at 1,743ft. and the lowest occurrence is at 2,770ft. The most notable feature about its occurrence is that it is only associated in this well with proven planktonic genera such as *Leiosphaera*, and foraminifera, suggesting strongly that the species is a marine planktonic organism, perhaps tolerant of marginal marine conditions. Other acritarchs noted but of rare and restricted occurrence include Leiofusa sp. in core 5 at 2,359ft. and poorly preserved Michystridium sp. in core 6 at 2,697ft.

Megaspores

Single specimens, probably from cavings, are recorded from 1,980-1,990ft. and 2,090-2,100ft. and will not be considered further. The first significant occurrence is at 1,920ft. - 1,930ft. where the assemblage consists of twenty specimens of the genera Carruthersiella and Triletes. Throughout the remainder of the Permian sequence to 630ft. Carruthersiella dominates the assemblages. There is possibly some significance in the first appearance of Mammilaespora at 950ft. At higher levels in the Mount Toondina Beds the genus is co-dominant with Carruthersiella. The only lageniculate trilete specimen was recovered from core 3 at 1,243ft. and is referred to the genus Dijkstraea. The genus Duosporites does not appear to show any marked changes in distribution but it might be noticed that it does not occur in assemblages with Mammilaespora above 950ft.

Taxonomic notes: In contrast with other Palaeozoic sediments of the world, megaspores from Australian Permian sediments have received little attention. They have been recorded frequently in foraminiferal washings as "lycopod megaspores" by Ludbrook (1961, 1967a). Høeg, Bose and Manum (1955) recognised the importance of examining megaspores in transmitted light and elucidating internal structures such as the mesosporium, its ornamentation and its attachment to the exosporium. Following these authors, Pant and Srivastava (1961, 1962) examined Gondwana megaspores paying particular attention to the number of walls, their attachment and ornament. The classification and nomenclature of Pant and Srivastava is adopted in this report. It must be realised however, that many more specimens will have to be bleached and examined before any finality on generic subdivisions can be achieved. No attempt has yet been made to relate the Cootanoorina forms specifically with described species. However, it can be noted that the majority of forms do differ from Permian species described from India, Africa and South America.

Miospores

The lowest occurrence of Permian miospores occurs in cuttings at 2,830ft. Parasaccites spp., Cycadopites cymbatus, Protohaploxypinus goraiensis and occasional trilete spores including Punctatisporites gretensis, and Vallatisporites sp. characteristise the assemblage. This assemblage changes little through Unit 2 but adding progressively more components of the striate bisaccate genera. Cores 6, 7 and 8 within Unit 2 failed to yield any miospores. The assemblages are, characteristically, not diverse, and there is little other organic debris in the residues apart from occasional microplankton.

Within Unit 1 the assemblages become more diversified in respect to the bisaccate and trilete spore component. Parasacites spp. remain prominent and towards the top of the unit G. cymbatus becomes very common. Apiculatisporis levis, Verrucosisporites pseudoreticulatus and Ovalipollis sp. first make their appearance; V. pseudoreticulatus at 2,100-2,110ft.

The distribution of miospores across the Mt. Toondina Beds - Unit 1 boundary show no significant qualitative changes. In character the microfloras of the lower sections of the Mt. Toondina Beds becomes dominated even more by striate bisaccate pollen.

In core 3, Striatoabietites fusus, Vesicaspora maxima and Marsupipollenites triradiata make their first appearance, the latter species occurring rarely. In contrast to other Permian sequences in the Lake Phillipson Region Marsupipollenites spp. do not reach a high proportion in the microfloral assemblages so far examined. Camptotriletes biornatus and Krauselisporites apiculatus appear in coal cuttings at 830ft. and continue to the top of the sequence. Core 2, the highest Permian sample examined, yielded a particularly diverse and well preserved assemblage dominated by bisaccate pollen (especially the larger forms; Platysaccus leschiki and Vesicaspora maxima), apiculate and acanthine trilete species, and cingulate mesosporoids. Parasaccites spp. still remain prominent in the assemblage. Of some importance is the occurrence at 633ft. of a species referable to Bascanisporites undosus.

Other Organic Remains

Specimens of several species of Permian foraminifera contain sponge spicules in the test agglutinate. The spicules are mostly pyritised.

The anhydritic sequence between 1900ft. and 2200ft., apparently barren of foraminifera, contains "objects" which appear to be organic in origin although thin sections show them to be structureless internally. They may be worm casts.

ENVIRONMENT

The analysis of Permian environments and their change in this profile through the Arckaringa Sub-basin can be divided conveniently into (a) Units 2 and 1, which are discussed in some detail, and (b) Mount Toondina Beds.

Units 2 and 1: Devonian-Permian Contact to base Mount Toondina Beds

The environmental analysis of fossil assemblages includes both the actualistic and the comparative, biofacies approaches. The first must be used with some caution here because of the great evolutionary changes of extinction and relay in foraminiferal faunas since the Palaeozoic. Mesozoic to Recent foraminiferal assemblages tend to become more arenaceous in their content as a response to any or all of the following environmental stresses: higher or lower salinity, lowered temperature, lowered oxygen, increased turbidity, acidity. This tendency will be less evident in the Palaeozoic where smaller species with secreted-calcareous tests never reached the degree of dominance in normal shelf assemblages later achieved by the lamellar foraminifera. Thus Permian assemblages tend to be more arenaceous than their younger counterparts. A comparative approach accordingly is heightened in value. Detailed studies of faunal distributions, their changes, and their relation to other groups, particularly shelly megafossils, are needed for the Gondwana sequences.

Clues to the environment in which the Cootanoorina sequence from 2925ft. to 2200ft. was deposited include: first appearance of foraminifera and microplankton at 2700-2750ft.; a general but sporadic increase in foraminiferal specimen and species numbers; the arenaceous but rather diverse nature of this fauna; the absence of a calcareous, shelly fauna; lithological evidence for a change from glacial to evaporitic conditions.

Features of the Unit 2 sequence (graded bedding, intraformational slumping, dolomitic beds, resistivity characters together with undisputed glacial sediments along the eastern margin of the Boorthanna Trough have led Wopfner and Allchurch (1967) to envisage remobilisation of glacigenes by density currents down a submarine slope. A marine environment (sensu lato) is supported by the presence of both foraminifera and microplankton. Foraminifera can live in very cold waters; their apparent absence below 2750ft. is explained, rather, by the coarse nature of the clastics, particularly since no specimens were found in core 6 or core 5 both of which contain microplankton.

On the other hand, the sporadic distribution of foraminifera between 2750ft. and 2400ft., where lithology is not an obvious control, followed by their consistent occurrence in some numbers and diversity up to 2300ft., indicates increasingly marine influence. That is, the sequence is transgressive, although it may have been "marine" throughout.

Ludbrook (1956-1967b) has stressed the restricted, sparse nature of local Permian faunas. In so far as calcareous fossils are almost entirely absent, this is so. However, the foraminiferal fauna of about 20 species in the richest sample (2300ft; table 1) compares quite favourably with arenaceous assemblages described from the Upper Palaeozoic. Assemblages recovered by washing techniques tend to contain 20-30 species in the Mississippian and Pennsylvanian of North America, occasionally with more and often with less (for example: Plummer 1945, Conkin 1961, Conkin, Conkin and Pike 1965). Acid residues (for example, Ireland 1956) yield comparable numbers, with better recovery of delicate arenaceous specimens but destruction of calcareous tests. Crespin (1958) has studied assemblages from the Byro Group and Noonkanbah Formation of the Carnarvon and Canning Basins respectively. In her lists of "characteristics" species in largely or entirely arenaceous assemblages there are always less than 20 species. It is not clear whether these lists refer to the total species numbers found. Against this, the lists refer to entire formations, so that numbers are broadly comparable with the Cootanoorina assemblage. Many of these Australian and North American assemblages are associated with rich, shelly, marine megafaunas.

That the Cootanoorina assemblages are close to normal marine, if not open marine, is also indicated by comparison with Recent and fossil assemblages from marginal marine environments (estuary, lagoon, marsh). Although these assemblages are predominantly arenaceous, they are characterised by low diversity and by the dominance of very few species (Phleger 1960, Walton 1964) Fossil examples include: the Ammobaculites - Haplophragmoides fauna in a regressive part of the Midway Group in Texas (Kellough 1965); the coastal facies in the Cretaceous of northern Alaska (Tappan 1960) with only one or two species per sample but locally abundant specimens; marine ingressions in the Westphalian of Germany (Bartenstein 1950) with monotonous arenaceous assemblages; a Glomospira - Hyperammina assemblage in the Permian of Tasmania, high in the Ferntree Group and preceding the non-marine Cygnet coal Measures (Conkin and Conkin 1965, unpublished).

When considered in the light of these examples of marine and marginal marine faunas, the Cootanoorina fauna at its level of maximum diversity (2300ft.) appears to indicate a fully marine environment. Hence, the problem is to explain a severely restricted but internally rather diverse fauna. Assemblages overlying glacigenes are known from the Quamby Mudstone in Tasmania and the Holmwood Shale in the Perth Basin, W.Aust. (Crespin 1958). In both cases the species are all arenaceous and diversity is rather low (about 10 species among several samples). In the similarly placed Grant Formation (Fitzroy Basin) Crespin has only five. The situation is similar in the Permian of South Australia (Ludbrook 1956-1967b). There is some evidence that the number of arenaceous species in Recent shelf assemblages increases at very high latitudes (Saidova 1966). Thus the Cootanoorina assemblage can be explained as a marine fauna colonizing a cold environment.

Obviously, however, this explanation does not cover the continued absence of calcareous foraminifera and shelly megafossil remains while the temperature rose to an evaporitic level. Another restriction must have operated. Physical restriction of the basin leading to evaporitic conditions (see below) appears to be foreshadowed in the composition of the fauna. Other evidence for this is found in the faunal change in the dark, sapropelic, silty shales between 2300 and 2200ft. In this interval specimen numbers tend to increase and species numbers to decrease so that Ammodiscus oonahensis and Digitina recurvata together account for more than 80% of the specimens at 2200ft. (text-fig. 3). The small numbers involved warrant caution, but these trends together would suggest regression (Walton 1964). Either or both raised salinity and lowered oxygen supply (but not anaerobic conditions) can account for the trends. It is noteworthy that "euxinic" conditions are suggested for the deposition of the Bulgadoo Shale and Quinnanie Shale in the Byro Group, Carnarvon Basin (Thomas 1958, McWhae et al. 1958). Foraminiferal lists for each formation appear to show no significant drop in diversity below normal marine assemblages (Crespin 1958). However, detailed studies of sections probably would yield valuable comparative information since the Quinnanie Shale contains a single-species assemblage of Hyperammina coleyi.

The sudden and complete disappearance of foraminifera but not microplankton above 2200ft. is consistent with the onset of evaporitic conditions.

The siltstones above 2080 feet no lorger contain anhydrite; they are replaced above 1945ft. by dark, carbonaceous shales. The disappearance of microplankton at about 1700ft. overlaps the lowest occurrence of megaspores at about 1900ft.; foraminifera are very rare and sporadic in their occurrence above 2000ft. Resistivity characters indicate broadly marine salinities. All this evidence combines to suggest the advance of a paludal environmental complex toward the depositional area. Increased runoff terminated anhydritic deposition, brought in megaspores, and eventually drove out microplankton. It also formed a surface layer of fresher water, thus lowering circulation with bottom waters retaining their high salinity. Occasional foraminifera indicate very slight marine influence; possibly they were transported.

In conclusion, the sequence represented by Unit 2 and Unit 1 can be interpreted as due to a complex of changing factors operating in and around a trough, which may have been barred throughout the time span involved. Ludbrook (1967b) has suggested the existence of fjords in this part of the Great Artesian Basin. The present evidence does not contradict this, but the origin by faulting of the Boorthanna Trough makes it unlikely. The Boorthanna Trough and Arckaringa Sub-Basin formed a gulf which became for a time normal marine, in a sense, but not open marine.

Local Comparisons: In terms of diversity, specimen abundance and preservation the best foraminiferal faunas known so far from South Australia are in the Engineering and Water Supply Department Stuart Range No. 3 subsurface section (text-fig. 1).

A comparison of Cootanoorina No. 1 with Stuart Range No. 3 is summarised in text-fig. 3. The comparison is restricted to intervals in which foraminifera are relatively common: Cootanoorina, 2200-2350ft., 7 samples; Stuart Range, 1182-1367ft., 9 samples. Data for the latter are based on samples assembled and reported by Ludbrook (1967a) Permian foraminifera are sufficiently rare to justify the assumption that no personal bias is involved in recovering either assemblage.

There are no significant differences between the two sections in presence-or-absence of species. The main differences in relative abundance are: (1) generally more Hyperamminids at Cootanoorina. (2) More Saccamminids at Stuart Range; the group is dominated by Saccammina orca. (3) Ammodiscus oonahensis is more common at Stuart Range. (4) The Lituolacea are dominated in the higher part of the Cootanoorina section by Digitina recurvata. This species is relatively rare at Stuart Range where Recurvoides wilsoni, relatively rare at Cootanoorina, is one of the most important species.

Below 2280ft. at Cootanoorina, mixed preservation indicates that foraminifera occur in both the dark shales and the interbedded pale grey, plastic shales. Specimens from the latter are similar to the Stuart Range specimens in preservation. Also Digitina recurvata is more similar morphologically to specimens from Stuart Range than those at 2280ft. and above. Finally Recurvoides wilsoni: occurs mostly in the lower part of the Cootanoorina section.

It would seem, then, that there are two biofacies at

Cootanoorina, distinguished largely by the abundance and form of Digitina recurvata in the dark, silty shales. The dark shale assemblage is the more divergent of the two from the Stuart Range assemblage and also from most of the other fossiliferous Permian in this State, as judged from inspection of all samples assembled by Ludbrook (1956-1967). The only exception occurs at Boorthanna (text-fig. 1; see Ludbrook 1961). Here, assemblages are sparser and more poorly preserved than at Cootanoorina, but there are indications that the change between 1800 and 2088 feet is similar. Digitina of the Cootanoorina type occurs at 1800ft; Recurvoides of the Stuart Range type at 2088ft; the preservation is of dark, sapropelic shale type at 1800-1950ft. but mixed at 2000-2088ft.

These comparisons indicate that faunal differences are due to environmental changes rather than differences in age. The dark shale facies at Boorthanna and Cootanoorina, underlying the anhydritic sediments in the latter section is due to formation of a barred basin in this region, whereas barring is not manifest in sequences described from the Lake Phillipson trough (Ludbrook 1961). Further studies of foraminiferal distribution as more sections become available should make these biofacies differences more meaningful.

Mount Toondina Beds

Allchurch and Wopfner (1967, p.25) concluded on the evidence of abundant plant fossil material, numerous coal beds, the high resistivity and the general lithological character of the sediments that the formation was of continental origin; paludal, lacustrine and fluviatile environments were recognised. The abundance of megaspores and the absence of marine fossils support this conclusion.

CORRELATION AND AGE

General Discussion: The biostratigraphic standard for subsurface sequences such as the present one is based on changes in microfloral assemblages. Accordingly, these are treated in most detail here, with contributory evidence from the foraminifera.

With the exception of a recent paper by Segroves (1967) no systematic studies of Australian Permian microfloras have been published since the series of pioneering papers by Balme and Hennelly (1955, 1956a, 1956b). In these papers some indications were given as to the usefulness of Permian microspores in correlation. Subsequently Balme (1964) produced a paper on the Australian pre-Tertiary floras in which he named the "Striatites-Microflora" as being characteristic and perhaps synonymous with the Permian. This microflora he divided into three assemblages, two in the lower Permian, the Nuskoisporites-Assemblage and the Vittatina-Assemblage, and the Dulhuntyispora-Assemblage in the upper Permian. Whilst this is the first formal naming of the units, they were already in use, as evidenced by Balme's paper on the Lake Phillipson Bore (1957). With regard to relating these units to the accepted Permian divisions, Balme relied on correlations with marine invertebrate assemblages, some containing ammonoids, from sequences in the Canning, Carnarvon and Perth Basins. Thus the Nuskoisporites-Assemblage is dated as Sakmarian and Lower Artinskian, the Vittatina-Assemblage as Artinskian and the Dulhuntyispora-Assemblage as Upper Permian.

Evans (1967 unpub.) has further resolved the Nuskoisporites and Vittatina Assemblages into two divisions each, using an informal nomenclature but giving them Stage status. Thus, Evans uses Stages 1 (the oldest) to 4, with his Stage 5 being equivalent to Balme's Dulhuntyispora Assemblage. The specific identity of many of the key fossils in the stages is, however, not clear and a systematic section in the paper would have been most useful. As a consequence there is some difficulty in recognising the Stages precisely. Although Evans discusses the limits of the Permian system on the basis of plant macrofossils and consequent microfloral expressions, he avoids any discussion of terms such as Sakmarian and Artinskian.

The correlation of Permian microfloras from Cootanoorina are discussed in relation to these two papers. It is however noted that finer divisions are possible in a more local setting using cores from the Lake Phillipson bore as a standard. Megaspores would appear to have some stratigraphic utility on a local scale. The results of this study as yet not completed, cannot be discussed in this report.

Unit 2: Miospores from this unit are referred to Stage 2 of Evans characterised by Parasaccites spp. and rare striate bisaccate species, Punctatisporites gretensis and Vallatisporites sp. and the unit is therefore of lower Permian age. Balme (1963,p. 59) states that the lower part of the glacial sequence in Western Australia is not rich in plant microfossils. This is true also for similar sequences in the western portion of the Great Artesian Basin.

Assemblages from this unit resemble closely those from the Lake Phillipson bore at about 2300ft. Although Evans (1967) regards these as representing Stage 1, examination of samples at this level has yielded bisaccate pollen of the P. goraiensis type and an assemblage of Stage 2. Unit 2 is therefore a correlative in part of the Lake Phillipson Beds (Ludbrook 1967b).

Unit 1: There are no perceptible qualitative changes in the microfloral component across the Unit 1-Unit 2 boundary. The absolute number of miospores does increase however as does the proportion of organic detritus. The appearance of spores characteristic of Stage 3 occurs at about 2100ft. In particular V. pseudoreticulatus makes its initial appearance at this level.

Stage 3 according to Evans, corresponds to the lower portion of the Vittatina Assemblage. The prominent genus of the Vittatina Assemblage, Marsupipollenites, does not reach significant frequencies in the assemblages and it is here suggested that Stage 3 may be in part correlated with the Nuskoisporites

Assemblage of Sakmarian age. The age of Unit 1 is therefore regarded as Sakmarian.

Unit 1 is correlated in part with the Stuart Range Beds (Ludbrook 1967b) and it is of some correlative value to note the appearance of megaspores within this unit throughout the region. Table 2 summarises the distribution of megaspores and their relationship to foraminifera in some bores in the area.

Table 2

Bore Name	Megaspores	Foraminifera
Cootanoorina No. 1	650-1900ft.	1730-2750ft.
Boorthanna Bore No. 1	185- 400ft.	1800-2088ft.
Stuart Range No. 3	507- 815ft.	740-1620ft.
Stuart Range No. 1	485- 668ft.	-

It is clear that there is some overlap between megaspores and foraminifera and in this region megaspores appear at a particular time later in Unit 1 or in the Stuart Range Beds. Ludbrook's (1967a) correlation of portion of the Stuart Range sequence with the Mt. Toondina Beds is not substantiated palaeontologically or lithologically. In particular two specimens of Thuramminoides sphaeroidalis (one at 740-745ft. and one at 750-755ft.) and the associated megaspores indicate a correlation with the upper portion of Unit 1.

Mt. Toondina Beds: Stage 3 assemblages continue into the base of this formation and the first appearance of Camptotriletes biornatus at 830ft. together with Verrucosisporites parmatus and Apiculatisporis cornutus marks the onset of Stage 4 of Artinskian age. The highest assemblage from Core 2 is unlike any from the Lake Phillipson Bore and the presence of ?Bascanisporites undosus, very common large bisaccate pollen and echinate species similar to and including Didecitriletes ericianus suggest that Stage 5 is present. The absence of Dulhuntyispora and Gnetaceaepollenties sinuosus places some restriction on this interpretation. Evans (1967 p.8) suggests that Stage 5 commences in the Lower Permian.

The age of the Mt. Toondina Beds is therefore Artinskian with some possible extension into the Sakmarian.

Correlation of the well section of the formation and the outcropping type section is based on one sample only. Although more than twenty samples were collected and processed, only one, a dark brown carbonaceous clay, yielded recognisable miospores. The sample is from Freytag's Unit 16 (1965, Fig. 4) and yielded the following assemblage:

- Acanthotriletes cf. A. filiformis
- A. tereteangularis
- Apiculatisporis levis
- Granulatisporites micronodosus
- Krauselisporites apiculatus
- Laevigatosporites vulgaris
- Marsupipollenites triradiata
- Microfoveolatispora directa
- Neoraistrickia ramosa
- Ovalipollis sp.
- Punctatisporites gretensis
- Parasaccites spp.
- Platysaccus leschiki
- Retusotriletes diversiformis
- Schizosporis scissus
- Striatiti undiff.
- Vesicaspora ovata
- V. maxima
- Verrucosisporites pseudoreticulata

The assemblage shows distinct similarity to Stage 3 microfloras occurring below 830ft. in Cootanoorina No. 1. As there is some distance (4½ miles) between the type section and the well a precise correlation in terms of coal seams is not attempted. It is apparent that the outcrop section is more eroded at its top in comparison with the well section.

Foraminiferal Evidence: Strata containing Permian microfaunas in South Australia have been dated as Lower Permian, Sakmarian, and Lower Sakmarian (Ludbrook, 1956-1967b). The clearest evidence for correlation, however, is palynological as discussed above.

The foraminiferal fauna of Yorke Peninsula was compared (Ludbrook 1956, 1965) with that from the Quamby Group in Tasmania, of Sakmarian age, but also (Ludbrook 1956) with that from the Mulbring Siltstone of the Maitland Group in New South Wales, of Upper Permian Age. Foraminifera have been used to make rather broad correlations within the Australian Permian (see particularly Crespin, 1958); and Conkin and Conkin (1965, unpublished) recently have presented preliminary results leading toward a zonation of the marine Permian in Tasmania. In both cases calcareous (secreted) foraminifera are available, thus adding significantly to the biostratigraphic potential of the group. Within South Australia no more than one assemblage, or "zone", can be recognised in known species ranges. Indeed, an assemblage of twelve species from the Eucla Basin was dated as Artinskian on palynological evidence, yet does not differ significantly from Sakmarian faunas found elsewhere in the State (Harris and Ludbrook 1966).

The Cootanoorina fauna is of Lower Permian aspect rather than Upper Permian. The presence of *Ammodiscus oonahensis* is evidence for a Sakmarian instead of Artinskian age. So far as is known (Crespin 1958, Conkin and Conkin 1965, unpublished) this species is limited to the Sakmarian. Ludbrook (1967b) records *A. oonahensis* from the Eucla Basin fauna, but the specimens are considered here to be distinct and conspecific with *Ammodiscus* cf. *multicinctus* as recorded herein.

MESOZOIC

Algebuckina Sandstone (467-615ft.)

Cuttings from this unit in the well were considered unsuitable for palynological examination. No foraminifera were found in three cuttings samples. The unit occurs in the Oodnadatta well below 1100', and Dettman regards this interval as falling within the Speciosus Assemblage and therefore of Lower Cretaceous age. This determination can be accepted realising that it is based solely on rotary cuttings (see Ludbrook 1966, p. 27). It is significant that the nominate species of the Stylosus Assemblage was not recorded in the well. It is acknowledged that the unit may be in part Jurassic in the deeper parts of the Basin (Wopfner, 1964). At present there is no fossil evidence for this supposition.

Cadna-Owie Formation (370-467ft.)

No foraminifera or other fossils were found in the two cuttings samples washed and examined.

Cuttings from this unit were not processed for palynology, but it is worth recording here a microfloral assemblage recovered from the type section of the formation, 2.5 miles southwest of Algebuckina Railway Siding, Algebuckina 1-mile sheet.

A very dark grey carbonaceous clay (Unit 8) 38ft. from the top of the Cadna-Owie Formation yielded a well preserved and diverse microflora. The assemblage is as follows:

Aequitriradites spinulosus
Alisporites grandis
A. similis
Ceratosporites equalis
Coronatispora perforata
Cicatricosisporites australiensis
Classopollis sp.
Cyathidites australis

C. asper
Cyclosporites hughesi
Contignisporites cooksonii
Dictyotosporites speciosus
Foraminisporis wonthaggiensis
Gleicheniidites cf. G. circinidites
Ischyosporites punctatus
Leptolepidites verrucatus
Lycopodiumsporites austroclavatidites
L. nodosus
Microcachryidites antarcticus
Osmundacidites wellmanii
Podocarpidites ellipticus
Rouseisporites reticulatus

The assemblage is dominated by an abundance of gymnosperm pollen, in particular A. similis and M. antarcticus.

Correlation and age: The presence of both C. hughesi and D. speciosus identifies the assemblage with the lower portion of the Speciosus Assemblage of Dettman (1963). Correlatives of this unit occur between 743 and 1292ft. in Santos Oodnadatta Bore No. 1 and between 1330 and 1472ft. in Cootabarlow Bore. On the basis of the apparent limited vertical distribution of Coronatispora perforata, which has not been recorded from any of the Bulldog Shale samples (see below), a finer subdivision gives the following correlation:-

Cootabarlow Bore between 1354 and 1402ft.

Oodnadatta Bore No. 1 between 1502 and 1292ft.

Dettmann (1963) considers the age of the assemblage to be Valanginian to Aptian.

In contrast to the younger Cretaceous units, the sample from the Cadna-Owie Formation did not yield any microplankton.

Bulldog Shale (0 - 370ft.)

Microfloras and Microplankton: Microfloral assemblages have been recovered from Core 1 at 362ft. and 370ft. and from the well velocity survey shot holes S.P.4 at 85ft. and S.P.5, 88ft. The shot hole samples ("Bottom of hole samples") were examined to provide an upper limit to the age of the Bulldog Shale in the drilled section. Their proximity to Cootanoorina No. 1 permits reliable extrapolation to the well and assemblages are therefore recorded in the general palaeontological log of this well (fig. 1).

Assemblages were well preserved and diverse with a high proportion of organic walled microplankton. There are few specific differences between the sampled intervals. Species of pollens and spores characteristic of the assemblage include Dictyotosporites speciosus, Cicatricosisporites australiensis, Cyclosporites hughesi, Contignisporites cooksonii, Trilobosporites perverulentus, Murospora florida (very rare), Lycopodiumsporites circolumenus and Pilosisporites notensis. Organic walled microplankton are represented by Canningia colliveri, Dingodinium cerviculum, Muderongia mcwhaei, Broomea ramosa, Palaeotetradinium hyalodermum and Gonyaulacacysta edwardsi.

Foraminifera: No foraminifera were found in weathered material from 17ft. At 50ft., a poor arenaceous fauna is dominated by Bigenerina loeblichae.

From 100 to 300ft. the assemblages are mixed arenaceous and calcareous. The more common species include Bigenerina loeblichae, Trochammina minuta, Ammobaculoides romaensis, Textularia wilgunyaensis, Lenticulina spp. including forms referable to warregoensis Crespin and dalhousiensis Ludbrook, Praebulimina hergottensis, Anomalinoides mawsoni, and a species of Gavelinella which appears closest to G. parvula among the species described so far. All of these species, however, fluctuate considerably in their occurrence.

The lowest part of the Bulldog Shale carries an almost entirely arenaceous fauna. The main species are Textularia anacooraensis, Pseudobolivina engeninensis, Miliammina inferior, Trochammina raggatti. Again, however, there are variations in occurrence and abundance.

Correlation and Age: Ludbrook (1966) has erected four foraminiferal zones for the Lower Cretaceous stratigraphic sequence in the western part of the Great Artesian Basin. From top to bottom they are:

Neobulimina australiana
Verneuilina howchini - Trochammina flosculus
Hergottella jonesi
Trochammina raggatti - Textularia anacooraensis

These "zones" are major biofacies units reflecting environmental fluctuation over a large region. Thus, the first (lowest) and third zones are based on arenaceous assemblages with the others containing a mixed calcareous-arenaceous fauna. At the same time each of the assemblages has its characteristic species so that these units, while probably allochronous, can be expected to become valuable in basin analysis.

The Trochammina raggatti - Textularia anacooraensis zone is recognisable at Cootanoorina below 350ft. As well as both name species, the species listed above are characteristic members of the assemblage.

The occurrence of Hergottella jonesi at 100ft. and 160ft. proves the presence of the H. jonesi zone, H. jonesi being restricted to its lower part (Ludbrook 1966). This is consistent with the relative abundance of calcareous species down to 300ft. and the presence of Praebulimina hergottensis and Anomalinoides mawsoni.

In Santos Oodnadatta No. 1 Well, Verneuilina howchini occurs down to 570ft. and Textularia anacooraensis first appears at 880ft. (Ludbrook 1966). Although the name fossil was not found, the Hergottella jonesi zonal assemblage accordingly should occur between 570 and 880ft.; this is supported by the specific composition and calcareous nature of the faunas from this interval. A more precise direct correlation with the Oodnadatta section is not possible on this evidence, but if restriction of H. jonesi to the lower part of the zone is assumed, and if we further assume relatively little time-transgression of these biostratigraphic units between Cootanoorina and Oodnadatta, then a correlation of the Bulldog Shale at Cootanoorina with the "Marree Formation" below about 700ft. at Oodnadatta is indicated. The faunas from the Cootanoorina section support other evidence for the lack of Albian Oodnadatta Formation in this section and in the Mt. Toondina region generally (Freytag et.al. 1967).

On a regional basis there are two microfloral, biostratigraphic schemes in use for the Lower Cretaceous, those of Dettmann (1963) and Evans (1966). A comparison between the two is summarised in table 3.

TABLE 3

P.R. EVANS (1966)		M.E. DETTMANN (1963)	
Characteristic Species	Unit	Unit	Characteristic Species
Coptospora paradoxa *Trilobosporites trioreticulatus*	K2b	Paradoxa Assemblage	*C. paradoxa*, *Pilosisporites grandis* *Cicatricosisporites pseudotripartitus* *Trilobosporites trioreticulatus*, *T. tribotrys* *Contigisporites glebulentus*, *Krauselisporites majus*.
Overlap of *C. paradoxa* and *Dictyotosporites speciosus*	K2a		
First appearance of *Crybelosporites striatus* with *D. speciosus*	K1d	Speciosus Assemblage "Upper"	*D. speciosus*, *C. striatus*, *Pilosisporites notensis*, *Coptospora striata*, *Rouseisporites radiatus*, *Arcellites reticulatus*
Cicatricosisporites australiensis, *D. speciosus*	K1b-c		
C. australiensis *Cyclosporites hughesi* *D. speciosus*	K1a	"Lower"	*D. speciosus*, *M. florida*, *Cyclosporites hughesi* *Contignisporites cooksonii*, *Krauselisporites linearis*, *Cooksonites variabilis*.
Top of range of *Murospora florida*		Stylosus Assemblage	*Crybelosporites stylosus*, *Coronatispora perforata*, *Murospora florida*, *Biretisporites spectabilis*, *C. cooksonii*.

Clearly, the assemblage from the Bulldog Shale is equivalent to Dettmann's Speciosus assemblage, more precisely the lower portion, and is of Valanginian to Aptian in age. The assemblage is represented in Santos Oodnadatta No. 1 Well between 742 and 1292ft. Very similar assemblages were reported (Harris 1964 unpub.) from the Toondina No. 1 Stratigraphic Well which also penetrated a section of the Bulldog Shale. Hence the Bulldog Shale is of Valanginian to Aptian in age on microfloral evidence.

The microplankton component is dominated by *D. cerviculum* and *G. edwardsi*. Evans (1966a p. 61) regards these species as being mutually exclusive and thus providing two microplankton divisions: "the lower marked by *Dingodinium cerviculum* and *Muderongia tetracantha* and the upper by *Gonyaulax edwardsi* and *Diconodinium* spp." He notes that the *D. cerviculum* zone corresponds to the spore pollen units K1b-c, and *G. edwardsi* occurs near the top of Unit K2 in the Otway Basin (see Table 2). Clearly the ranges and facies relationships of Australian Cretaceous microplankton need further study. Alberti (1961 p. 6) compares *G. orthoceras* Eisenack with *G. edwardsi* and notes a gradation between the two species, which suggests that they may be synonymous. *G. orthoceras* ranges in Europe from Barremian to Albian.

WKH:BMcG:CC
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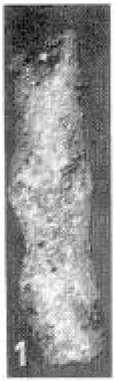
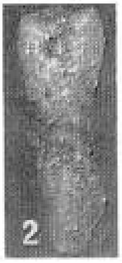
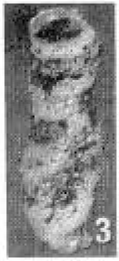
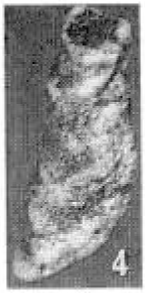
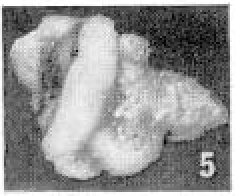
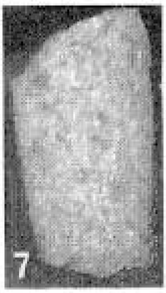


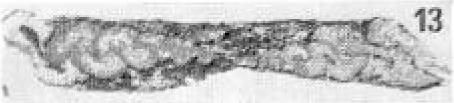


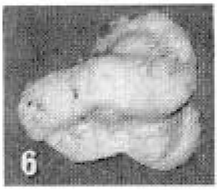


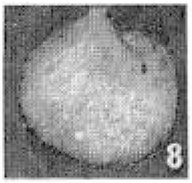


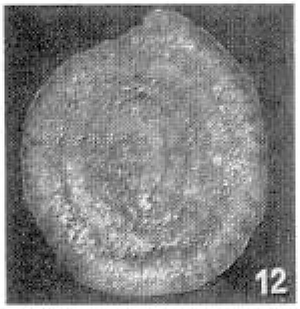


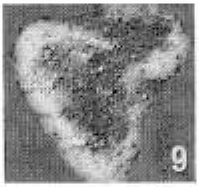


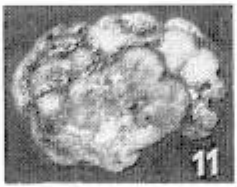


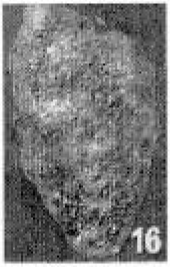


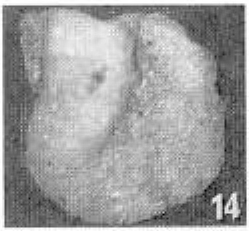


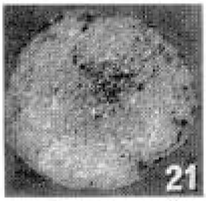


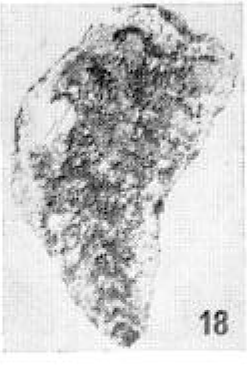


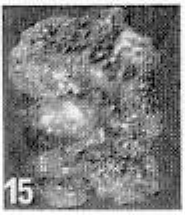


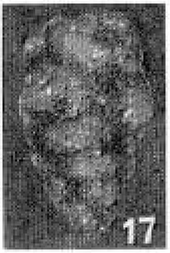


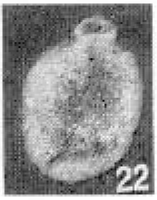


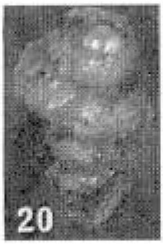


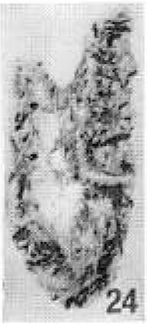












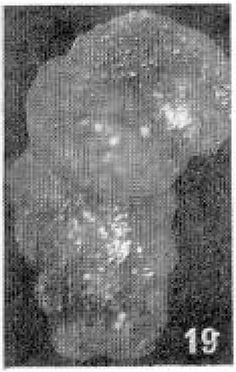


PLATE 1

PLATE 1

PERMIAN FORAMINIFERA

Figs. 13, 18, 23-24, oriented thin sections in non-polarised transmitted light, Ca. x 50; other specimens, Ca. x 30 approx. All specimens from cuttings.

1 - 2 *Hyperammina* *acicula* 1, fragment; 2, with initial end; both from 2230ft.

3 - 4 *Hippocrepinella* *Diaperta*, showing characteristic wrinkling of test; both from 2250ft.

5 - 6 *Tolypammina* *undulata* Both from 2300ft.

7 - 8 *Hyperammina* *Lebdenensis* Two fragments, one an initial end; both from 2300ft.

9 - 10 *Hyperammina* *expansa* Showing variation in flare of test, although both distorted; both from 2250ft.

11 cf. *Ammovertella* *Lowchini* 2300ft.

12 - 13 *Ammodiscus* *Oonalensis*

12, somewhat flattened; 2300ft. 13, showing shear-type distortion closing chamber, also tough, adherent, sapropelic matrix; 2250ft.

14 cf. *Hemidiscus* *balmei* 2300ft.

15 - 20 *Digitina* *Recurvata* and Parr. 15, 16, 18, 20, 2200ft.; 17, 19, 2300ft. Lack of clarity due to low contrast in sapropelic shale preservation. 15, distal, biserial fragment , with large, incorporated quartz grains out of focus. 16-17, 20, showing *Eggerella* - like triserial growth. 18, axial section showing poor condition of most tests; triserial (or initially multiserial) up to change in direction of growth, subsequently biserial.

19, Large specimen, proximal end missing, with two large, biserially arranged final chambers; 2300ft.

21 *Thuramminoides sphaeroidalis* 2300ft.

22 *Pelosina ampulla* Flattened; 2250ft.

23 - 24 "Axial" sections of probable Saccammina area, showing incorporated, variously oriented, pyritized sponge spicules; both from 2300ft.

25 *Saccammina area*. Flattened fragment; 2300ft.

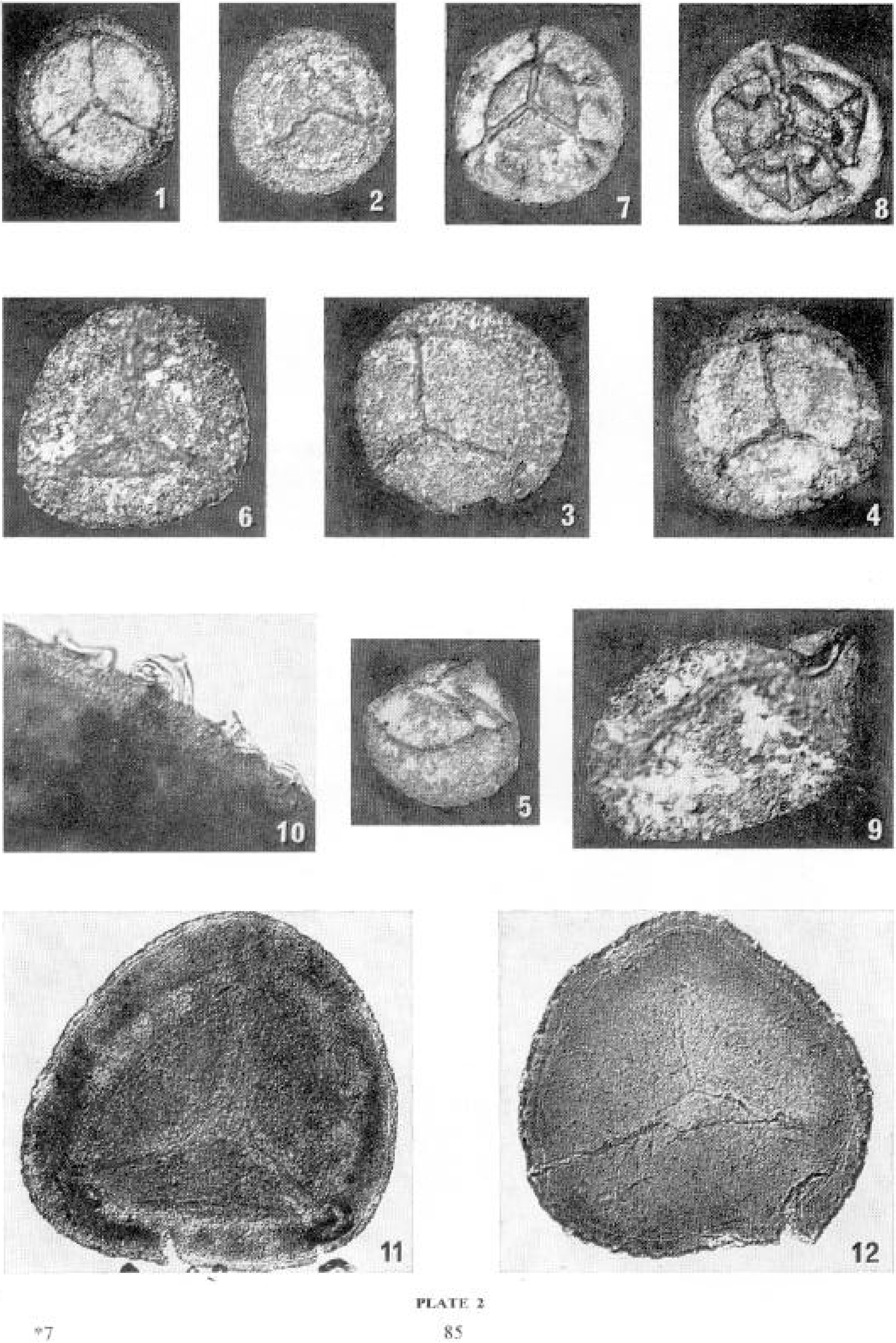


PLATE 2

PLATE 2

PERMIAN MEGASPORES

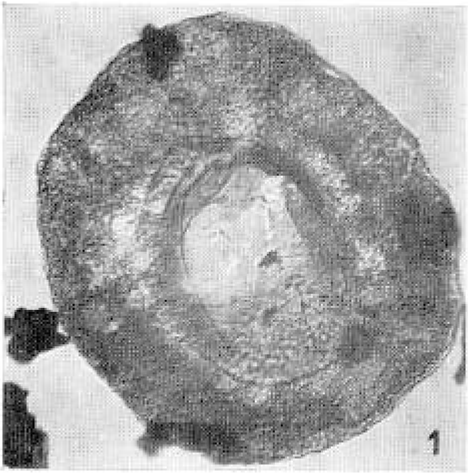
Figs. 1-9, specimens photographed in reflected light Ca. x 30. Other figs. in transmitted light.

1 - 5, 11-12. *Carruthersiella* spp. Note the well contact areas, the wrinkled appearance of the aperture margins and the papillate exosporium. 1, 4, 5, 11812 in cuttings at 1000', 2 core at 1749'6", 3-cuttings at 950ft. 11, 12 - Ca. x 125; note mesosporium in 11. Aperture margins and contact areas less distinct.

6, 10 *Mammilaespora* sp. Note, in 6, small contact area. 10, Ca x 500 - note branded processes on the exosporium. Cuttings at 750ft.

7, 8 *Duosporites* spp. Note prominent proximal attachment area of mesosporium and the nearly smooth surface of the exosporium. Core 3 at 1243ft., and core 4 at 1748'6" respectively.

9. *Dijkstraea* sp. Note lageniculate proximal surface. Distal surface ornamentation consists of dense branched processes similar to those in *Mammilaespora*. Core 3 at 1243ft.



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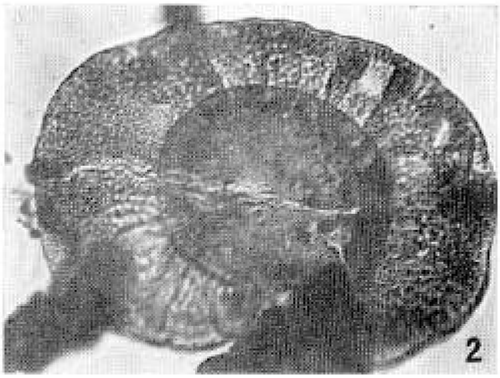

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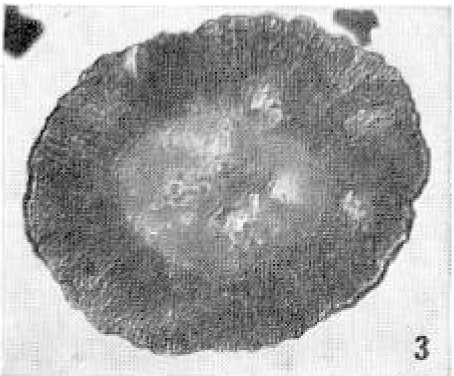

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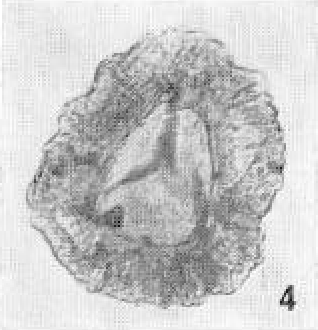

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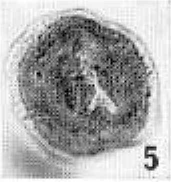

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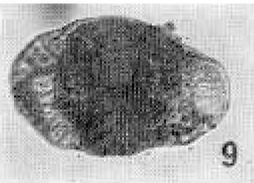

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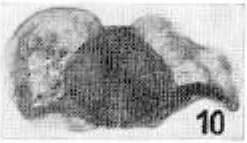

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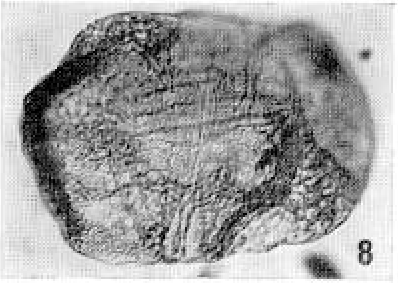

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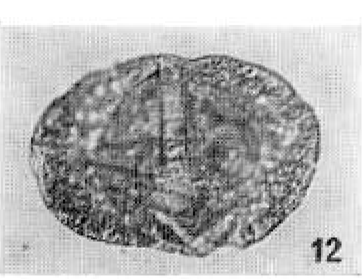

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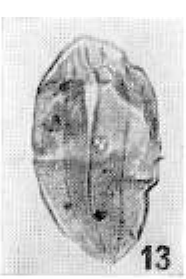

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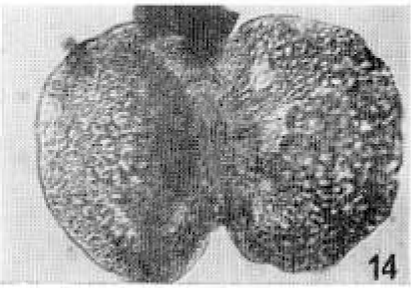

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PLATE 3

PLATE 3

PERMIAN MIOSPORES

Fig. 1, ca x 320, all other figs. ca. x 500.

1. *Plicatipollenites gondwanensis*. Note trilete aperture and body infold system. Core 2 at 633ft.

2. *?Potonieisporites* sp. Central body split. Core 2 at 633ft.

3, 4. *Parasaccites* spp. Note in 4 the strongly upturned margins of the aperture and the sub-triangular shape of the central body. 3-from core 3 at 1244ft. and 4 from core 4 at 1743ft.

5. ?*Bascanisporites undosus*. Note reticulation of bladder. Core 2 at 633ft.

6, 7. *Marsupipollenites triradiator*. Core 2 at 633ft. Note striate form in 6 as against non-striate in 7.

8. *Protohaploxypinus goraiensis* - Outcrop sample, Mt. Toondina.

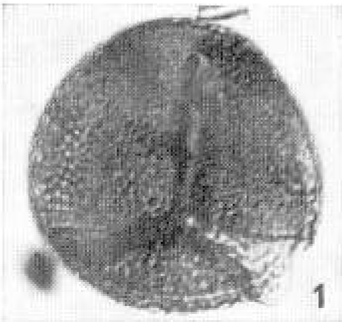
9. *Ovalipollis* sp. - Note monolite scar on distal surface. Core 3 at 1244ft.

10, 11. *Striatites cancellatus* (Balme & Hennelly) Core 2 at 633ft. and Mt. Toondina outcrop sample respectively.

12. *Striatites linupidus* (Balme & Hennelly) Core 3 at 1244ft.

13. *Cycadopites* of *C. cymbatus* Core 2 at 633ft.

14. *Striatopodocarpidites fusus* Core 3 at 1244ft.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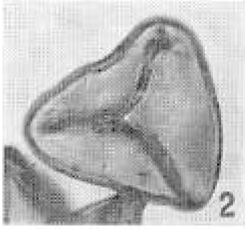
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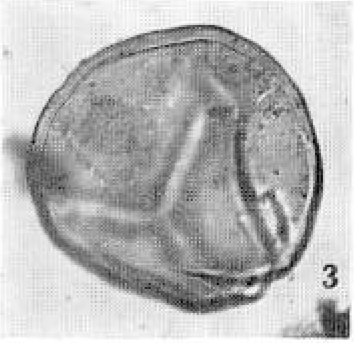
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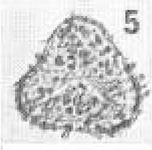
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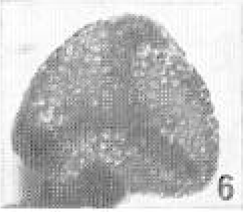
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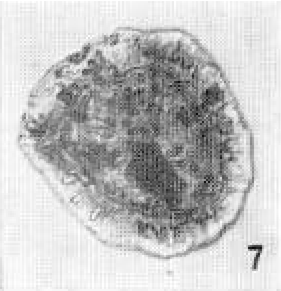
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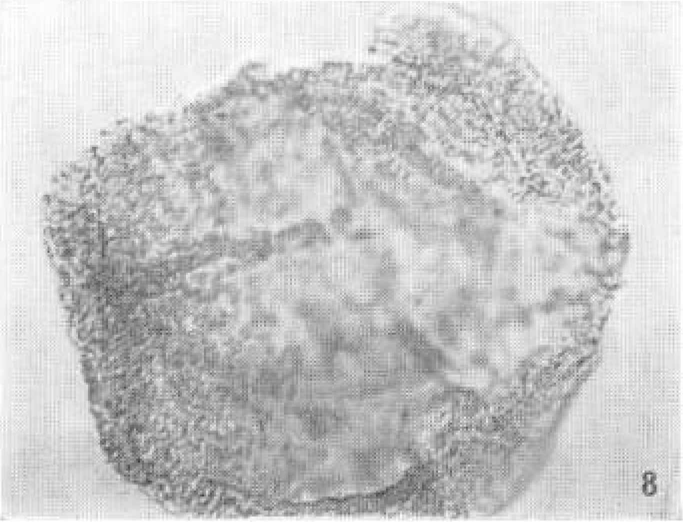
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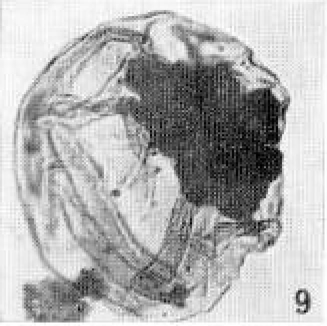
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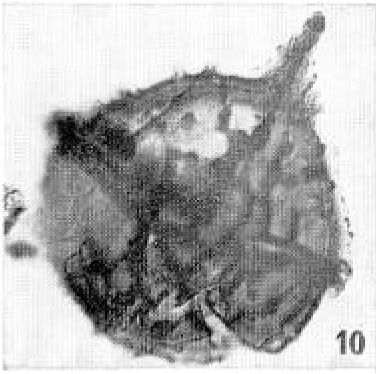
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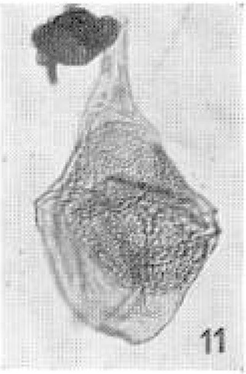
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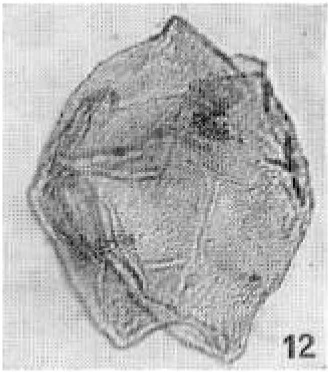
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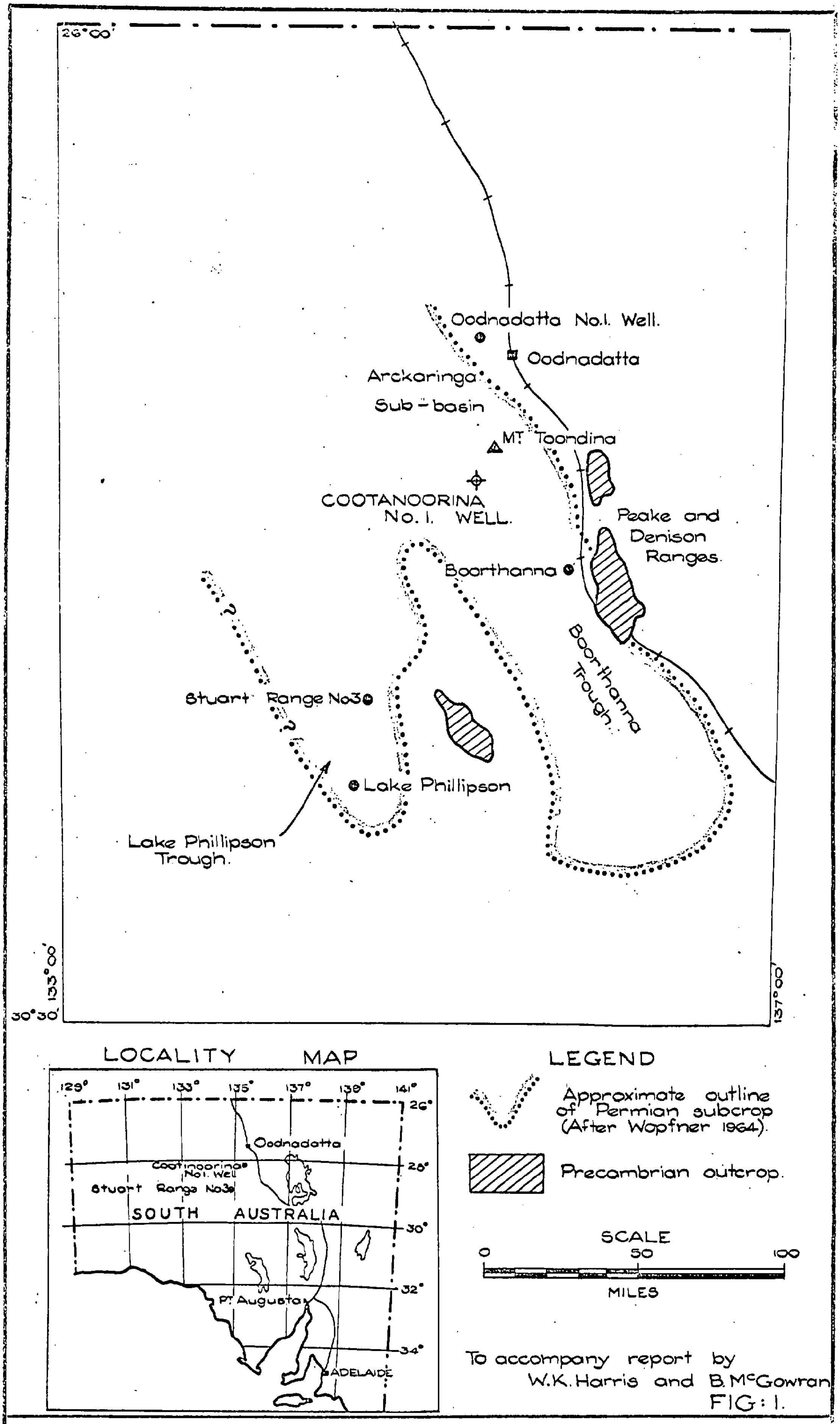
PLATE 4

PLATE 4

PERMIAN & DEVONIAN TRILETE MIROSPORES:
PERMIAN & CRETACEOUS MICROPLANKTON.

All figures except fig. 8 ca. x 500. Fig. 8, ca x 1000

1. *Verrucosisporites* of *V. trisecatus*
   Outcrop sample, Mt. Toondina
2. *Microfoveolatispora directa*
   Core 2 at 633ft.
3. *Punctatisporites gretensis*
   Core 3 at 1244ft.
4. *Tuberculatosporites modicus*
   Outcrop sample, Mt. Toondina
5. *Neoraistrickia ramosa*
   Core 3 at 1244ft.
6. *Verrucosisporites* sp.
   Core 3 at 1244ft.
7. *Krauselisporites apiculatus*
   Cuttings at 850ft.
8. *Geminospora lemurata*
   Note mesosporium. Proximal face and ornament
   is also similar to *Retusotriletes* of *R. devonicus*
   Naumora cuttings at 3010ft.
9. *Leiosphaera* sp.
   Core 6 at 2697ft.
10. *Gonyaulacacysta edwardsi*
    Core 1 at 362ft.
11. *Dingodinium cerviculum*
    Core 1 at 362ft.
12. *Canningia colliveri*
    Core 1 at 362ft.



To accompany report by
W.K. Harris and B. McGowran
FIG: 1.

DEPARTMENT OF MINES — SOUTH AUSTRALIA

Drn. BH
Tcd. AMcD
Ckd.

LOCALITY MAP
COOTANOORINA No. 1. WELL

SCALE: As Shown

S 6306
Bd

S.A.G. COOTANOORINA Nº 1. WELL

MICROPALAEONTOLOGICAL LOG

AND

Composite Well Log.

(Adapted from Wopfner and Allchurch 1967)

SILTY SHALE, pale grey with olive-green ovoids of smectite, slightly calcareous, laminated; interbedded with SILTSTONE and thin brown LIMESTONES.

CALCAREOUS SANDSTONE offwhite to pale grey, shaley.

SANDSTONE, pale grey coarse to very coarse quartz, some feldspar, subangular to subrounded, minor kaolinitic matrix.

SILTSTONE, pale to dark grey micaceous, interbedded with CARBONACEOUS SHALE dark brown, and COAL, black, fibrous. Minor calcareous sandstone.

SANDSTONE, pale grey, very fine to fine grained.

SILTSTONE, pale grey, clayey, slightly calcareous and carbonaceous. Some thin CALCAREOUS SANDSTONES.

SHALE, dark grey, laminated, slightly silty and carbonaceous.

SILTSTONE, mid-grey with specks of white sericite up to 0·5mm. dia. laminated. Anhydritic between 2080 and 2190 ft.

SILTY SHALE, dark grey, micromicaceous, slightly calcareous.

SANDY SHALE, pale grey, plastic when wet, slightly calcareous, interbedded with SHALE dark grey, non-plastic, and thin calcareous sandstones, offwhite, pebbly.

SANDSTONE, pale grey fine grained pebbly to conglomerate in places, interbedded with SHALE, grey, plastic when wet, and thin dolomite, brown to black, crystalline, vuggy.

DOLOMITE, pale grey sandy, interbedded with DOLOMITIC SHALE, green-grey and ANHYDRITE pink.

To accompany Pal. Report 1/68 by W. Harris and B. McGowran.

DEPARTMENT OF MINES — SOUTH AUSTRALIA

COOTANOORINA Nº 1. WELL
MICROPALAEONTOLOGICAL LOG AND
COMPOSITE WELL LOG

Director of Mines

Drn. V.H.
Tcd. A McD
Ckd.
Exd.

SCALE: AS SHOWN

68-84 Bd

DATE: 16-1-68

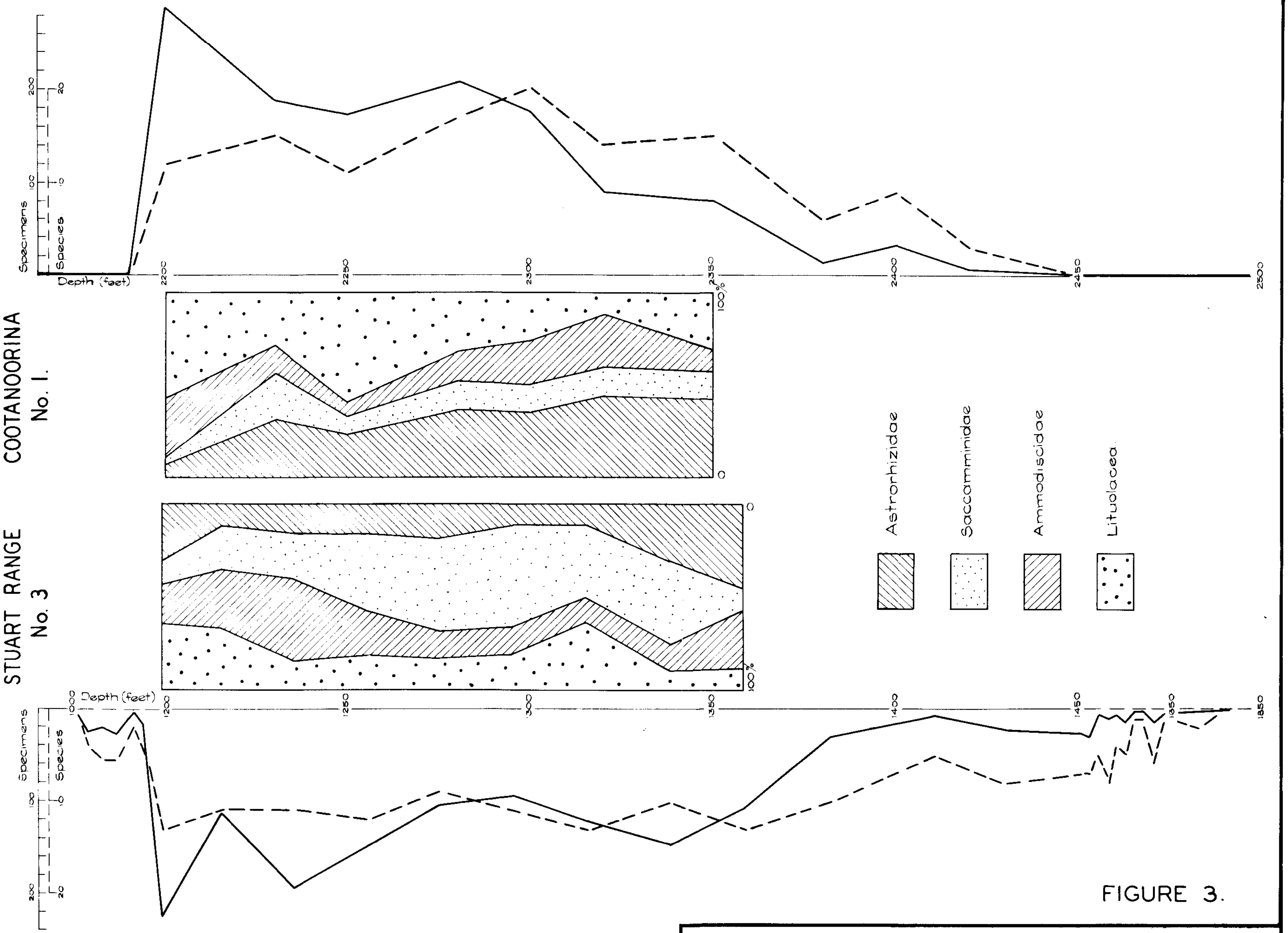


FIGURE 3.

To accompany report by W. K Harris and B McGowran.

DEPARTMENT OF MINES — SOUTH AUSTRALIA

FORAMINIFERAL FAUNAL TRENDS IN PERMIAN STUART RANGE No. 3. AND COOTANOORINA No. 1.

		Drn. B McG	**SCALE:** As shown
		Tcd. A McD	68 - 71 Bb+d
		Ckd.	
Director of Mines		**Exd.**	**DATE:** 4 - 1 - 68

TABLE 1.
COOTANOORINA No. 1.
DISTRIBUTION OF PERMIAN FORAMINIFERA

DEPTH (FEET) / SPECIES	*Lagenammina ampulla.*	*Thuramminoides sphaeroidalis*	*Glomospira adhaerens*	*Saccammina orca*	*Recurvoides wilsoni.*	*Digitina recurvata*	*Textularia bookeri*	*Ammodiscus oonahensis*	*Tolypammina undulata*	*Hemidiscus balmei*	*Hippocrepinella biaperta.*	*Hyperammina hobartensis.*	*Hyperammina acicula.*	*Hyperammina expansa.*	*Lugtonia thomasi.*	*Reophax subasper.*	*Reophax tricameratus.*	*Ammodiscus cf. multicinctus.*	*Ammovertella howchini.*	*Ammovertellina glomospiroides.*	*Ammobaculites woolnoughi.*
1690 - 1700																					
1720 - 1730	V	V																			
1730 - 1740																					
1745 (Core 4)	V	R																			
1749 (Core 4)	R	R																			
1790 - 1800																					
1820 - 1830																					
1840 - 1850																					
1890 - 1900																					
1920 - 1930																					
1940 - 1950																					
1970 - 1980	V																				
1990 - 2000																					
2040 - 2050																					
2090 - 2100																					
2140 - 2150																					
2150 - 2160																					
2170 - 2180																					
2180 - 2190																					
2190 - 2200	V	F	R	R	C	A	V	A	V	V	V	C									
2220 - 2230	F	C	R	C		A		C	R	R	C	C	C	R	R	F	R				
2240 - 2250	V	F	R	F		A		V		F	C	C		F		V					
2270 - 2280	F	C	C	F	C	A		F	F	C	C	A	C	R	F	F		V	R		
2290 - 2300	V	F	V	C	F	A	R	V	C	C	C	A	R	C	R	V		V	R	R	V
2310 - 2320	V	F		F	R	R		F	F	F	C	F	C	R	V	R					
2340 - 2350		F		R	F	F		A	R	V	F	C	C	V	R	R		V		V	
2357 - (Core 5)																					
2358 (Core 5)																					
2370 - 2380		V							V	V	V	F	V								
2390 - 2400	V	V				R				V	R	C	R			R		V			
2410 - 2420										V		R	V								
2440 - 2450																					
2490 - 2500																					
2540 - 2550																					
2590 - 2600												V									
2610 - 2620						V				V		F	F								
2640 - 2650													V								
2697 (Core 6)																					
2690 - 2700									V			V	V								
2720 - 2730											V	V									
2740 - 2750									V			V									
2790 - 2800																					

V. Very Rare 1-2 Specimens
R. Rare 2-5 "
F. Frequent 6-10 "
C. Common 11-25 "
A. Abundant 25+ "

DEPARTMENT OF MINES — SOUTH AUSTRALIA

Drn. AMD
Tcd. AMD
Ckd. LVW
Exd.

TABLE 1
COOTANOORINA No. 1.
DISTRIBUTION OF PERMIAN FORAMINIFERA

SCALE:

S 6333 Bd.

DATE: 22 - 1 - 68