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CONTENTS

PALEOCENE PLANKTONIC FORAMINIFERA FROM PAPUA AND NEW GUINEA

by D. J. Belford*

SUMMARY

Paleocene foraminifera are recorded for the first time from the Territory of Papua and New Guinea; they have been found in the Wabag area, Western Highlands, New Guinea, and the Cape Vogel area, Papua. Fourteen planktonic species referred to the genera *Subbotina, Globigerina, Globorotalia,* and *Chiloguembelina* are recorded and illustrated. Free specimens have been obtained from only part of the two measured sections; these intervals are referred mainly to the *Globorotalia pseudomenardii* Subzone. The total stratigraphic range of the sections is not known; the oldest beds may be referable to the *Globigerina daubjergensis* - *G. trinidadensis* Zone.

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* Manuscript completed 28 March, 1966.

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INTRODUCTION

The first Paleocene foraminifera found in the Territory of Papua and New Guinea were discovered in samples collected during a survey of the Wabag area, Western Highlands, New Guinea, carried out by F. E. Dekker, I. G. Faulks, J. E. Thompson, R. G. Horne, and D. J. Belford in 1963 (Dekker & Faulks, 1964). Paleocene foraminifera were found in samples collected over measured sections on the Andebare River and at Tibinini, and also at two isolated localities, one in the head of the Andebare River and the other in the headwaters of the Lagaip River (see Fig. 1). Details of the two measured sections are shown in Figure 3. In addition to the planktonic species, a large benthonic assemblage is present, but has not yet been examined in detail.

In October 1964 J. E. Thompson mapped part of the Cape Vogel area, Papua, and in one sample collected during this survey Paleocene foraminifera were again found (Fig. 2). The fauna recorded from this area is not as rich as that from the Western Highlands, and the specimens are small, but well preserved.

This paper is intended only to record the presence of Paleocene beds in Papua and New Guinea, to illustrate the planktonic foraminiferal species found and to give their known distribution, and to discuss the age significance of the fauna. Many papers have recently been written concerning the Paleocene, particularly its zonal subdivision and correlation, and evolutionary trends within the planktonic foraminifera; many of these references are given in the following pages. Nothing can be added to these discussions from a study of the present material; the scope of the investigation is limited by the wide sampling intervals, the absence of foraminifera from several samples, and the impossibility of obtaining free specimens from limestones in the sections.

All figured specimens and thin sections are deposited in the Commonwealth Palaeontological Collection, Canberra.

I wish to thank Dr B. McGowran, Department of Geology, University of Adelaide, for examining and commenting on the specimens here identified as *Globorotalia* sp. cf. *G. kolchidica* Morozova; and Dr H. P. Luterbacher, Esso-REP, Begles (Gironde), France, for confirming the identification of *G. pasionensis* (Bermudez).

DESCRIPTION OF SECTIONS

The measured section on the Andebare River is about 2500 feet thick; the beds dip to the north-east, from 45° to 60° at the base of the section and at about 15° near the top. This section is part of a thick sedimentary sequence ranging in age from the Upper Cretaceous to the upper Miocene, which has

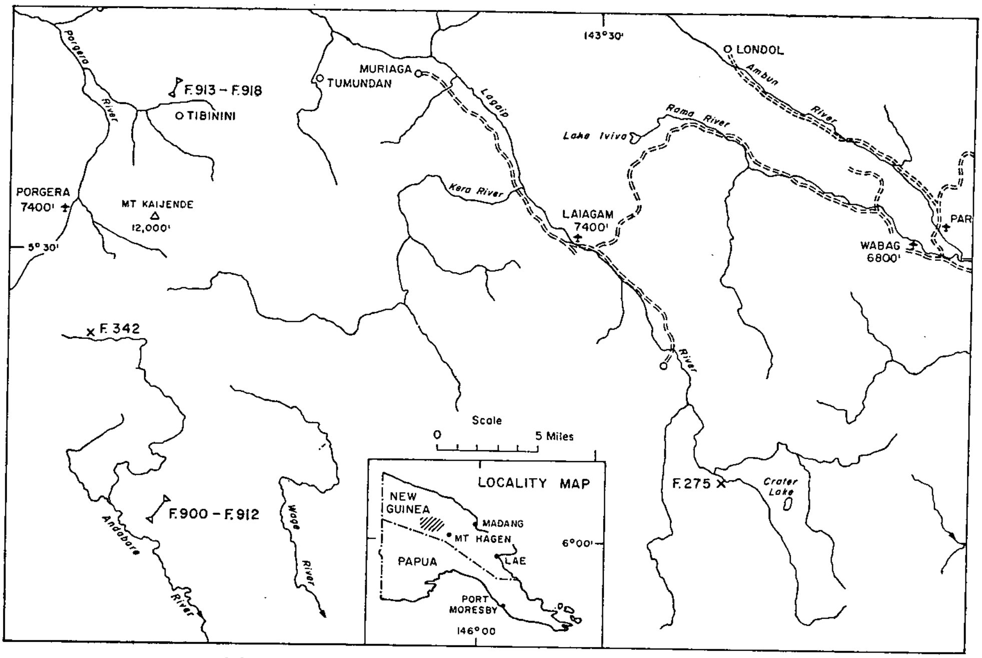

Fig. 1: Locality map Wabag area, New Guinea.

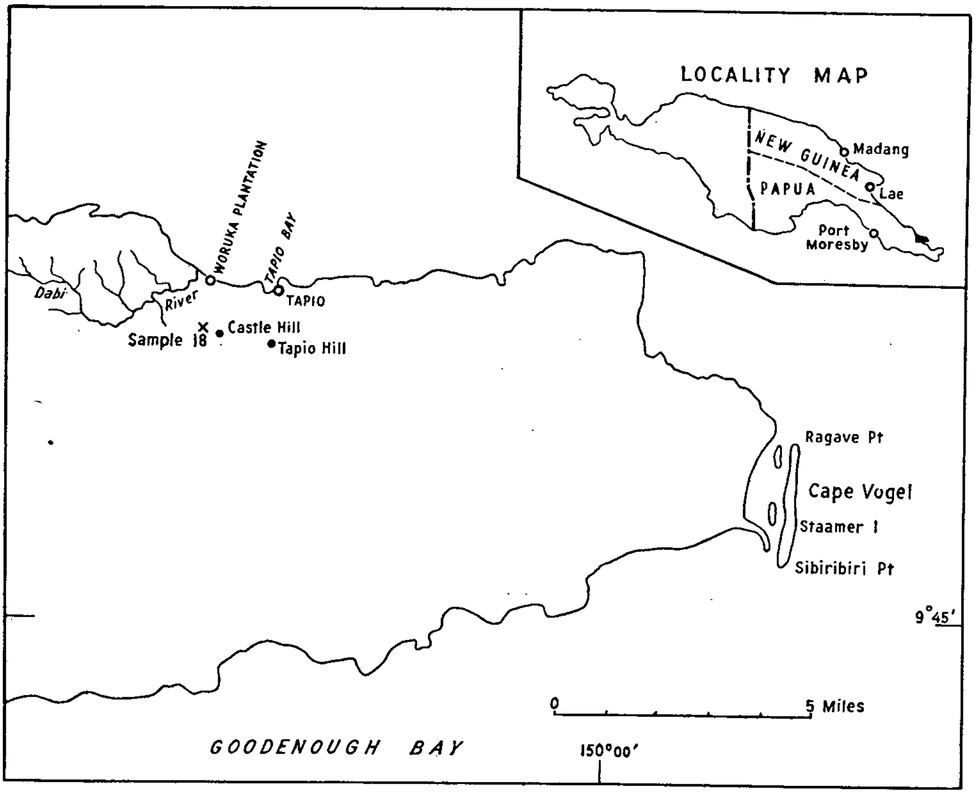

Fig. 2: Locality map, Cape Vogel, Papua.

been called Lagaip Beds*. The sequence has been overfolded and thrust-faulted, but the measured section (Fig. 3) apparently is not faulted. In the north the Lagaip Beds contain a large limestone lens called the Tibinini Limestone Member.

The lower 1350 feet of the Andebare section consists of a fine-grained limestone, with a slightly coarser band represented by sample F909. Samples F910, F911, and F912 contain abundant indeterminable smaller foraminifera, with rare planktonic specimens; sample F909 has only rare foraminifera with *Elphidium* sp. and planktonic specimens; F908 contains fragments of Discocyclinidae, planktonic foraminifera again being rare. No keeled species of *Globorotalia* have been found in samples from the limestone. Overlying the limestone is about 150 feet of a fine-grained sandstone, represented by sample F907, which is barren of foraminifera.

The upper part of the section consists of 1000 feet of siltstone, which has yielded free specimens. F906 is unfossiliferous; samples F903 to F905 contain abundant foraminifera, with a high proportion of planktonic specimens. F902 contains abundant arenaceous foraminifera, the planktonic specimens being very rare and occurring only as casts. Numerous planktonic specimens again occur in sample F901; sample F900 near the top of the section is a harder calcareous siltstone, with some evidence of recrystallization, and no identifiable fossils have been found.

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* The names Lagaip Beds and Tibinini Limestone Member were coined by Dekker & Faulks (1964), but have not been published. They are defined as follows (D.B. Dow, pers. comm.):

Lagaip Beds

Rock Type: Mostly fine-grained marine sediments consisting of calcareous and non-calcareous siltstone and shale, calcareous quartz sandstone and greywacke, fine-grained limestone, calcarenite, and pebble conglomerate. A thick limestone bed within the unit has been mapped separately as the Tibinini Limestone Member.

Distribution: Western Highlands of New Guinea between Mount Hagen Range (144°02′E, 5°30′S) and Porgera patrol post (143°07′E, 5°29′S).

Derivation of Name: From the Lagaip River, which drains a large area of these rocks.

Type Area: Along the Lagaip Valley between Laiagam patrol post (143°30′E, 5°30′S) and Yeim village (143°11′E, 5°11′S). No type section has been designated.

Stratigraphic Relationships: The bottom of the unit has not been seen because it is everywhere faulted against older rocks. The Beds are overlain, probably unconformably, by Lower Miocene sediments.

Thickness: 8000 feet of sediments were measured in the south, but the unit is probably much thicker.

Age: Upper Cretaceous to lower Miocene.

Tibinini Limestone Member

Rock Type: Fine-grained grey limestone containing highly fossiliferous chalky bands.

Distribution: Along the Lagaip Valley west of Laigam patrol post.

Derivation of Name: From Tibinini village (143°11′S, 5°22′S).

Type Area: East of Porgera patrol post between Mount Kaijende (143°09′E, 5°29′S), and Tibinini village. No type section was measured.

Stratigraphic Relationships: Appears to be a large limestone lens within the Lagaip Beds.

Thickness: Up to 3000 feet.

Age: Probably lower Miocene.

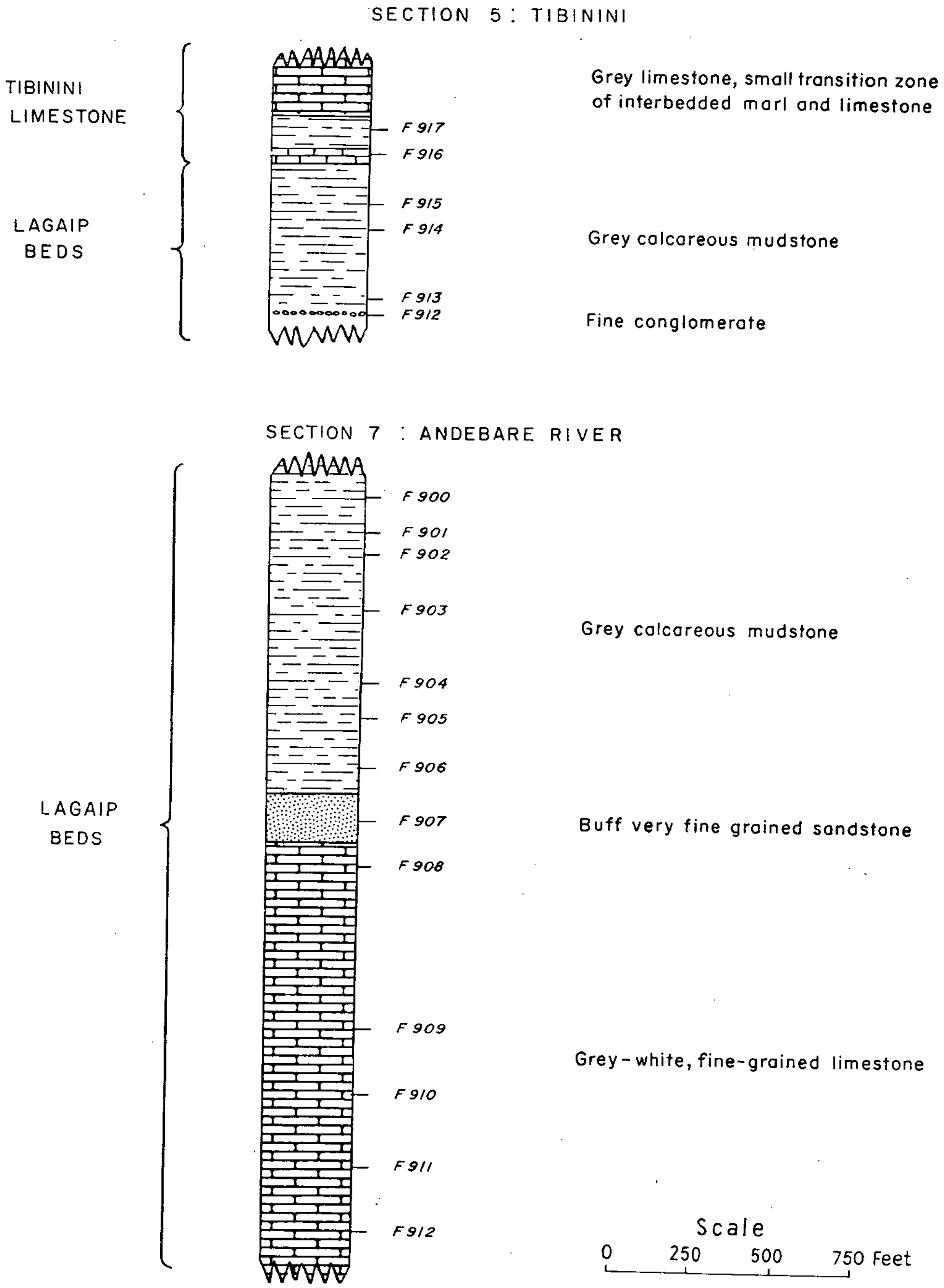


Fig. 3: Columnar sections 5 and 7.

The section at Tibinini is about 875 feet thick, the beds dipping north-east at about 35°. The lower 700 feet consists mainly of fine-grained calcareous shale with conglomerate at the base and a band of limestone near the top. The upper 175 feet is a fine-grained limestone of the Tibinini Limestone Member. In this section only two samples, F914 and F915, have yielded free specimens, with abundant planktonic foraminifera. Samples F913 near the base and F917 near the top of the section contain keeled species of *Globorotalia.* Sample F916, from the limestone band in the lower 700 feet of section, contains abundant indeterminable smaller foraminifera, but no planktonic specimens have been found.

SYSTEMATIC DESCRIPTIONS

Genus SUBBOTINA Brotzen & Pozaryska, 1961

SUBBOTINA TRILOCULINOIDES (Plummer, 1926)

(Pl. 1, figs 1-5)

1926	*Globigerina triloculinoides* Plummer, p. 134, pl. 8, figs 10a-c.
1957a	*Globigerina triloculinoides* Plummer; Loeblich & Tappan, p. 183, pl. 40, figs 4a-c; numerous other figures. (Synonymy).
1957	*Globigerina triloculinoides* Plummer; Bolli, p. 70, pl. 15, figs 18-20; pl. 17, figs 25-26.
1957	*Globigerina triloculinoides* Plummer; Troelsen, p. 129, pl. 30, figs 3a-c, 4a-c.
1960	*Globigerina triloculinoides* Plummer; Bolli & Cita, p. 13, pl. 31, figs 1a-c. (Synonymy).
1961	*Subbotina triloculinoides* (Plummer); Brotzen & Pozaryska, p. 160, text-fig. 2.
1962	*Globigerina triloculinoides* Plummer; Hillebrandt, p. 119, pl. 11, figs 1a-c.
1963	*Globigerina triloculinoides* Plummer; Hinte, p. 129, pl. 21, figs 3a-c.

Material examined: 130 specimens.

S. triloculinoides is the most common species in the samples, and shows the full range of variation illustrated by Loeblich & Tappan (1957). Some specimens have a small abnormally placed final chamber partly obscuring the primary aperture.

Dimensions of figured specimens (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7194	0.47	0.38	0.37
CPC 7195	0.41	0.32	0.32

Occurrence: Figured specimens (CPC 7194 and 7195) from a section on the Andebare River, about 2000 feet above the base of the measured section (locality 3d); other localities: 2, 3b, 3e, 4b, 4c, 5.

Remarks: The species described as *Globigerina triangularis* White and *G. linaperta* Finlay are very similar to *Subbotina triloculinoides,* and there has been much uncertainty with regard to specific identification and disagreement as to specific limits. This applies particularly to the species *triloculinoides* and *linaperta,* and is reflected in the differing stratigraphic range shown for them by different authors. Loeblich & Tappan (1957a, p. 176) considered that *triloculinoides* disappeared at the end of the Paleocene and was replaced by *linaperta.* Bolli (1957) showed *triloculinoides* extending only as high as the top of the *Globorotalia pusilla pusilla* Zone, being succeeded in the *G. pseudomenardii* Zone by *linaperta.* He figured as *Globigerina linaperta* Finlay a specimen which is indistinguishable from specimens figured by Loeblich & Tappan as *G. triloculinoides.* Stolk (1965) showed *G. triloculinoides* (and *G. triangularis*) extending into the lower Eocene. Berggren (1964) considered the specimen identified by Said (1960) as *G. triloculinoides* to be referable to *G. triangularis.* McGowran (1965) also referred to the confused nomenclature in this species group, and referred specimens which appear to be similar to those from Papua-New Guinea to *Globigerina* aff. *G. linaperta* Finlay. While the difficulties in recognizing specific limits persist I prefer to use the older name *triloculinoides.*

The New Guinea specimens referred to *Subbotina triloculinoides* are coarsely reticulate, with a distinct apertural lip, and have 3 to 4 chambers visible from the ventral side. In smaller specimens also referred to *S. triloculinoides,* 4 chambers are generally visible and the apertural lip is not as strongly developed. Like the Victorian specimens noted by McGowran (1965), the Papua-New Guinea specimens are variable, but apparently represent only one species.

Genus GLOBIGERINA D'Orbigny, 1826

The generic name *Acarinina* has been used for species of the group which would include *Globigerina mckannai* White. Luterbacher (1964) discussed classification within the genus *Globorotalia* and noted that although Subbotina originally included *Turborotalia centralis,* the type species of *Turborotalia,* in *Acarinina,* it was later excluded and *Acarinina* restricted to highly spinose forms. Berggren (1956b) noted that the generic name *Acarinina* has been used for heterogeneous forms, but considered it possible that the name could be used in a restricted sense; the interpretation given by Hillebrandt (1926) was cited as an example. Hillebrandt restricted *Acarinina* to include spinose non-keeled globorotaliids, excluding *Turborotalia centralis* from the group; this would seem to be very similar to the later ideas of Subbotina.

Attention is now being given to the external nature of the shell wall of planktonic foraminifera as an aid to classification; the restriction of the generic name *Acarinina* to spinose non-keeled forms is one example of this. Other papers dealing with this feature are those of Bolli & Pozaryska (1961), with the original definition of the genus *Subbotina,* and Parker (1962) dealing with Recent planktonic species. Although this aspect of wall structure may help in the development of a more 'natural' grouping of the planktonic foraminifera, undue emphasis placed upon it in any classificatory scheme possibly would not give any more satisfactory results than those based on other criteria. It is often difficult when dealing with fossil species to reach any firm conclusion regarding the original external appearance of the wall. The Papua-New Guinea specimens of *G. mckannai* are strongly hispid (in the meaning of Parker, 1962, p. 221), particularly around the umbilical margin, and on the diagnosis of *Globigerina* given by Parker may be placed in this genus. It is also probable that the term 'spinose' has been used by others to describe such an appearance of the wall, and in this case the present specimens satisfy the requirements for inclusion in the genus *Acarinina* Subbotina. To prevent further confusion it will be necessary to define the different terms to be used in describing the external appearance of the wall; meanwhile, the specimens are here placed in the genus *Globigerina.* Gartner & Hay (1962), although placing *mckannai* in the genus *Globorotalia,* stated that it could with equal justification be placed in *Globigerina.*

GLOBIGERINA MCKANNAI White, 1928

(Pl. 4, figs 4-12)

1928 *Globigerina mckannai* White, p. 194, pl. 27, figs 16a-c.
1958 *Globigerina gravelli* Bronnimann; Hornibrook, p. 665, figs 21, 25.
1962 *Globorotalia mckannai* (White); Gartner & Hay, p. 564, pl. 1, figs 1a-c. (Synonymy).
1962 *Globorotalia* (*Acarinina*) *mckannai* (White); Hillebrandt, p. 140, pl. 14, figs 8a-c, 9a-c, 10a-c.
1962 *Globorotalia* (*Acarinina*) *pentacamerata* Subbotina; Hillebrandt, p. 142, pl. 14, figs 7a-c.
1963 *Globigerina mckannai* White; Hinte, p. 130, pl. 21, figs 4a-c.

Material examined: 44 specimens.

The variation of specimens referred to *G. mckannai* is illustrated in the synonymic references. The present specimens generally have 5 chambers visible from the ventral side, but rare specimens, such as that illustrated in Plate 4, figures 4 to 6, are high-spired forms with 7 to 8 chambers visible from the ventral side. They may be compared with the specimen figured by Loeblich & Tappan (1957a, pl. 47, figs 7a-c). Some specimens show the small nearly smooth obliquely placed chamber mentioned by Berggren (1960).

Dimensions of figured specimens (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7224	0.38	0.37	0.36
CPC 7225	0.37	0.33	0.31
CPC 7226	0.33	0.32	0.31
CPC 7227	0.28	0.25	0.22

Occurrence: Figured specimens CPC 7224 to 7226 from a section on the Andebare River, about 2000 feet above the base of the measured section (locality 3d);

figured specimen CPC 7227 from a sample near the Andebare River about 24 miles west-south-west of Laiagam (locality 2); other localities: 3e, 4c.
Remarks: Bolli (1957) regarded *G. mckannai* White as restricted to the *Globorotalia pseudomenardii* Zone of the Trinidad succession, but other authors, for example Loeblich & Tappan (1957) and Stolk (1965), extend its range into the lower Eocene. This again has resulted from a differing interpretation of specific limits. Bolli recognized *Globigerina gravelli* Bronnimann as a distinct species, ranging through the lower Eocene, but it was placed in the synonymy of *G. mckannai* by Loeblich & Tappan, and also by Gartner & Hay (1962) and Berggren (1965). Bronnimann (1952) recorded *Globigerina gravelli* in the Paleocene and lower Eocene. Other species which have been placed in the synonymy of *G. mckannai* are *Globorotalia pentacamerata* Subbotina, *G. strabocella* Loeblich & Tappan (by Gartner & Hay, 1962) and *Globigerina aspensis* Colom (by Berggren, 1965b).

Genus GLOBOROTALIA Cushman, 1927

Classification of species which may be broadly grouped under the generic name *Globorotalia* has been discussed recently by several workers; for example Hillebrandt (1962), Luterbacher (1964), and Berggren (1965b). Some indication of the differing approaches to the classification of this group and the lack of agreement on the relative importance of different morphological features may be obtained from these papers. The concept of *Globorotalia* used here is that of Bolli, Loeblich, & Tappan (1957a); adoption of some current proposals would prevent the use of the generic name *Globorotalia* for any Paleocene species. One possible solution, already suggested by Luterbacher (1964), is to retain *Globorotalia* as the generic name, with other terms which may be considered necessary used at the subgeneric level.

GLOBOROTALIA PSEUDOMENARDII Bolli, 1957

(Pl. 1, figs 13-23)

1957	*Globorotalia pseudomenardii* Bolli, p. 77, pl. 20, figs 14-17.
1962	*Globorotalia pseudomenardii* Bolli; Gartner & Hay, p. 566, pl. 1, fig. 5. (Synonymy).
1962	*Globorotalia (Globorotalia) pseudomenardii* Bolli; Hillebrandt, p. 127, pl. 12, figs 5a-c, 6a-b.
1965	*Globorotalia pseudomenardii* Bolli; McGowran, p. 66, pl. 6, fig. 3.

Material examined: 56 specimens.

G. pseudomenardii is a common species in the present samples. In some samples, particularly in the section at Tibinini, specimens which have a very conical dorsal surface and concave ventral surface occur (Pl. 1, figs 18-23); these are regarded as merely individual variants.

Dimensions of figured specimens (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7199	0.39	0.30	0.20
CPC 7200	0.36	0.28	0.16
CPC 7201	0.48	0.38	0.19
CPC 7202	0.48	0.42	0.18

Occurrence: Figured specimens CPC 7199 and 7200 from a section on the Andebare River, about 2000 feet above the base of the measured section (locality 3d); figured specimens CPC 7201 and 7202 from a section at Tibinini, about 400 feet above the base of the measured section (locality 4c); other localities: 2, 3b, 3e, 4b.

Remarks: *G. pseudomenardii* is generally recorded as being restricted to the *Globorotalia pseudomenardii* Zone of the Trinidad succession, or of equivalent beds; however, as noted later in the discussion of the age and correlation of the beds, it may have a longer stratigraphical range. Stolk (1965) has recorded specimens 'sensu Loeblich & Tappan, 1957, pl. 47, fig. 4' ranging into the *G. formosa* Zone, and others 'sensu Loeblich & Tappan, 1957, pl. 54, fig. 10' ranging throughout the lower Eocene. This may again be a case of overlapping specific limits, and Stolk may have been dealing with a species such as *G. pseudoscitula* Glaessner. McGowran (1964) has stated that *G. pseudoscitula elongata* Glaessner is very similar to young forms of *G. pseudomenardii* and that Russian workers no longer formally separate the variety *elongata* from *G. pseudoscitula.*

GLOBOROTALIA VELASCOENSIS VELASCOENSIS (Cushman, 1925)

(Pl. 1, figs 6-12)

1925	*Pulvinulina velascoensis* Cushman, p. 19, pl. 3, figs 5a-c.
1949	*Globorotalia* (*Truncorotalia*) *velascoensis* (Cushman): Cushman & Bermudez, p. 41, pl. 8, figs 4-6.
1957	*Globorotalia velascoensis* (Cushman); Bolli, p. 76, pl. 20, figs 1-4.
1957a	*Globorotalia velascoensis* (Cushman); Loeblich & Tappan, p. 196, pl. 64, figs 1a-c, 2a-c.
1960	*Globorotalia velascoensis* (Cushman) 1925; Bolli & Cita, p. 31, pl. 33, figs 7a-c.
1962	*Globorotalia* (*Truncorotalia*) *velascoensis velascoensis* (Cushman); Hillebrandt, p. 139, pl. 13, figs 16-21.

Material examined: 88 specimens.

Specimens of *G. velascoensis velascoensis* in the present samples range from slightly to strongly rugose around the umbilical area. Some specimens have a concave surface on chambers of the last whorl. The size of the umbilicus also varies, as was noted by Bolli (1957) in specimens from a Velasco Shale sample. Coiling is dominantly sinistral, only 8 dextrally coiled specimens being observed.

Dimensions of figured specimens (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7196	0.48	0.42	0.27
CPC 7197	0.55	0.44	0.28
CPC 7198	0.50	0.42	0.28

Occurrence: Figured specimens CPC 7196 to 7198 from a section on the Andebare River, about 2000 feet above the base of the measured section (locality 3d); other localities: 3b, 3e, 4b, 4c, 5.

GLOBOROTALIA VELASCOENSIS OCCLUSA Loeblich & Tappan, 1957

(Pl. 2, figs 7-12).

1957a	*Globorotalia occlusa* Loeblich & Tappan, p. 191, pl. 55, figs 3a-c; pl. 64, figs 3a-c.
1962	*Globorotalia (Truncorotalia) velascoensis occlusa* Loeblich & Tappan; Hillebrandt, p. 139, pl. 13, figs 22-26.

Material examined: 15 specimens.

All specimens of *G. velascoensis occlusa* observed closely resemble the holotype and are unlike the figured paratype, which has 4 chambers visible from the ventral side and a smooth umbilical shoulder. The New Guinea specimens are weakly to distinctly pustulose around the umbilical margin and have 5 chambers visible from the ventral side; all are sinistrally coiled.

Dimensions of figured specimens (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7206	0.48	0.40	0.24
CPC 7207	0.42	0.38	0.23

Occurrence: Figured specimens CPC 7206 and 7207 from a section on the Andebare River, about 2000 feet above the base of the measured section (locality 3d); other locality: 2.

GLOBOROTALIA CHAPMANI Parr, 1938

(Pl. 2, figs 1-6)

1938	*Globorotalia chapmani* Parr, p. 87, pl. 3, figs 8-9.
1964	*Globorotalia chapmani* Parr; McGowran, p. 85, pl. 1, figs 1-9. (Synonymy).
1965	*Globorotalia chapmani* Parr; McGowran, p. 63, pl. 6, fig. 2; text-fig. 12: 6-10.

Material examined: 12 specimens.

Specimens referred to *G. chapmani* occur only rarely, in two samples. McGowran (1964) considered the specimens identified by Loeblich & Tappan (1957a) and Bolli (1957) as *G. elongata* Glaessner to be referable to *G. chapmani* Parr, and this interpretation is followed here. Berggren (1962) also recognized that the specimens examined by Loeblich & Tappan and Bolli were not referable to Glaessner's species, but noted only that a new name was required for them. The present specimens are all very small, the largest observed having a maximum diameter of about 0.36 mm. Few of them have as angular a periphery as specimens of *G. chapmani* from the Boongerooda Greensand, Western Australia, that I have examined. This applies particularly to the two figured specimens, which more closely resemble the specimens figured by McGowran (1964) from the Kings Park Shale, Perth Basin, Western Australia.

Dimensions of figured specimens (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7204	0.33	0.23	0.15
CPC 7205	0.30	0.24	0.15

Occurrence: Figured specimens CPC 7204 and 7205 from a section on the Andebare River, about 4000 feet above the base of the measured section (locality 3d); other locality: 2.

GLOBOROTALIA AEQUA AEQUA Cushman & Renz, 1942

(Pl. 2, figs 13-18)

1942	*Globorotalia crassata* var. *aequa* Cushman & Renz, p. 12, pl. 3, figs 3a-c.
1962	*Globorotalia aequa* Cushman and Renz; Gartner & Hay, p. 560, pl. 2, figs 1a-c, 2a-b. (Synonymy).
1962	*Globorotalia* (*Truncorotalia*) *aequa aequa* Cushman & Renz; Hillebrandt, p. 133, figs 1a, 1c, 2, 3a, 3c, 4.
1965	*Globorotalia aequa* Cushman & Renz; McGowran, p. 63, pl. 6, fig. 6; text-fig. 11.

Material examined: 36 specimens.

Specimens of *G. aequa* observed show very little variation; they closely resemble the specimens figured by Bolli (1957, pl. 17, figs 1-3) and by Gartner & Hay (1962). All have a narrow deep umbilicus and 4 chambers visible from the ventral side. Specimens from locality 2 are very well preserved and have a hispid surface; those from other samples have the surface covered by low rounded pustules. The coiling of the test is dextral in all specimens.

Dimensions of figured specimens (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7208	0.53	0.42	0.32
CPC 7209	0.50	0.40	0.30

Occurrence: Figured specimens CPC 7208 and 7209 from a section at Tibinini, about 400 feet above the base of the measured section (locality 4c); other localities: 2, 5.

GLOBOROTALIA PUSILLA PUSILLA Bolli, 1957

(Pl. 3, figs 10-14)

1957	*Globorotalia pusilla pusilla* Bolli, p. 78, pl. 20, figs. 8-10.
1960	*Globorotalia pusilla pusilla* Bolli, 1957; Bolli & Cita, p. 28, pl. 32, figs 4a-c.
1962	*Globorotalia (Globorotalia?) pusilla pusilla* Bolli; Hillebrandt, p. 128, pl. 11, figs 18a-b.

Material examined: 11 specimens.

G. pusilla pusilla has been found rarely, at only one locality. The specimens are small and biconvex, with a narrowly rounded periphery, and 5 to 6 chambers visible from the ventral side. Two specimens have a faint keel and are possibly transitional to *G. pusilla laevigata* Bolli. All specimens observed are sinistrally coiled.

Dimensions of figured specimens (in mm):

	Maximum Diameter	*Minimum Diameter*	*Height*
CPC 7218	0.22	0.19	0.13
CPC 7219	0.20	0.17	0.12

Occurrence: Figured specimens CPC 7218 and 7219 from a sample near the Andebare River, about 24 miles west-south-west of Laiagam (locality 2); known only from this sample.

GLOBOROTALIA sp. cf. G. APANTHESMA Loeblich & Tappan, 1957

(Pl. 4, figs 1-3)

cf. 1957a	*Globorotalia apanthesma* Loeblich & Tappan, p. 187, pl. 48, figs 1a-c; several other figures.

Only one specimen of this form has been found; it resembles a figured paratype (Loeblich & Tappan, 1957a, pl. 48, figs 1a-c), but is not as angulate or as strongly spinose as the holotype and other figured paratypes. The last chamber of the New Guinea specimen, which is dextrally coiled, is much smaller than the penultimate chamber. It is not possible to make a definite specific identification.

Dimensions of figured specimen (in mm):

	Maximum Diameter	*Minimum Diameter*	*Height*
CPC 7723	0.37	0.33	0.27

Occurrence: Figured specimen CPC 7223 from a section on the Andebare River, about 2000 feet above the base of the measured section (locality 3d); known only from this sample.

GLOBOROTALIA sp. cf. G. ANGULATA (White, 1928)

(Pl. 1, figs 24-26)

cf.
1928 *Globigerina angulata* White, p. 191, pl. 27, figs 13a-c.

Only one specimen of this form has been found. It is planoconvex, with a finely spinose surface, a distinctly spinose keel, and a wide deep umbilicus with narrow umbilical shoulders, slightly ornamented on younger chambers; the coiling is sinistral. It is similar to some published figures of *G. angulata,* but has a somewhat more angular umbilical margin; New Guinea specimens here referred to *G. velascoensis* are more strongly ornamented on the umbilical margin, and many have a concave ventral chamber surface. More specimens would be needed to identify the form definitely.

Dimensions of figured specimen (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7203	0.35	0.28	0.23

Occurrence: Figured specimen CPC 7203 from a sample near the Andebare River, about 24 miles west-south-west of Laiagam (locality 2); known only from this sample.

GLOBOROTALIA PASIONENSIS (Bermudez, 1961)

(Pl. 3, figs 1-9)

1961 *Pseudogloborotalia pasionensis* Bermudez, p. 1.346, pl. 16, figs 8a-b.
1964 *Globorotalia pasionensis* (Bermudez); Luterbacher, p. 690, figs 108a-c, 109a-c, 110a-c.

Material examined: 26 specimens.

G. pasionensis has been found in only one sample. I am indebted to Dr H. P. Luterbacher for examining the specimens and confirming my identification. Dr Luterbacher states (pers. comm., 17 Dec. 1965) that the Papua-New Guinea specimens differ from topotypes in having 5-6 chambers instead of 6-7 in the last whorl, in being less tightly coiled, having less high chambers and a more rounded umbilical shoulder; however, they are very close to specimens from the central Apennines of Italy, which have been figured by Dr Luterbacher.

Dimensions of figured specimens (in mm):

	Maximum Diameter	*Minimum Diameter*	*Height*
CPC 7214	0.67	0.59	0.30
CPC 7215	0.61	0.54	0.29
CPC 7216	0.66	0.56	0.32

Occurrence: Figured specimens CPC 7214 to 7216 and thin section CPC 7217 from a section at Tibinini, about 350 feet above the base of the measured section (locality 4b); known only from this sample.

Remarks: Of the 26 specimens of *G. pasionensis* examined, 12 are dextrally and 14 sinistrally coiled. This occurrence appears to be the earliest known; the sample in which it occurs is most probably referable to the *G. pseudomenardii* Subzone. Luterbacher recorded *G. pasionensis* from the basal Eocene in a section at Gubbio, central Apennines, Italy, and specimens similar to *G. pasionensis* in a sample from Mexico referred to the base of the *G. velascoensis* Zone.

GLOBOROTALIA sp. cf. G. KOLCHIDICA Morozova, 1961

(Pl. 2, figs 19-27)

Material examined: 21 specimens.

Dr B. McGowran of the University of Adelaide has kindly examined and commented on specimens from the Western Highlands (pers. comm., 18 Mar. 1966), and has also forwarded specimens from the Boongerooda Greensand, Carnarvon Basin, Western Australia, for comparison. The specimens from the two areas are undoubtedly conspecific, and Dr McGowran has identified those from the Boongerooda Greensand as *G. kolchidica* Morozova, although they lack the 'thickenings' of the umbilical shoulders. The specimens from the Western Highlands also lack this feature, and for this reason are not referred definitely to Morozova's species.

The Western Highlands specimens have a flat or slightly convex dorsal surface and a strongly convex ventral surface; the periphery is narrow and lobate, with a pustulose keel. The umbilicus is wide and open and the umbilical shoulders smooth and rounded. Sutures on the dorsal side are often indistinct, smooth and curved, and on the ventral side are narrow, radial, and depressed; 4 to 5 chambers are visible from the ventral side. The surface of the test is finely pustulose. Coiling of the specimens is random: 9 are dextrally and 12 sinistrally coiled.

Dimensions of figured specimens (mm):

	Maximum Diameter	*Minimum Diameter*	*Height*
CPC 7210	0.54	0.46	0.23
CPC 7211	0.51	0.48	0.26
CPC 7212	0.50	0.44	0.30

Occurrence: Figured specimens CPC 7210 to 7212 and thin section CPC 7213 from a section at Tibinini, about 350 feet above the base of the measured section (locality 4b); known only from this sample.

GLOBOROTALIA sp.

(Pl. 3, figs 15-22)

Material examined: 13 specimens.

Included here are specimens of a small biconvex species of *Globorotalia* with a narrow umbilicus, spinose keel, narrow curved smooth dorsal sutures, and radial slightly depressed ventral sutures; all specimens are sinistrally coiled. The surface of the test is very finely hispid and the wall is thin and finely perforate. The specimens vary considerably, particularly in the convexity of the dorsal surface, which ranges from slightly to strongly convex; 5 to 7 chambers are visible from the ventral side.

Among the specimens are some which resemble those figured by Luterbacher (1964) as *G. simulatilis* (Schwager). However, considering the variation shown by the present specimens, and also that of published illustrations of specimens referred to *G. simulatilis,* no definite identification is attempted.

Dimensions of figured specimens (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7220	0.27	0.24	0.16
CPC 7221	0.33	0.28	0.18
CPC 7222	0.32	0.25	0.17

Occurrence: Figured specimens CPC 7220 to 7222 from a sample near the Andebare River, about 24 miles west-south-west of Laiagam (locality 2); known only from this sample.

Genus CHILOGUEMBELINA Loeblich & Tappan, 1956

CHILOGUEMBELINA CRINITA (Glaessner, 1937)

(Pl. 4, figs 13-15)

1937	*Guembelina crinita* Glaessner, p. 383, pl. 4, fig. 34.
1957	*Chiloguembelina crinita* (Glaessner); Beckmann, p. 89, pl. 21, figs 4a-b; text-fig. 14, figs 1-4.
1965	*Chiloguembelina crinita* (Glaessner); McGowran, p. 68, pl. 5, figs. 2-3; text-fig. 13: 1-2.

Material examined: 28 specimens.

C. crinita has been recorded from only one locality. The specimens are very finely spinose; the chambers increase rapidly in size. The aperture is asymmetric, semicircular, in some specimens with a narrow transparent flange.

Dimensions of figured specimens (in mm):	*Length*	*Maximum Width*
CPC 7228	0.23	0.17
CPC 7229	0.22	0.17

Occurrence: Figured specimens CPC 7228 and 7229 from a sample near the Andebare River, about 24 miles west-south-west of Laiagam (locality 2); known only from this locality.

AGE AND CORRELATION

Bolli (1957) proposed a zonal subdivision for the Paleocene succession in Trinidad, based on the ranges of planktonic foraminifera, which has since been widely used and is followed here. It has been modified by Berggren (1965a, b), Luterbacher & Premoli Silva (1964), and Luterbacher (1964). Loeblich & Tappan (1957a, b) established a planktonic sequence for the Gulf and Atlantic Coast regions, and Russian workers have also proposed subdivisions. The different proposals have been discussed and evaluated by Berggren (1965b, c) and Luterbacher (1964).

A definite correlation with the zonal scheme based on that of Bolli is attempted only for those beds which have yielded free and specifically determinable specimens. It is not claimed that the stratigraphical ranges of species are exactly the same in Papua-New Guinea as elsewhere; nevertheless, the stratigraphical succession established in other areas provides a valuable reference framework. The specific association found in Papua-New Guinea indicates an upper Paleocene age, and suggests a correlation with the *Globorotalia velascoensis* Zone. A finer subzonal division is more difficult; definite subzonal boundaries cannot be established. The most significant species for correlation are *Globorotalia pseudomenardii, G. chapmani,* and *G. velascoensis occlusa.* McGowran (1964) has discussed the significance of *pseudomenardii* and *chapmani,* both in their world-wide occurrences and locally in the Perth and Carnarvon Basins, Western Australia. It is uncertain if *G. pseudomenardii* is everywhere restricted to the *G. pseudomenardii* Subzone; McGowran (1964) stated: 'It seems probable that, like *G. chapmani,* it persisted with restricted numbers and distribution into the *G. velascoensis* subzone'. Luterbacher (1964) recorded both *G. pseudomenardii* and *G. chapmani* first appearing in the *G. pusilla pusilla* Zone. Loeblich & Tappan (1957a) showed *G. velascoensis occlusa* occurring in their *velascoensis-acuta-spiralis* Subzone, which was correlated by Berggren (1965*a, b*) with the *G. pseudomenardii* Subzone.

Both Berggren (1965*b*) and Hillebrandt (1962) regarded *G. crosswickensis* Olsson as a synonym of *G. velascoensis occlusa; G. crosswickensis* was described from the Hornerstown Formation of New Jersey, which is referable to the *G. pseudomenardii* Subzone. Hillebrandt also placed *G. acutispira* Bolli & Cita in the synonymy of *G. velascoensis occlusa;* Bolli & Cita (1960) showed *G. acutispira* ranging through the upper part of the *G. pseudomenardii* Zone and the lower part of the *G. velascoensis* Zone, but changed the time-stratigraphic concept of these zones from that generally accepted. This change was considered by Berggren (1963; 1965b, c).

From an assessment of the available information the intervals under discussion, or at least the greater part of them, are here referred to the *Globorotalia pseudomenardii* Subzone. In the Tibinini section the interval between samples F914 and F915 is only about 20 feet. The entire Tibinini section may be referable to the *G. velascoensis* Zone, but again this cannot be definitely demonstrated. Samples F913 and F917, near the base and top of the section respectively, contain keeled anguloconical globorotaliids, observed only in random thin sections; no specific identifications can be made and the available information

SPECIES	SAMPLE NUMBER						
	Andebare River	Andebare section			Tibinini section		Cape Vogel
	F.342	F.904	F.903	F.901	F.914	F.915	18
Subbotina triloculinoides	X	X	X	X	X	X	X
Globigerina mekannai	X	X	X			X	
Globorotalia pseudomenardii	X	X	X	X	X	X	
G. chapmani	X		X				
G. velascoensis velascoensis		X	X	X	X	X	X
G. velascoensis occlusa	X		X				
G. aequa aequa	X					X	X
G. pusilla pusilla	X						
G. pasionensis					X		
G. sp. cf. G. kolchidica					X		
G. sp. cf. G. angulata	X						
G. sp. cf. G. apanthesma	X		X				
G. sp.	X						
Chiloguembelina crinita	X						

Fig. 4: Occurrence of species.

is not sufficient to enable the stratigraphical interval represented by this section to be determined.

The interval between samples F901 and F904 in the Andebare River section is about 450 feet thick, and the same conclusions apply, namely that while the greater part is probably referable to the *G. pseudomenardii* Subzone, the total extent cannot be determined. This interval could range from the upper part of the *G. pusilla pusilla/G. angulata* Zone to the lower part of the *G. velascoensis* Subzone.

The stratigraphical interval represented by samples F908 to F912 in the Andebare River section also is not known accurately. No keeled, compressed, or anguloconical globorotaliids have been observed in random thin sections; in other areas these are first known to appear in the upper part of the *G. uncinata* Zone. The observed evidence suggests that this interval may be correlated with the *Globigerina daubjergensis/G. trinidadensis* Zone and the lower part of the *Globorotalia uncinata* Zone, but this has yet to be confirmed. The evidence from sample F908 is very poor, as only fragments of planktonic species have been observed, and these conclusions should more correctly be applied only to the interval between, and including, samples F909 and F912. Lack of evidence prevents the placing of a boundary between any pair of successive zones, and in the Andebare River section there is a thickness of some 1000 feet, from sample F909 to sample F904, from which no information has been obtained.

Of the two isolated samples examined, F275 contains keeled anguloconical globorotaliids, observed only in random thin sections, and is referred to the upper Paleocene, with no definite subzonal determination possible. Sample F342 contains, in addition to the previously mentioned species of *Globorotalia, G. pusilla pusilla* Bolli and *Chiloguembelina crinita* (Glaessner). Beckmann (1957) showed *Chiloguembelina crinita* as occurring in the *Globorotalia pseudomenardii* and *G. velascoensis* Subzones; McGowran (1965) considered *C. crinita* to be a species indicating a general upper Paleocene age. The additional presence of *Globorotalia pusilla pusilla* suggests that this sample is to be referred to the lower part of the *G. pseudomenardii* Subzone. The one sample from the Cape Vogel area contains only *Subbotina triloculinoides, Globorotalia velascoensis velascoensis,* and *G. aequa aequa.* This is suffcient to place this sample at least in the *Globorotalia velascoensis* Zone, and it is most probably also referable to the *G. pseudomenardii* Subzone.

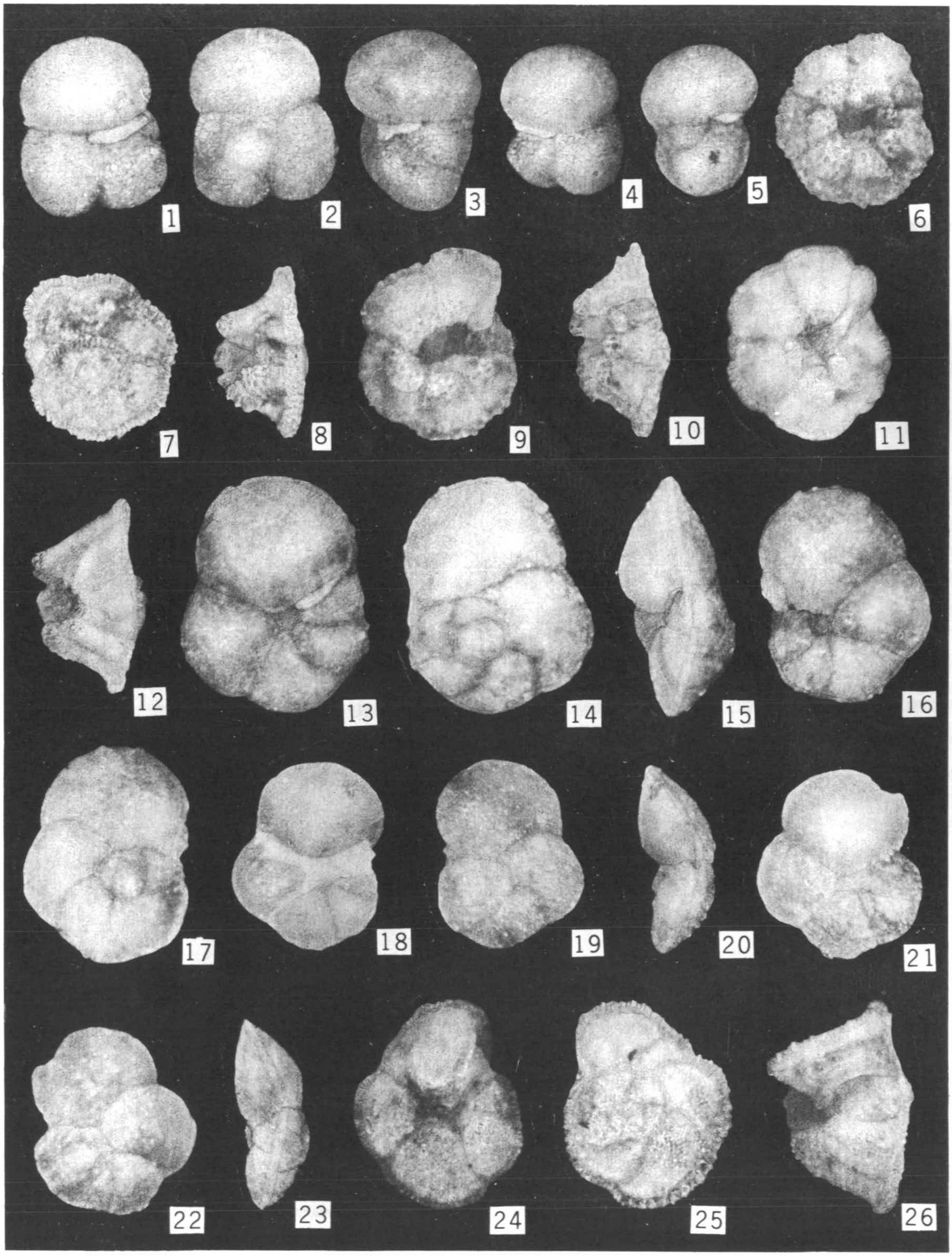
McGowran (1964; 1965) has described Paleocene faunas from Western Australia and Victoria. Of the faunas recorded by McGowran, the Papua-New Guinea assemblages are similar to that from the Rivernook Member of the Dilwyn Clay in western Victoria, which McGowran (1965) referred to the upper part of the *Globorotalia pseudomenardii* Subzone. Paleocene foraminifera were recorded by Visser & Hermes (1962) from the then Netherlands New Guinea (now West Irian). The stratigraphical interval represented seems to be much the same as that covered by the present sections. Only two species were determined by Visser & Hermes: *Globorotalia velascoensis* and *G.* cf. *membranacea.* Bolli (1957) introduced the new name *G. ehrenbergi* for the *G. membranacea* of authors (*non* Ehrenberg). The specimen figured by Hermes & Visser does not resemble *G. ehrenbergi,* being more elongate and biconvex and more strongly keeled. It closely resembles published figures of *G. pseudomenardii* and is most probably referable to this species. It seems that the beds discussed by Visser & Hermes may also be placed in the *G. pseudomenardii* Subzone.

SAMPLE LOCALITIES

1. F275 on the Lagaip River, about 14 miles south-east of Laiagam.
2. F342 near the Andebare River, about 24 miles west-south-west of Laiagam.
3. Section on Andebare River, south-west of Laiagam.
    (a) F900.
    (b) F901.
    (c) F902.
    (d) F903.
    (e) F904.
    (f) F905.
    (g) F906.
    (h) F907.
    (i) F908.
    (j) F909.
    (k) F910.
    (l) F911.
    (m) F912.
4. Section at Tibinini, west-north-west of Laiagam.
    (a) F913.
    (b) F914.
    (c) F915.
    (d) F916.
    (e) F917.
    (f) F918.
5. Cape Vogel area, sample 18.

PLATE 1

Figures		
1-5	*Subbotina triloculinoides* (Plummer). .... 1-3, CPC 7194; 1, ventral view; 2, dorsal view; 3, edge view; all x62. 4-5, CPC 7195; 4, ventral view; 5, edge view; both x62.	Page 7
6-12	*Globorotalia velascoensis velascoensis* (Cushman). .... 6-8, CPC 7196; 6, ventral view; 7, dorsal view; 8, edge view; all x60. 9-10, CPC 7197; 9, ventral view; 10, edge view; both x60. 11-12, CPC 7198; 11, ventral view; 12, edge view; both x60.	Page 11
13-23	*Globorotalia pseudomenardii* Bolli. .... 13-15, CPC 7199; 13, ventral view; 14, dorsal view; 15, edge view; all x100. 16-17, CPC 7200; 16, ventral view; 17, dorsal view; both x100. 18-20, CPC 7201; 18, ventral view; 19, dorsal view; 20, edge view; all x65. 21-23, CPC 7202; 21, ventral view; 22, dorsal view; 23, edge view; all x65.	Page 10
24-26	*Globorotalia* sp. cf. *G. angulata* (White). .... CPC 7203; 24, ventral view; 25, dorsal view; 26, edge view; all x98.	Page 15



Paleocene planktonic Foraminifera

PLATE 2

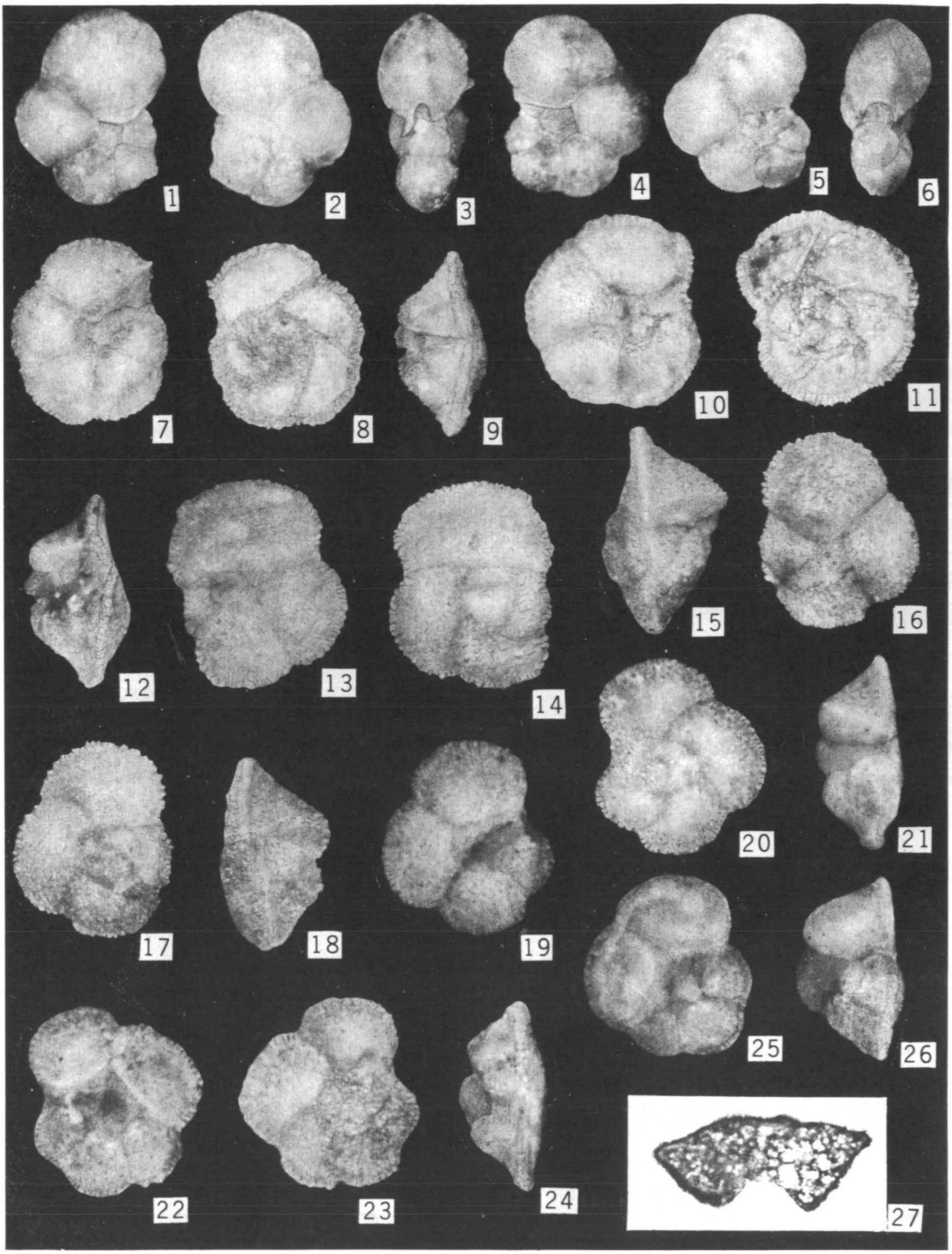
Figures

1-6 *Globorotalia chapmani* Parr. .... Page 12
1-3, CPC 7204; 1, ventral view; 2, dorsal view; 3, edge view; all x98.
4-6, CPC 7205; 4, ventral view; 5, dorsal view; 6, edge view; all x98.

7-12 *Globorotalia velascoensis occlusa* Loeblich & Tappan. .... Page 12
7-9, CPC 7206; 7, ventral view; 8, dorsal view; 9, edge view; all x62.
10-12, CPC 7207; 10, ventral view; 11, dorsal view; 12, edge view; all x75.

13-18 *Globorotalia aequa* Cushman & Renz. .... Page 13
13-15, CPC 7208; 13, ventral view; 14, dorsal view; 15, edge view; all x64.
16-18, CPC 7209; 16, ventral view; 17, dorsal view; 18, edge view; all x64.

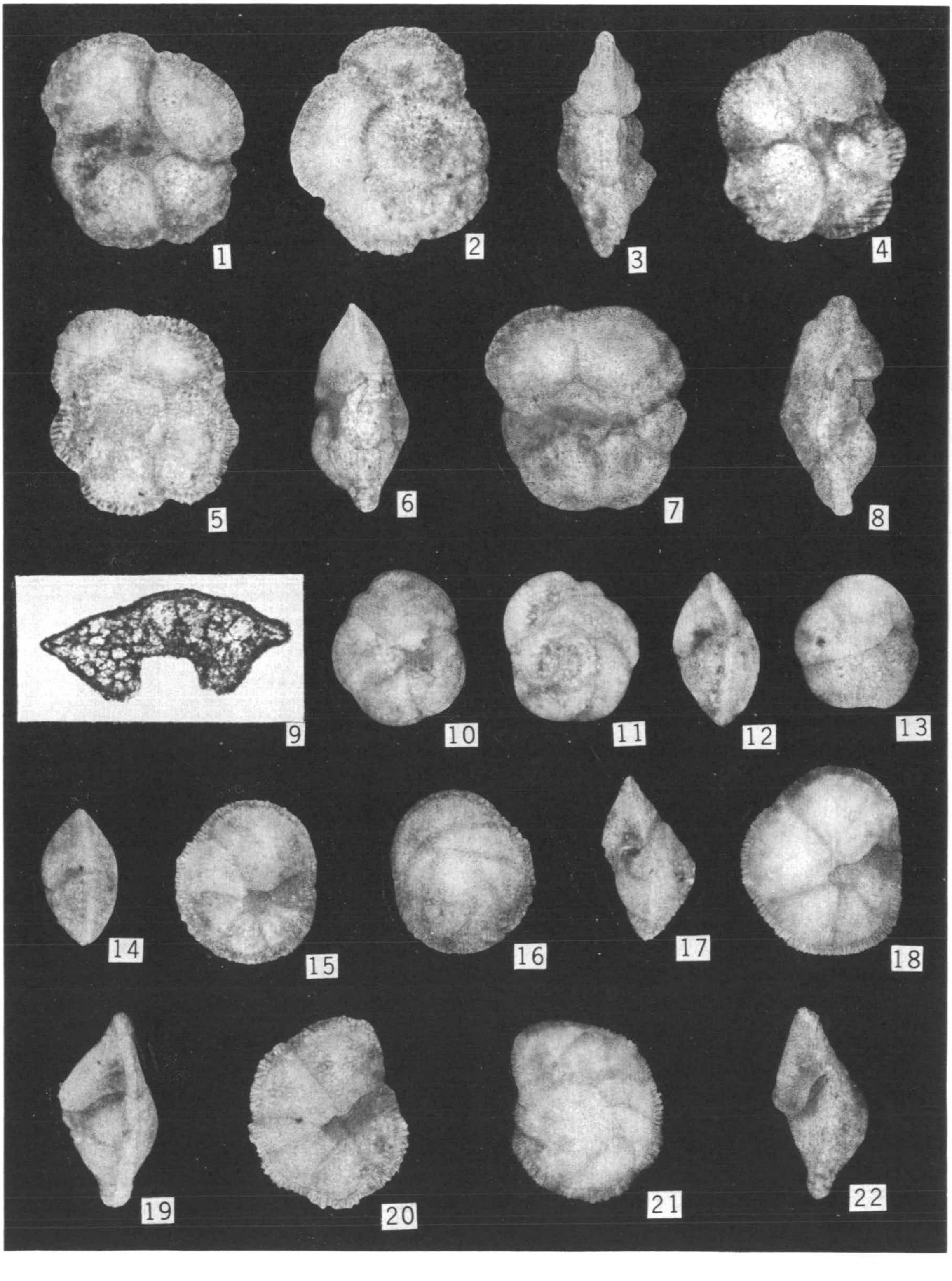
19-27 *Globorotalia* sp. cf. *G. kolchidica* Morozova. .... Page 16
19-21, CPC 7210; 19, ventral view; 20, dorsal view; 21, edge view; all x60.
22-24, CPC 7211; 22, ventral view; 23, dorsal view; 24, edge view; all x60.
25-26, CPC 7212; 25, ventral view; 26, edge view; both x60.
27, vertical section, CPC 7213; x65.



Paleocene planktonic Foraminifera

PLATE 3

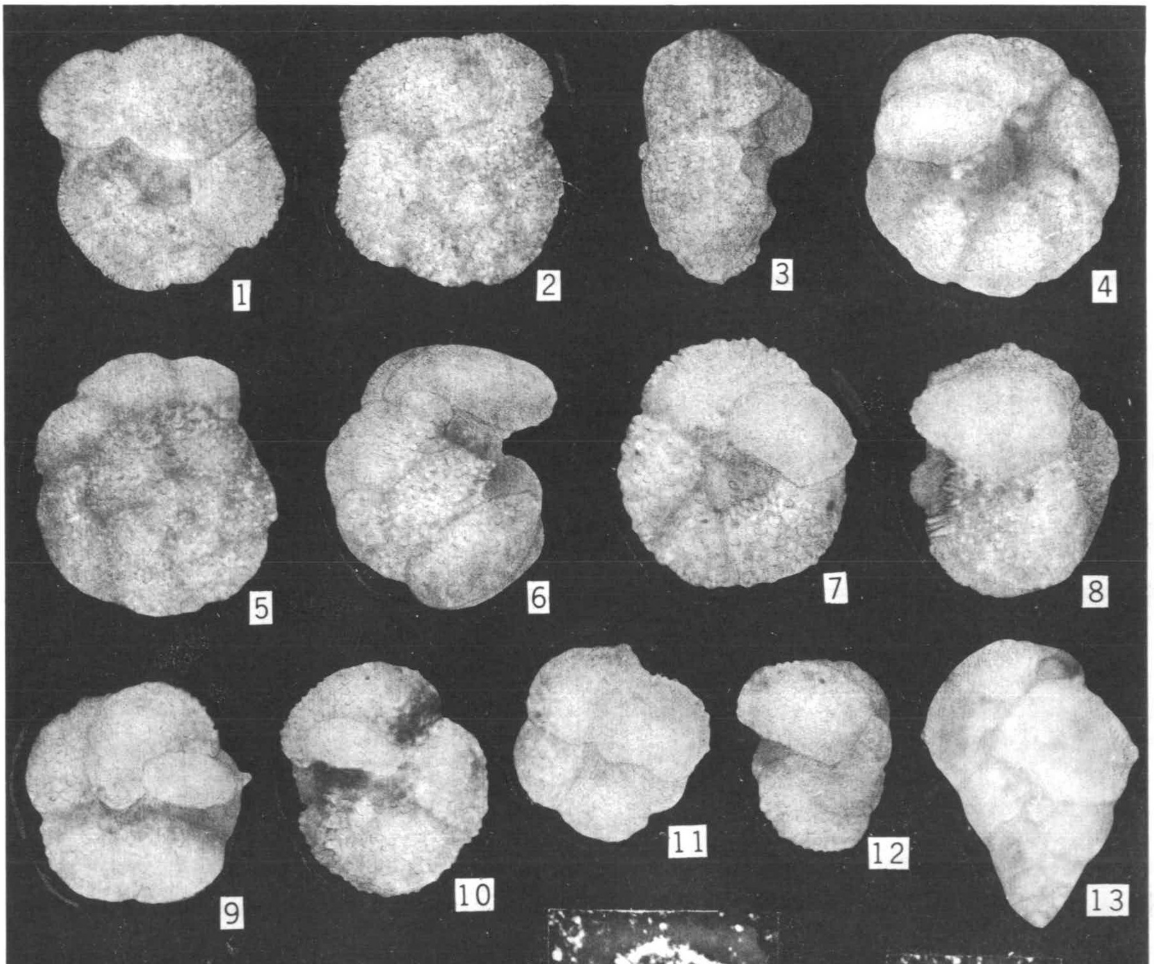
Figures		
1-9	*Globorotalia pasionensis* (Bermudez). .... 1-3, CPC 7214; 1, ventral view; 2, dorsal view; 3, edge view; all x54. 4-6, CPC 7215; 4, ventral view; 5, dorsal view; 6, edge view; all x54. 7-8, CPC 7216; 7, ventral view; 8, edge view; both x54. 9, vertical section, CPC 7217; x65.	Page 15
10-14	*Globorotalia pusilla pusilla* Bolli. .... 10-12, CPC 7218; 10, ventral view; 11, dorsal view; 12, edge view; all x116. 13-14, CPC 7219; 13, ventral view; 14, edge view; both x116.	Page 14
15-22	*Globorotalia* sp. .... 15-17, CPC 7220; 15, ventral view; 16, dorsal view; 17, edge view; all x98. 18-19, CPC 7221; 18, ventral view; 19, edge view, both x98. 20-22, CPC 7222; 20, ventral view; 21, dorsal view; 22, edge view; all x98.	Page 17



Paleocene planktonic Foraminifera

PLATE 4

Figures		
1-3	*Globorotalia* sp. cf. *G. apanthesma* Loeblich & Tappan CPC 7223; 1 ventral view; 2, dorsal view; 3, edge view; all x93.	Page 14
4-12	*Globigerina mckannai* White. 4-6, CPC 7224; 4, ventral view; 5, dorsal view; 6, edge view; all x93. 7-8, CPC 7225; 7, ventral view; 8, edge view; both x93. 9-10, CPC 7226; 9, ventral view; 10, edge view; both x93. 11-12, CPC 7227; 11, ventral view; 12, edge view; both x93.	Page 9
13-15	*Chiloguembelina crinita* (Glaessner). 13-14, CPC 7228, 13, side view; 14, edge view; both x167. 15, CPC 7229, side view; x167.	Page 17
16-23	*Globigerina* and *Globorotalia* in thin sections of limestones 16-17, section CPC 7230, locality 1; x55. 18-19, section CPC 7231, locality 4a; x55. 20, 22, section CPC 7232, locality 4e; x55. 21, 23, section CPC 7233, locality 4e; x55.	



Paleocene planktonic Foraminifera

BIBLIOGRAPHY

BECKMAN, J. P., 1957—*Chiloguembelina* Loeblich and Tappan and related Foraminifera from the Lower Tertiary of Trinidad, B.W.I. *Bull. U.S. nat. Mus.*, 215, 83-95.

BERGGREN, W. A., 1960—Some planktonic Foraminifera from the Lower Eocene (Ypresian) of Denmark and North-western Germany. *Stockholm Contr. Geol.*, 5, 41-108.

BERGGREN, W. A., 1963—Some problems of Paleocene stratigraphic correlation. *Rev. Inst. franç. Pétrole*, 18(10), 134-143.

BERGGREN, W. A., 1964—Biostratigraphy of the Paleocene-Lower Eocene of Luxor and nearby Western Desert. *Petrol. Explor. Soc. Libya, 6th Ann. Field Confer.*, 149-176.

BERGGREN, W. A., 1965a—The recognition of the *Globorotalia uncinata* Zone (Lower Paleocene) in the Gulf Coast. *Micropaleontology*, 11(1), 111-113.

BERGGREN, W. A., 1965b—Some problems of Paleocene - Lower Eocene planktonic foraminiferal correlations. *Micropaleontology*, 11(3), 278-300.

BERGGREN, W. A., 1965c—Paleocene — a micropaleontologist's point of view. *Bull. Amer. Ass. Petrol. Geol.*, 49(9), 1473-1484.

BERMUDEZ, P. J., 1961—Contribucion al estudio de las Globigerinidea de la region Caribe-Antillana (Paleoceno-Reciente). *Mem. 3rd Cong. Geol. Venez., Bol. Geol.* 3, *publ. espec.* 3, 1.119-1.393.

BOLLI, H., 1957—The genera *Globigerina* and *Globorotalia* in the Paleocene - Lower Eocene Lizard Springs Formation of Trinidad, B.W.I. *Bull. U.S. nat. Mus.*, 215, 61-81.

BOLLI, H. M., and CITA, Maria B., 1960—Globigerine e Globorotalie del Paleocene di Paderno d'Adda (Italia). *Riv. ital. Paleont.*, 66(3), 361-402.

BRONNIMANN, P., 1952—Trinidad Paleocene and lower Eocene Globigerinidae. *Bull. amer. Paleont.*, 34 (143).

BROTZEN, F., and POZARYSKA, K., 1961—Foraminifères du Paléocene et de l'Eocène inférieur en Pologne septentrionale; remarques paléogéographiques. *Rev. Micropaleont.*, 4(3), 155-166.

CUSHMAN, J. A., 1925—Some new Foraminifera from the Velasco Shale of Mexico. *Contr. Cushman Lab.*, 1(1), 18-22.

CUSHMAN, J. A., 1927—An outline of a reclassification of the Foraminifera. *Contrib. Cushman Lab.*, 3(1), 1-105.

CUSHMAN, J. A., and BERMUDEZ, P. J., 1949—Some Cuban species of *Globorotalia*. *Ibid.*, 25(2), 26-45.

CUSHMAN, J. A., and RENZ, H. H., 1942—Eocene, Midway, Foraminifera from Soldada Rock, Trinidad. *Ibid.*, 18(1), 1-14.

DEKKER, F. E., and FAULKS, I. G., 1964—The geology of the Wabag area, New Guinea. *Bur. Miner. Resour. Aust. Rec.* 1964/137 (unpubl.).

Page 30 is blank.

GARTNER, S., Jr, and HAY, W. W., 1962—Planktonic Foraminifera from the type Ilerdian. *Ecl. geol. helv.*, 55(2), 554-572.

GLAESSNER, M. F., 1937—Studien über Foraminiferen aus der Kreide und dem Tertiär des Kaukasus. I. Foraminiferen der ältesten Tertïarschichten der Nordwest-Kaukasus. *Prob. Paleont., Moscow Univ.*, 2-3, 349-408.

HILLEBRANDT, A. VON, 1962—Das Paleozän und seine Foraminiferenfauna im Becken von Reichenhall und Salzburg. *Abh. bayer. Akad. Wiss., math.-naturw. Kl.*, 108, 1-182.

HINTE, J. E., VAN, 1963—Zur Stratigraphie und Mikropaläontologie der Oberkreide und des Eozäns des Krappfeldes (Kärnten). *Jb. Geol., Bd A.*, 8, 1-147.

HORNIBROOK, N. DE B., 1958—New Zealand foraminifera: key species in stratigraphy—No. 6. *N.Z. J. Geol. Geophys.*, 1(4), 653-676.

LOEBLICH, A. R., Jr, and TAPPAN, Helen, 1956—*Chiloguembelina*, a new Tertiary genus of the Heterohelicidae (Foraminifera). *J. Washington Acad. Sci.*, 46 (11), 340.

LOEBLICH, A. R., Jr, and TAPPAN, Helen, 1957a—Planktonic Foraminifera of Paleocene and early Eocene age from the Gulf and Atlantic coastal plains. *Bull. U.S. nat. Mus.*, 215, 173-198.

LOEBLICH, A. R., Jr, and TAPPAN, Helen, 1957b—Correlation of the Gulf and Atlantic Coastal Plain Paleocene and Lower Eocene formations by means of planktonic Foraminifera. *J. Paleont.*, 31(b), 1109-1137.

LUTERBACHER, H. P., 1964—Studies in some *Globorotalia* from the Paleocene and Lower Eocene of the central Apennines. *Ecl. geol. helv.*, 57(2), 631-730.

LUTERBACHER, H. P., and PREMOLI SILVA, Isabella, 1964—Biostratigrafia del limite Cretaceo-Terziario nell'Appennino centrale. *Riv. ital. Paleont.*, 70(1), 67-128.

MCGOWRAN, B., 1964—Foraminiferal evidence for the Paleocene age of the King's Park Shale (Perth Basin, Western Australia). *J. Roy. Soc. W. Aust.*, 47(3), 81-86.

MCGOWRAN, B., 1965—Two Paleocene foraminiferal faunas from the Wangerrip Group, Pebble Point coastal section, Western Victoria. *Proc. Roy. Soc. Vic.*, 79(1), 9-74.

MOROZOVA, V. G., 1961—Planktonic Foraminifera from the Danian-Montain of the Southern U.S.S.R. *Paleont. J. Akad. Nauk SSSR*, 1/2, 8-19. (In Russian).

ORBIGNY, A. D. D', 1826—Tableau méthodique de la classe des Céphalopodes. *Ann. Sci. nat. Paris*, 1(7), 245-314.

PARKER, Frances L., 1962—Planktonic foraminiferal species in Pacific sediments. *Micropaleontology*, 8(2), 219-254.

PARR, W. J., 1938—Upper Eocene foraminifera from deep borings in King's Park, Perth, Western Australia. *J. Roy. Soc. W. Aust.*, 24, 69-101.

PLUMMER, Helen J., 1926—Foraminifera of the Midway Formation in Texas. *Bull. Univ. Texas Bur. econ. Geol.*, 2644, 1-206.

SAID, R., 1960—Planktonic Foraminifera from the Thebes Formation, Luxor, Egypt. *Micropaleontology*, 6(3), 277-286.

STOLK, J., 1965—Contribution à l'étude des correlations microfauniques de Tertiaire inférieur de la Nigérie méridionale. *Mem. Bur. Rech. geol. min.*, 32, 247-276.

TROELSEN, J. C., 1957—Some planktonic Foraminifera of the type Danian and their stratigraphic importance. *Bull. amer. Paleont.*, 215, 125-131.

VISSER, W. A., and HERMES, J. J., 1962—Geological results of the exploration for oil in Netherlands New Guinea. *Netherlands Government.*

WHITE, M. P., 1928—Some index Foraminifera of the Tampico embayment area of Mexico. *J. Paleont.*, 2(3), 177-215.

ADDITIONAL MIOCENE AND PLIOCENE PLANKTONIC FORAMINIFERA FROM PAPUA AND NEW GUINEA

by D. J. Belford*

SUMMARY

Three additional species of planktonic foraminifera, *Globorotalia crassaformis* (Galloway & Wissler), *G. archaeomenardii* Bolli, and *Sphaeroidinellopsis kochi* (Caudri), are recorded and figured from Papua-New Guinea. The possible development of the species *Sphaeroidinella dehiscens* (Parker & Jones) as an ecophenotypic variant of other species is discussed; the generic names *Sphaeroidinella* and *Sphaeroidinellopsis* are retained. The bulla in planktonic foraminifera is discussed and the opinion that it is not a feature of taxonomic significance is maintained.

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INTRODUCTION

Thirty-four species of planktonic foraminifera from Papua and New Guinea were recorded in a previous paper (Belford, 1962); three species not included in that study are now figured. Little is known about the stratigraphical distribution of the species, but where possible the known occurrence as contained in unpublished reports of the Australasian Petroleum Company Pty Ltd has been given. The sample locality numbers refer to the list of samples given in Belford (1966); this publication also has sample locality maps.

All figured specimens and thin sections are deposited in the Commonwealth Palaeontological Collection, Canberra, Australia.

SYSTEMATIC DESCRIPTIONS

Genus GLOBOROTALIA Cushman, 1927

GLOBOROTALIA CRASSAFORMIS (Galloway & Wissler, 1927)

(Pl. 5, figs 1-5)

1927 *Globigerina crassaformis* Galloway & Wissler, p. 41, pl. 7, fig. 12.
1962 *Globorotalia crassaformis* (Galloway & Wissler); Parker, p. 235, pl. 4, figs 17a-c, 18a-c, 20a-c, 21a-c. (Synonymy).
1964 *Globorotalia punctulata* (d'Orbigny); Todd, p. 1095, pl. 239, figs 1a-c. (Synonymy).

Material examined: 87 specimens.

G. crassaformis appears to be the correct name for these specimens; the confusion in nomenclature has been discussed particularly by Phleger, Parker, & Peirson (1953) and Parker (1962). Takayanagi & Saito (1962, pl. 27, figs 11a-b, 12a-c) illustrated specimens referred by them to *G.* cf. *oceanica* which are very similar to those from Papua-New Guinea.

Dimensions of figured specimens (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7234	0.57	0.51	0.42
CPC 7235	0.56	0.48	0.42

Occurrence: Figured specimens CPC 7234 and 7235 from a sample 2 miles east of Josefstaal, Lower Ramu-Atitau area, New Guinea (locality 38, upper Miocene); other localities: 16a, 16i, 18, 21, 23, 25, 28, 33, 35.

Specimens here referred to *G. crassaformis* have been recorded as *G. crassula* Cushman & R. E. Stewart, ranging from lower Miocene (Burdigalian) to Pliocene.

GLOBOROTALIA ARCHEOMENARDII Bolli, 1957

(Pl. 5, figs 6-8)

1957 *Globorotalia archeomenardii* Bolli, p. 119, pl. 28, figs 11a-c.

Material examined: 12 specimens.

Rare specimens, found at only one locality, are referred to *G. archeomenardii.* They agree well with the description of this species given by Bolli (1957), having 5 chambers visible from the ventral side, a convex dorsal surface, curved dorsal sutures, and radial to slightly curved depressed ventral sutures. They differ in the total number of chambers, which ranges from 15 to 17, as against 12 to 15 given by Bolli.

Dimensions of figured specimen (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7236	0.40	0.33	0.19

Occurrence: Figured specimen from a sample on the sea-cliff 250 yards north of the L.M.S. Mission, Delena, Papua (locality 3, lower Miocene, Burdigalian); known only from this sample.

G. archeomenardii has not previously been recorded from Papua-New Guinea; specimens of the type here referred to *G. archeomenardii* may have been included in the records of *G. menardii* (=*G. cultrata*).

Genus SPHAEROIDINELLOPSIS Banner & Blow, 1959

Bé (1965) considered the species *Sphaeroidinella dehiscens* (Parker & Jones) to be an aberrant, ecophenotypic varient of *Globigerinoides sacculifer* (Brady) and by inference regarded *Sphaeroidinella* as an artificial genus. This conclusion was also applied to the genus *Sphaeroidinellopsis.* He stated: '*S. dehiscens* stripped of its cortex and chamber flanges would be indistinguishable from *G. sacculifer*', emphasis was also placed on the fact that the smooth cortex of *S. dehiscens* is only a surficial feature. Bé referred to *S. dehiscens* as a terminal stage of *G. sacculifer,* but also noted a size gradation from about 200 microns to 1000 microns in *dehiscens* and concluded that the '*dehiscens*' stage may be developed by small as well as large *sacculifer* individuals.

Bandy, Ingle, & Frerichs (1965) regarded *Sphaeroidinella* as a morphotypic derivative of different species of planktonic foraminifera, but stated that *Sphaeroidinellopsis* may be a valid genus originating from a species of *Globigerina. Sphaeroidinella* is said to have developed by the addition of a thick cortex to specimens of *Globigerinoides triloba sacculifera, G. conglobata,* and possibly other species.

Several references have been made to the occurrence of thick-shelled specimens of planktonic foraminifera occurring in deeper water, for example by Bé (1960), Bé & Ericson (1963), and Bé & Lott (1964). *Globorotalia truncatulinoides* has been the species most studied, and the 'secondary thickening' of the test is stated to occur at a late ontogenetic stage. The genus *Orbulina* can also develop a thick multilamellar test by the addition of successive layers to the original spherical test. These thick-walled specimens also seem to occur in deeper water; Bronnimann (1951) referred to the possibility of such individuals becoming benthonic, but this needs to be verified. Brady (1884) referred to bottom specimens of *Orbulina,* but although it may be inferred that living specimens were meant, this was not definitely stated. Loeblich & Tappan (1964) mentioned a paper by Le Calvez (1936), who postulated that benthonic and planktonic stages may alternate in *Orbulina,* but again this needs to be verified. In *Orbulina* the thickening begins at a late ontogenetic stage: the successive laminae are added to the adult globular chamber. The wall of *Sphaeroidinella* is considered to be secondarily thickened; however, the smooth cortex develops on specimens with a diameter of 200 microns, which is not a late ontogenetic stage. It is apparent that the cortex began to form before the final chamber was added; in thin sections that I have prepared the test wall is much thicker on the early than on the late chambers. I have not been able to observe the three layers in the wall distinguished by Blow (1959).

Thickening of the wall of *Globorotalia truncatulinoides, Orbulina universa,* and other species does not cause any major change in appearance of the test. In contrast, the suggested origin of *Sphaeroidinella dehiscens* from *Globigerinoides sacculifer* by thickening of the test wall causes such a change in appearance that no part of the original *sacculifer* test is recognizable. Bé's statement that *Sphaeroidinella dehiscens* without the cortex would be indistinguishable from *Globigerinoides sacculifer* is not supported by examination of specimens available to me. In samples from Papua-New Guinea and from Portuguese Timor I have observed decorticated specimens of both *Sphaeroidinella dehiscens* and *Sphaeroidinellopsis subdehiscens;* the initial chambers of these two species differ very little in appearance, and consist of a coarsely reticulate *Globigerina* stage, with no resemblance to accompanying specimens of *Globigerinoides sacculifer.* Although adult tests of *Sphaeroidinella dehiscens* do have two apertures the earlier chambers do not have the additional dorsal apertures of *Globigerinoides.*

Bandy, Ingle, & Frerichs (1965) stated that *Sphaeroidinellopsis* of the Miocene did not give rise to *'Sphaeroidinella'* of the Pliocene. Samples from Papua-New Guinea which I have examined make it difficult to reach any but the contrary conclusion. The smallest specimens found have only one aperture and are referable to *S. seminulina* (Schwager) and *S. subdehiscens* (Blow); they range in size from 0.30 mm to 0.37 mm. Specimens forming a second group are indistinguishable only by a small supplementary aperture, and a small flange on the primary aperture in some specimens; they range in size from 0.35 mm to 0.45 mm. The largest specimens, ranging in size from 0.52 mm to 0.71 mm, are those showing the characteristics of 'typical' *S. dehiscens,* with large primary and supplementary apertures, and wide imperforate flanges. The samples in which these specimens are found are regarded as upper Miocene. Samples of lower to middle Miocene age contain only specimens of *Sphaeroidinellopsis,* suggesting that the appearance of *Sphaeroidinella* is an evolutionary development, apparently in the upper Miocene.

There are different opinions on when *Sphaeroidinella dehiscens* appeared in the geological column. Blow (1959) made a subspecific distinction between Miocene specimens of *Sphaeroidinella* and 'typical' *S. dehiscens;* the Miocene specimens placed by Blow in *Sphaeroidinella* are now referred to *Sphaeroidinellopsis.* Bandy (1964) recognized a *Sphaeroidinella dehiscens* Datum at the base of the Pliocene, and Bandy, Ingle, & Frerichs (1965) again referred to the *S. dehiscens* Datum, marked by the 'first good appearance' of this form. *S. dehiscens* occurs in samples from Papua-New Guinea which I regard as upper Miocene, and is recorded from the upper Miocene in unpublished reports of the Australasian Petroleum Company. Saito (1963) recorded *S. dehiscens* as first appearing in the *Globorotalia menardii menardii/Globigerina nepenthes* Zone, which was referred to the Tortonian, but stated that it is not as common in the Miocene as in overlying formations. Although the time of first appearance of *S. dehiscens* has yet to be agreed, it is apparent that it appeared much later than any of the species from which it is said to have developed. This, as Bé (1965) said, is one difficulty to be overcome if *S. dehiscens* is in fact to be regarded as an ecophenotypic variant.

Sphaeroidinella dehiscens appears to have a more restricted equatorial distribution than *Globigerinoides sacculifer* or other species, although published records of its occurrence differ considerably. Bandy (1964) compiled a chart showing the distribution of several planktonic species; this shows *Sphaeroidinella dehiscens* restricted to a belt between 10° North and 10° South latitude. Bradshaw (1959) recorded *S. dehiscens* between 5° South and 15° North in the Pacific Ocean, but Parker (1962) reported it as occurring north of 40° South. Kustanowich (1963) recorded *S. dehiscens* to 30° South; this author (pers. comm.) regards *S. dehiscens* as diagnostic of the subequatorial and northern (not north-central) faunas. Bé (1965) recorded *S. dehiscens* from a plankton tow in the North Atlantic, at 37°42′ North, but referred to most of the specimens as morphological intergradations between *S. dehiscens* and *Globigerinoides sacculifer. G. sacculifer* was stated by Bé to extend to 50° North during the warmer months. Bandy also compiled a chart showing the approximate range of surface temperature for some planktonic species, indicating that *dehiscens* prefers somewhat warmer water than does *G. sacculifer.* This suggests that factors other than adaptation to increasingly deeper habitats are involved, and together with the apparently more restricted equatorial distribution is also an argument against the view that *S. dehiscens* is merely an ecophenotypic variant of other species.

Another point raised by Bé concerns the difficulty of distinguishing between juvenile *Globigerinoides sacculifer* and young specimens of *Sphaeroidinella dehiscens* that have not developed the cortex. In an earlier paper Bé (1959) noted several species-groups in which juveniles less than 150 microns in diameter often cannot be distinguished from each other, and one case in which specimens larger than 500 microns showed morphological intergradation; one species-group given by Bé was *Globigerinoides ruber* - *Globigerinoides sacculifer* - *Globigerinita glutinata.* Specimens of *Sphaeroidinella dehiscens* about 200 microns in diameter are known to have the outer cortex, and it seems that below this size limit *Globigerinoides sacculifer* could be confused with species other than *Sphaeroidinella dehiscens.*

These considerations lead me to regard *dehiscens* as a valid species. The question as to whether or not it is necessary to retain the generic names *Sphaeroidinella* and *Sphaeroidinellopsis* is another matter, but again I would retain them. This involves consideration of the development and recognition of 'higher categories' (see, for example, Simpson, 1953). In this connexion, it may be significant that Bé refers to the 'evolutionary development of the cortex' and the 'need to adapt to increasingly deeper habitats'. It is here suggested that *Sphaeroidinella* may well be an example of a higher category (genus) resulting from evolutionary development in response to occupation of a new adaptive zone.

SPHAEROIDINELLOPSIS KOCHI (Caudri, 1934)

(Pl. 5, figs 9-17)

1934	*Globigerina kochi* Caudri, p. 144.
1964	*Sphaeroidinella kochi* (Caudri): Todd, p. 1088, pl. 289, figs 5a-c, 6a-c. (Synonymy).
1966	*Sphaeroidinellopsis kochi* (Caudri); McTavish, pl. 7, figs 9-10.

Material examined: 27 specimens.

Specimens of *S. kochi* have been found at only two localities. Most specimens have the characteristic spinose area at the central part of the final chamber; several specimens develop a small final chamber more or less covering the aperture (Pl. 5, fig. 12) and one specimen has two such chambers (Pl. 5, fig. 14). These may be the same as the structures occurring on *Sphaeroidinella dehiscens* (Parker & Jones), regarded by Bolli, Loeblich, & Tappan (1957) as bullae, and by Banner & Blow (1959) as abnormally placed abortive chambers. Also referred here to *Sphaeroidinellopsis kochi* is one six-chambered specimen; it closely resembles the specimens figured by Todd (1964, pl. 289, figs 6a-c) and by McTavish (1966) and also that figured by Bolli (1957, pl. 26, figs 12a-c) as *Sphaeroidinella* cf. *grimsdalei* (Keijzer).

Dimensions of figured specimens (in mm):	*Maximum Diameter*	*Minimum Diameter*	*Height*
CPC 7237	0.53	0.46	0.37
CPC 7238	0.52	0.46	0.35
CPC 7239	0.46	0.44	0.37
CPC 7240	0.74	0.56	0.42

Occurrence: Figured specimens CPC 7237 to 7239 and thin section CPC 7241 from a sample east of the Ekiere Fault, Aipa Hills area, Papua (locality 8, middle Miocene); figured specimen CPC 7240 from a sample 1 mile south of the Kumil River, Lower Ramu-Atitau area, New Guinea (locality 42, upper Miocene); known only from these two localities.

Sphaeroidinellopsis kochi has been recorded as *Sphaeroidinella seminulina* (Schwager) var. *kochi,* but no information on its stratigraphic distribution is available.

COMMENTS ON THE BULLA IN PLANKTONIC FORAMINIFERA

In an earlier paper (Belford, 1962) I briefly discussed the bulla and its application to the classification of planktonic foraminifera, and stated 'I agree with Hofker that the bullae have no taxonomic significance, and that genera defined on this basis have no value'. Bé (1965) regarded this as 'the lumper's view held by Belford', but accepted the view that a division of species based on different types of bullae is artificial. I would also accept this and agree with the statement made by Parker (1962, p. 249), referred to by Bé. As pointed out by Parker, the structure of the test, apart from the bullae, is the same.

My objection to the use of the bulla in defining generic categories was, and is, based on three points: (a) the bulla is not a constant feature of any given population; for example, there are instances of the species *Globigerina glutinata* Egger being referred to the genus *Globigerinita* although in the assemblages examined no specimens with a bulla were observed; (b) the bulla is variable on those specimens on which it does occur; again referring to the species *Globigerina glutinata* I have seen assemblages in which the specimens could be referred to different genera depending on the nature of the bulla, if this criterion were strictly applied; (c) the bulla as a taxonomic feature is not used consistently—this point overlaps somewhat with (b). For example, specimens of the species *Globigerinoides conglobatus* (Brady) may have bullae over the primary and supplementary apertures, and these specimens satisfy requirements for inclusion in the genus *Globigerinoita* as originally defined. Such a division of the specimens is obviously artificial.

Takayanagi & Saito (1962) independently reached conclusions similar to mine, stating 'The present authors believe the bulla to be an inconsistent character for definition of specific as well as generic categories'; for the purposes of qualitative analysis they separated the specimens with a bulla as a variety of no taxonomic value. Bandy (1960) also believed that the bulla should not be used for establishing generic categories. Lipps (1964) considered the bulla to be 'taxonomically unimportant at the suprageneric level'.

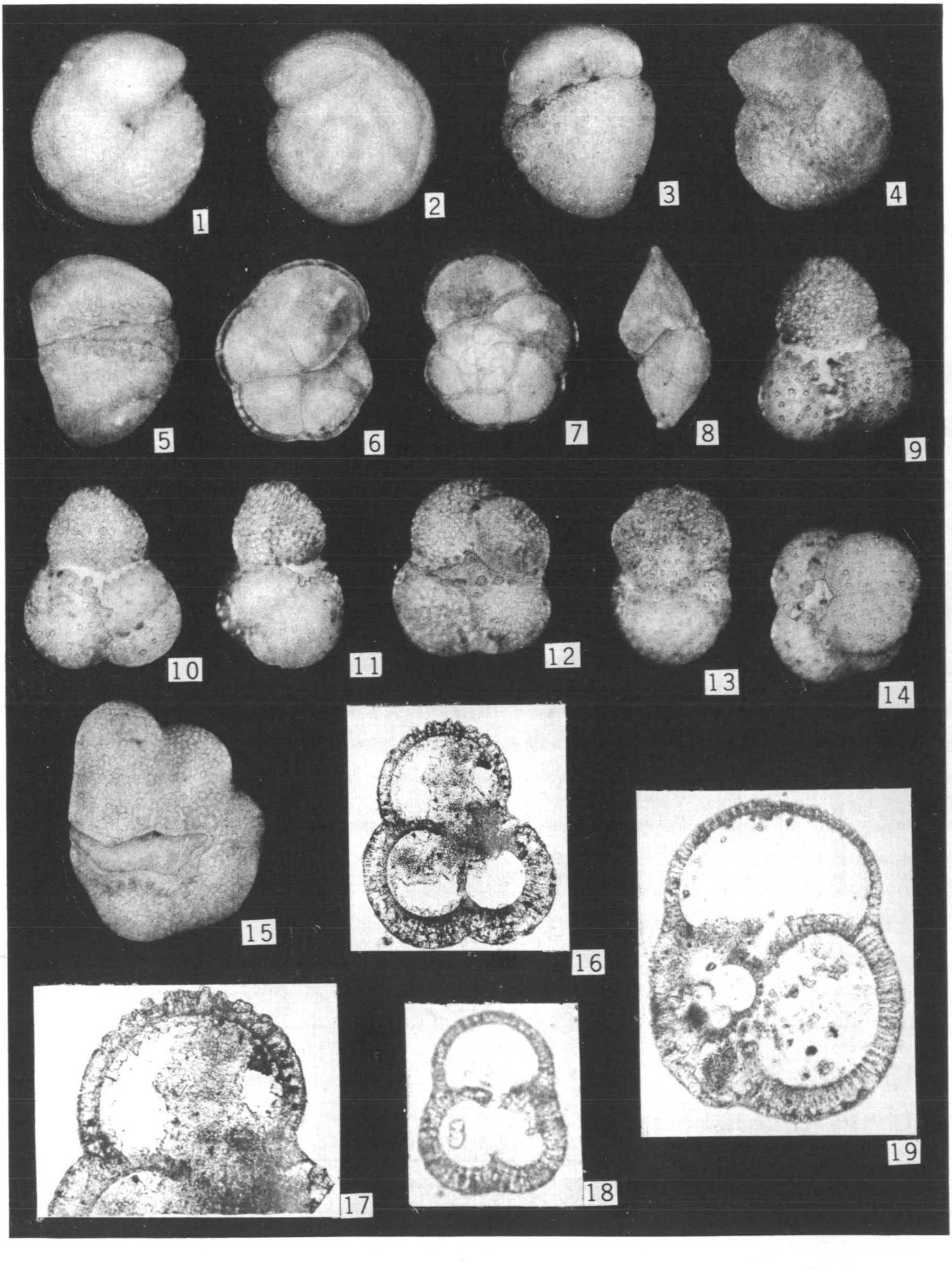
Parker (1962) retained the genus *Globigerinita,* but considered the character of the test wall to be an important feature and stated that the genus was not defined primarily on the presence of bullae. That Parker does not regard the bulla as an important taxonomic feature may be inferred from the fact that she placed *Globigerinoita* Bronnimann in the synonymy of *Globigerinoides* Cushman, basing this conclusion on the hispid wall of species referred to both genera, and the fact that bullae occur 'to a greater or lesser extent' in all Recent species. Previously (Belford, 1962, p. 12) I noted a connexion between specimens of *Globigerina glutinata* with supplementary apertures and bullae and the genera *Globigerinoides* and *Globigerinoita.* The sentence referred to contains a typing error and should read 'There is thus in these specimens a connexion with the genera *Globigerinoides* and *Globigerinoita'.* If the wall structure is to be regarded as an important classificatory feature then the genera *Globigerinita* and *Globigerinoides* (including *Globigerinoita*) are not closely related; however, this would again emphasize that the bulla is not a taxonomic feature restricted to any one group, or closely related groups, of planktonic foraminifera.

Bé (1965) referred to the bulla as a 'terminal growth feature'; this, if so, would invalidate the opinion that the bulla is a reproductive feature, as maintained, for example, by Hofker (1959). Parker (1962) regarded this as an unlikely function of the bulla, since it occurs on both young and adult specimens; we must conclude that the physiological or other function of the bulla is unknown. However, the fact that it occurs on young specimens indicates that it is not a final growth feature. I have examined Recent specimens of *Globigerina glutinata* from a bottom sample (50 fathoms) in the Timor Sea, at 10°17.5'S., 127°17'E., collected by HMAS Warrego; about half of them have a bulla. They range from specimens with 9 chambers and a maximum diameter of 0.17 mm to specimens with 12 chambers and a maximum diameter of 0.32 mm; those without a bulla range from 0.19 mm to 0.28 mm in maximum diameter, with 10 to 12 chambers.

The use of the bulla in planktonic foraminiferal taxonomy has now been criticized at all taxonomic levels from subspecific to suprageneric. I am still of the opinion that it is not a feature of taxonomic significance; to accommodate the full range of published opinion my former comment referring to generic categories should be modified to state that the bulla is taxonomically valueless at *any* level.

PLATE 5

Figures	
1-5	*Globorotalia crassaformis* (Galloway & Wissler). .... Page 37 1-3, CPC 7234; 1, ventral view; 2, dorsal view; 3, edge view; all x57. 4-5, CPC 7235; 4, ventral view; 5, edge view; both x57.
6-8	*Globorotalia archeomenardii* Bolli. .... Page 38 CPC 7236; 6, ventral view; 7, dorsal view; 8, edge view; all x78.
9-17	*Sphaeroidinellopsis kochi* (Caudri) .... Page 41 9-11, CPC 7237; 9, ventral view; 10, dorsal view; 11, edge view; all x57. 12-13, CPC 7238; 12, ventral view; 13, edge view; both x57. 14, CPC 7239, ventral view; x57. 15, CPC 7240, ventral view; x57. 16-17, thin section, CPC 7241, showing thick cortex on early chambers, thin cortex on last chamber, and spines extending beyond cortex on last chamber. 16, x66; 17, x110.
18	*Sphaeroidinellopsis subdehiscens* (Blow) .... Page 39 Thin section, CPC 7242, locality 7b, showing development of cortex on earlier chambers and last chamber; x66.
19	*Sphaeroidinella dehiscens* (Parker & Jones) .... Page 39 Thin section, CPC 7243, locality 39, showing development of cortex on earlier chamber and last chamber; x66.



Miocene-Pliocene planktonic Foraminifera

BIBLIOGRAPHY

BANDY, O. L., 1960—Planktonic foraminiferal criteria for paleoclimatic zonation. *Sci. Reps. Tokoku Univ., 2nd Ser. (Geol.), spec. Vol.* 4, 1-8.

BANNER, F. T., and BLOW, W. H., 1959—The classification and stratigraphical distribution of the Globigerinaceae. *Palaeontology,* 2(1), 1-27.

BE, A. W. H., 1959—Ecology of Recent planktonic Foraminifera: Part I—Areal distribution in the western North Atlantic. *Micropaleontology,* 5(1), 77-100.

BE, A. W. H., 1965—The influence of depth on shell growth in *Globigerinoides sacculifer* (Brady). *Micropaleontology,* 11(1), 81-97.

BE, A. W. H., and ERICSON, D. B., 1963—Aspects of calcification in planktonic Foraminifera (Sarcodina). *Ann. N.Y. Acad. Sci.,* 109, art. 1, 65-81.

BE, A. W. H., and LOTT, L., 1964—Shell growth and structure of planktonic foraminifera. *Science,* 145 (3634), 823-824.

BELFORD, D. J., 1962—Miocene and Pliocene planktonic Foraminifera, Papua-New Guinea. *Bur. Miner. Resour. Aust. Bull.* 62, 3-50.

BELFORD, D. J., 1966—Miocene and Pliocene smaller Foraminifera from Papua and New Guinea. *Bur. Miner. Resour. Aust. Bull.* 79, i-iv, 1-306.

BOLLI, H. M., 1957—Planktonic Foraminifera from the Oligocene - Miocene Cipero and Lengua Formations of Trinidad, B.W.I. *Bull. U.S. nat. Mus.,* 215, 97-123.

BOLLI, H. M., LOEBLICH, A. R., Jr, and TAPPAN, Helen, 1957—Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae and Globotruncanidae. *Bull. U.S. nat. Mus.,* 215, 3-50.

BRADSHAW, J. S., 1959—Ecology of living planktonic Foraminifera in the north and equatorial Pacific Ocean. *Contr. Cushman Fdn,* 10(2), 25-64.

*CALVEZ, J. le, 1936—Modifications du test des Foraminifères pélagiques en rapport avec la reproduction: *Orbulina universa* d'Orb. et *Tretomphalus bulloides* d'Orb. *Ann. Protistologie,* 5, 125-133.

CAUDRI, C. M. B., 1934—TERTIARY DEPOSITS OF SOEMBA. *Amsterdam, H.J. Paris.*

CUSHMAN, J. A., 1927—An outline of a re-classification of the Foraminifera. *Contr. Cushman Lab.,* 3(1), 1-105.

GALLOWAY, J. J., and WISSLER, S. G., 1927—Pleistocene Foraminifera from the Lomita Quarry, Palos Verdes Hills, California. *J. Paleont.,* 1(1), 35-87.

HOFKER, J., 1959—On the splitting of *Globigerina. Contr. Cushman Fdn,* 10(1), 1-9.

LIPPS, J. H., 1964—Miocene planktonic Foraminifera from Newport Bay, California. *Tulane Studies in Geology,* 2(4), 109-133.

LOEBLICH, A. R., Jr, and TAPPAN, Helen, 1964—Protista 2. Sarcodina, chiefly 'Thecamoebians' and Foraminiferida. *Treatise on Invertebrate Paleontology,* Part C. XXXI + 900 pp. University of Kansas Press.

McTavish, R. A., 1966—Planktonic foraminifera from the Malaita Group, British Solomon Islands. *Micropaleontology,* 12(1), 1-36.

Parker, Frances L., 1962—Planktonic foraminiferal species in Pacific sediments. *Micropaleontology,* 8(2), 219-254.

Phleger, F. B., Parker, Frances L., and Peirson, Jean F., 1953—North Atlantic Foraminifera. *Reps. Swedish Deep-Sea Exped.,* 7(1), 3-122.

Simpson, G. G., 1953—THE MAJOR FEATURES OF EVOLUTION. *N.Y., Columbia University Press.*

Takayanagi, Y., and Saito, T., 1962—Planktonic Foraminifera from the Nobori Formation, Shikoku, Japan. *Sci. Reps. Tohoku Univ., 2nd Ser. (Geol.), spec. Vol.,* 5, 67-106.

Todd, Ruth, 1964—Planktonic Foraminifera from deep-sea cores off Eniwetok Atoll. *Prof. Pap. U.S. geol. Surv.,* 260-CC, 1067-1100.

OCCURRENCE OF THE GENUS **DRAFFANIA** CUMMINGS IN WESTERN AUSTRALIA

by D. J. Belford*

SUMMARY

Specimens referable to the genus *Draffania* Cummings have been found in core samples from the Bonaparte No. 1 and No. 2 wells, Western Australia; they are identified as the species *D. quasibiloba* Fomina, 1960.

INTRODUCTION

During examination of core samples from the Bonaparte No. 1 well, drilled on behalf of Alliance Oil Development Australia, N.L., in the Bonaparte Gulf Basin, Western Australia, numerous specimens referable to the genus *Draffania* Cummings, 1957, were found in core 6 (1840 feet to 1851 feet); most specimens occurred in a thin band of calcareous siltstone between 1842 feet and 1842 feet 4 inches. Later, a single specimen was found in core 11, Bonaparte No. 2 well, at a depth of 4931 feet. These two wells are shown on the accompanying locality map.

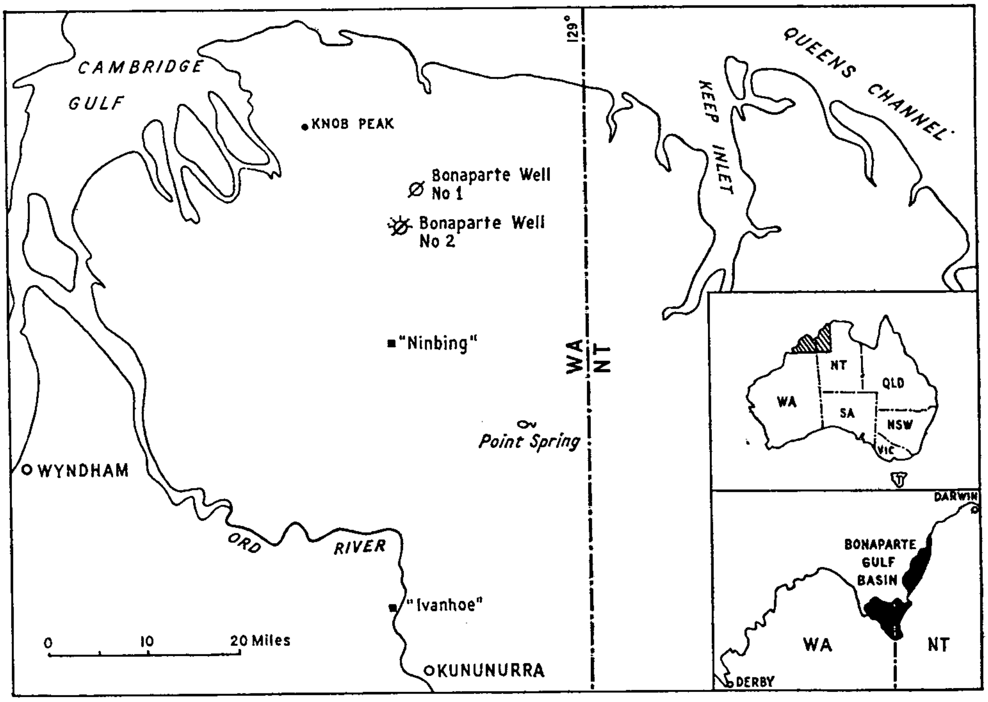


Fig. 1: Locality map showing position of Bonaparte No. 1 and 2 Wells.

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* Manuscript completed 28 March 1966.

The specimens have been identified as *Draffania quasibiloba* Fomina, 1960. I am indebted to Professor B. L. Mamet of the University of Brussels for information on this species, including its stratigraphic range, and also for comments on the age significance of the accompanying foraminiferal fauna; and to Dr R. H. Cummings of the Robertson Research Company Ltd for information on the stratigraphic range of *D. quasibiloba* in the British Lower Carboniferous.

All figured specimens and thin sections are deposited in the Commonwealth Palaeontological Collection, Canberra, Australia.

SYSTEMATIC DESCRIPTION

INCERTAE SEDIS

Genus DRAFFANIA Cummings, 1957

Type species: (by original designation) *Draffania biloba* Cummings, 1957, p. 407.

Type level: Lower Carboniferous (upper Visean). Shales above the Dockra Limestone, Lower Limestone Group.

Type locality: Draffan, near Lesmahagow, Lanarkshire, Scotland.

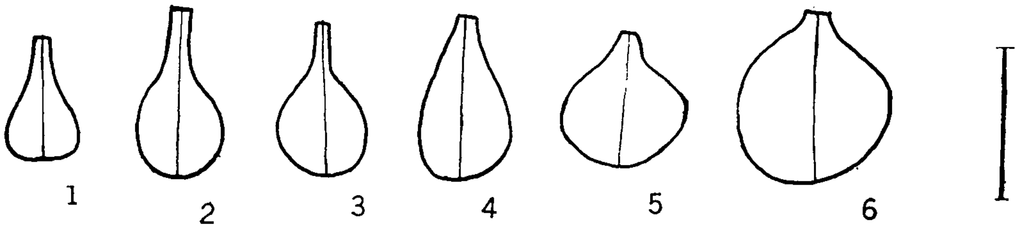
DRAFFANIA QUASIBILOBA Fomina, 1960

(Pl. 6, figs 1-8; Text-fig. 2)

1960 *Draffania quasibiloba* Fomina, p. 116, pl. 1, figs 9, 15-21.

Material examined: 27 specimens.

D. quasibiloba differs from *D. biloba* in its smaller size, relatively longer neck, and nature of the partition separating the two hemispherical chambers. Not all the sections prepared from the Western Australian specimens clearly show the nature of the dividing partition, but it has been shown to be double throughout, with communication between the two chambers at the base of the partition. The filamentous texture of the wall of the test, and of the dividing partition, is clearly shown. One section prepared (Pl. 6, fig. 8) shows a thick clear apparently imperforate inner lining to the chambers; this feature has not been reported previously from either of the two known species of *Draffania*. However, on the evidence of the Western Australian specimens, it is not a constant feature of the test. The thickness of the wall varies considerably, as may be seen from the illustrated thin sections. The one feature of *Draffania quasibiloba* as described by Fomina which is not shown by the Western Australian specimens is the flattening of one side of the test. The specimens are in general uniformly oval in section, with at the most only a slight flattening at one side. One section illustrated by Fomina (1960, pl. 1, fig. 19) shows the oval outline of most of the Western Australian specimens.



TEXT-FIGURE 2

Text-fig. 2. *Draffania quasibiloba* **Fomina, CPC 7266 to 7271, Camera-lucida outline drawings showing variations in the outline, size, and shape of the test; specimen 6 distorted. The scale indicates 0.5 mm.**

All specimens from core 6, Bonaparte No. 1 well, 1842 feet - 1842 feet 4 inches.

Measurements of Western Australian specimens identified as *Draffania quasibiloba* are given in the following table (all measurements in mm):

		Length of Test	*Width of Test*	*Length of Neck*	*Width of Neck at Aperture*	*Height of Chamber*	*Width of Chamber*	*Thickness of Wall*
1	(CPC 7262)* ..	0.56	0.42	0.12	0.05	0.37	0.17	0.033
2	(CPC 7263)* ..	0.53	0.37	0.15	0.04	0.35	0.15	0.041
3	(CPC 7264)* ..	0.51	0.35	0.16	0.05	0.32	0.13	0.016
4	(CPC 7265)* ..	—	0.41	—	—	—	0.14	0.041
5	Complete specimen	0.45	0.39	0.10	0.05	—	—	—
6	Complete specimen	0.55	0.52	0.09	0.07	—	—	—
7	Complete specimen	0.41	0.35	0.06	0.06	—	—	—
8	Complete specimen	0.46	0.31	0.07	0.05	—	—	—
9	Complete specimen	0.41	0.40	0.08	0.05	—	—	—
10	Complete specimen	0.48	0.28	0.16	0.03	—	—	—
11	Complete specimen	0.53	0.43	0.06	0.06	—	—	—
12	Complete specimen	0.48	0.30	0.15	0.04	—	—	—
13	Complete specimen	0.47	0.32	0.06	0.05	—	—	—
14	Complete specimen	0.39	0.22	0.15	0.03	—	—	—
15	Complete specimen	0.47	0.32	0.13	0.04	—	—	—
16	Complete specimen	0.48	0.32	0.11	0.04	—	—	—
17	Complete specimen	0.52	0.31	0.09	0.06	—	—	—
18	Complete specimen	0.52	0.27	0.18	0.05	—	—	—
19	(CPC 7260) ..	0.55	0.39	0.16	0.04	—	—	—
20	(CPC 7261) ..	0.56	0.42	0.14	0.03	—	—	—

* Thin section

Occurrence: Figured specimens CPC 7260 and 7261 and thin sections CPC 7262 to 7265 from core 6, Bonaparte No. 1 well, Bonaparte Gulf Basin, Western Australia, at a depth of 1842 feet to 1842 feet 4 inches; also from core 11, Bonaparte No. 2 well, at a depth of 4931 feet (one specimen only).

Re*marks*: B. L. Mamet states (pers. comm., 6 December 1965) that the stratigraphic range of the species *Draffania quasibiloba* is from V2b to V3c of the Belgian succession; this may be correlated with the interval from CuIIδ to CuIIIγ of the standard sequence of goniatite zones. He has also recognized the genus *Draffania* in the uppermost Visean of Southern Oranais (Colomb-Bechar). R. H. Cummings (pers. comm., 3 May 1966) has informed me that *D. quasibiloba* ranges from S2 to D2 of the British Lower Carboniferous sequence, but that *Draffania* is normally dominant in the D2 interval. The foraminiferal fauna occurring with *Draffania quasibiloba* in Western Australia, which includes the genera *Endothyra, Eostaffella, Mediocris, Haplophragmella, Stacheoides, Fourstonella, Archaediscus, Tetrataxis,* and *Valvulinella,* indicates an age from V3b to lower V3c (=CuIIIα).

The occurrence of *Draffania* in Western Australia does not give any indications of its possible affinities. The beds in which it has been found also contain foraminifera, ostracods, fragments of conodonts, brachiopods, corals, gastropods, pelecypods, algae, and echinoid fragments. The specimens of *Draffania* are always isolated and not closely associated with other organic remains.

REFERENCES

Cummings, R. M., 1957—A problematic new microfossil from the Scottish Lower Carboniferous. *Micropaleontology,* 3(4), 407-409.

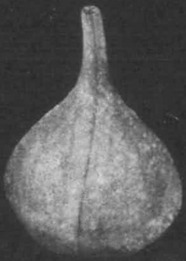
Fomina, E. V., 1960—Some new species of foraminifera from the Visean deposits of the Sub-Moscow Basin. *Mat. Geol. polezn. iskop., Centralnii Rayon Europeiskoi Yast SSSR.,* 114-119.

EXPLANATION OF PLATE

PLATE 6

Draffania quasibiloba Fomina

1-2	CPC 7260; 1, side view; 2, top view; both x61.
3	CPC 7261; side view; x61.
4-5	Vertical section, CPC 7262; 4, showing double dividing partition and communication between chambers at the base of the partition; x90; 5, showing filamentous texture of the wall and dividing partition and communication between the chambers; x223.
6	Vertical section, CPC 7263, showing double dividing partition; x90.
7	Vertical section, CPC 7264, showing thin-walled test and indistinct doubling of the dividing partition in the upper part; x90.
8	Horizontal section, CPC 7265, showing thick wall and clear inner lining to chambers; x90.



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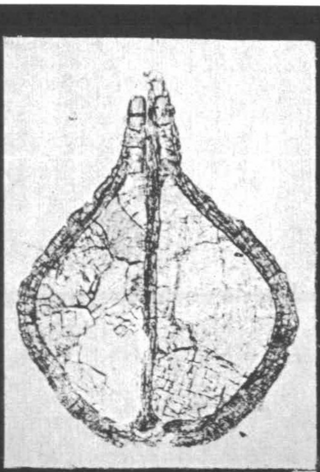

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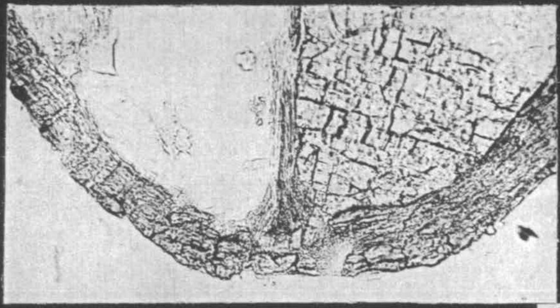

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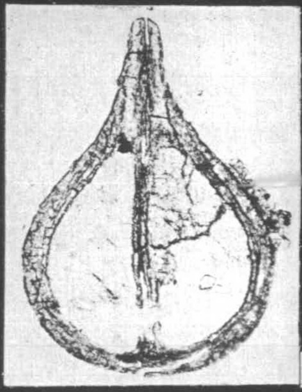

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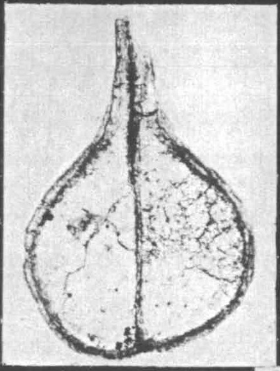

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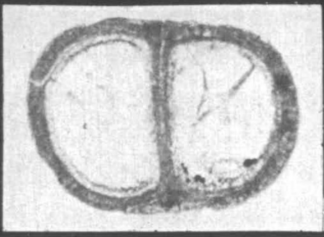

8

Draffania

FIRST RECORD OF LITHISTID SPONGES IN THE CAMBRIAN OF AUSTRALIA

by C. G. Gatehouse

SUMMARY

Early Middle Cambrian lithistid rhizomorine sponge spicules have been found in the Georgina Basin of Australia; this is the earliest known record of rhizomorine sponges.

Arborella mors gen. nov. et sp. nov. occurs as a spicule assemblage in cores and cuttings from six drill holes in two areas 350 and 150 to 200 miles north-east of Alice Springs. Although the initial find was from core 11 of BMR 13 Sandover, a rich assemblage of spicules was found in a water bore—Gidyea 1—in cuttings at 120 feet. Other localities are BMR 11 Cattle Creek, BMR Grg 8, BMR Grg 16, and Gidyea 3, a water bore.

The trilobites *Xystridura* and *Pagetia significans* (Etheridge Jr, 1902) are associated with *Arborella mors* in core 12 of BMR 13 Sandover, and are evidence of the early Middle Cambrian age of the sponge.

INTRODUCTION

The first lithistid sponges known in the Cambrian of Australia were found in BMR 13 Sandover, drilled in 1964, by the Bureau of Mineral Resources 190 miles north-east of Alice Springs, Northern Territory, as part of a drilling programme for subsurface information in the Georgina Basin (Milligan, 1963).

Lithistid sponge spicules were subsequently found in BMR Grg 8 and 16, water bores Gidyea 1 and 3, and BMR 11 Cattle Creek, after treatment of cores and cuttings with monochloracetic acid.

BMR Grg 16, 172 miles east of Tennant Creek, was drilled in 1962 as part of a programme to determine the western extent of the Georgina Basin; core 35 (291 feet) and core 36 (299-303 feet) both yielded lithistid sponge spicules. BMR Grg 8, part of the same programme and located 173 miles east-north-east of Alice Springs, contained a spicule in core 17 (178-208 feet).

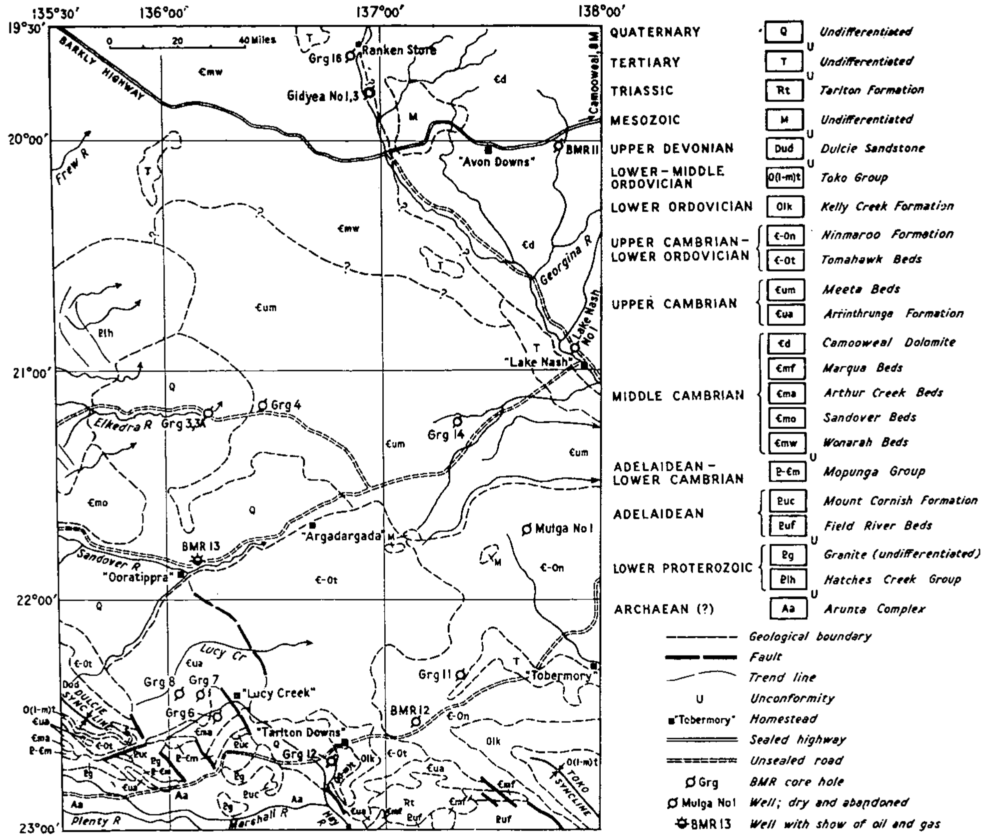

Fig. 1: Locality map.

Two water bores, drilled by the Water Resources Branch of the Northern Territory Administration, 13 and 12 miles respectively south of Ranken store on the Barkly Tableland, were found to contain spicules at all levels.

A recent examination of BMR 11 Cattle Creek showed lithistid spicules in core 3 (701-702 feet) and again in core 12 (1202-1205 feet). This stratigraphic hole is sited 20 miles west-south-west of Camooweal.

Discussion

The assemblage of sponge spicules from 120 feet in Gidyea 1 water bore is described as *Arborella mors* gen. nov. et sp. nov. Spicules were also encountered in 15 samples of cuttings from this bore, which was drilled to a total depth of 402 feet in limestone and calcareous shale regarded as Ranken Limestone; and in all samples from Gidyea 3, which was drilled in rocks essentially similar to Ranken Limestone to a total depth of 304 feet. The cuttings at 304 feet contained *Pagetia,* a peronopsid trilobite, hyolithids, and sponge spicules, indicating an early Middle Cambrian age.

BMR Grg 16, which is 3 miles north-west from the Gidyea water bores, was continuously cored for more complete subsurface information. *Biconulites* and ptychopariid trilobites were found in core 27 (220 feet 9 inches - 230 feet 2 inches); core 29 (240 feet - 250 feet 1 inch) also contains *Biconulites.* Both cores are probably early Middle Cambrian in age. Only lithistid sponge spicules were found in core 35 (291 feet) and core 36 (299 - 303 feet); the age of these cores is not younger than early Middle Cambrian.

Lithistid spicules were recently found in core 3 (701 - 720 feet) and core 12 (1202 - 1205 feet) of BMR 11 Cattle Creek. The interval 547 to 1016 feet is most probably early Middle Cambrian (Gatehouse, 1967); core 14 contains a trilobite free cheek and therefore is still in the Cambrian.

BMR 13 Sandover, 150 miles south-south-west of Camooweal, was found to contain lithistid sponge spicules in core 11 (2579 feet-2582 feet 6 inches) and core 12 (2817 - 2827 feet). *Xystridura* and *Pagetia significans* (Etheridge Jr, 1902) are associated with the spicules in core 12, indicating an early Middle Cambrian age. Lloyd (1967) regards cores 11 and 12 as part of the Arthur Creek Beds, which are of the same age as the Ranken Limestone.

A spicule which possibly could be referred to *Arborella* gen. nov. was found in core 17 (178 - 208 feet) of BMR Grg 8, which was a continuously cored hole through the lower part of the Upper Cambrian Arrinthrunga Formation (Milligan, 1963, p. 12).

The occurrence of rhizomorine sponge spicules in the Cambrian of Australia is noteworthy. *Nipterella paradoxica* (Billings, 1865) dated by Hinde (1889) as

Upper Cambrian, and by de Laubenfels (1955) as Cambro-Ordovician, is, according to Bolton (1960, p. 9), of Lower Ordovician age. *Arborella mors* gen. nov. et sp. nov., being of early Middle Cambrian age, antedates *Nipterella* Hinde, and therefore is the oldest known rhizomorine sponge.

Systematic Affinities

The systematic affinities of *A. mors* are important because of its age and geographical position. An assemblage consisting of a large number of spicules is available for study; the spicules are unique in their shape and association, and cannot be compared with any other sponge. The spicules belong in the Suborder Rhizomorina of the Order Lithistida. Generic classification and familial groupings are based on the form of the sponge body, and as this is not known for *Arborella mors* the family position is left open.

Class DEMOSPONGEA Sollas, 1875

Order LITHISTIDA Schmidt, 1870

Suborder RHIZOMORINA Zittel, 1878

Family UNCERTAIN

Genus ARBORELLA nov.

ARBORELLA MORS gen. nov. et sp. nov.*

(Pls 7, 8)

Arborella mors is a species comprising an assemblage of siliceous lithistid spicules. Five types of spicules are recognizable; as they all occur at one horizon in Gidyea No. 1 (120 feet) they are regarded as belonging to one species. The form of the living sponge is not known because the spicules are dispersed.

Material. The material comprises several hundred spicules, a selection of which is illustrated here.

Age and Occurrence: As previously mentioned, *Arborella mors* occurs in Arthur Creek Beds and Ranken Limestone associated with *Xystridura* and *Pagetia significans,* which indicate an early Middle Cambrian age.

Differential diagnosis. Arborella mors is unique amongst rhizomorine sponges because of the shape and assemblage of the spicules.

Description

Type I (Pl. 7, figs 1 - 5)

The primordium is straight or slightly curved and circular or oval in section. A pair of secondary rays occurs at each end, from which arises a series of short

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* Arborella — Lat., fem., 'little tree'; mors — death; alluding to the 'dead tree' appearance of some spicules.

nodes possessing flat extremities. In the living sponge type I spicules lie parallel to one another (Pl. 7, fig. 2) and form a more or less rigid framework upon which the sponge is based.

Type II (Pl. 7, figs 6 - 8)

This group includes spicules with an irregularly shaped primordium with overgrowths of silica along its length. They are less common than type I but more common than types III, IV, or V.

Type III (Pl. 8, figs 1 - 3)

Type III spicules are curved units with siliceous overgrowths on the outside of the curve only; the inside edge is smooth.

Type IV (Pl. 8, figs 4, 5, 7, 8)

Type IV spicules comprise a short primordium with secondary rays which are bigger than the primordium. The secondary rays bifurcate to form either short or long rays. Figures 4 and 5 of Plate 8 are end views of one of these spicules viewed along the axis of the primordium; it shows the secondary ray bifurcating. The specimen in Figure 8 has very short bifurcate secondary rays.

Type V (Pl. 8, figs 6, 9)

The spicules of this group are composed of a number of short rays with no regular form; each ray may bear a small group of nodes at its extremities. Overgrowths are evident on some.

REFERENCES

BOLTON, T. E., 1960—Catalogue of type invertebrate fossils of the Geological Survey of Canada. Volume 1. *Dep. Min. tech. Surv. Canada.*

GATEHOUSE, C. G., 1967—Appendix *in* Smith, K. G., et al. — Stratigraphic drilling Georgina Basin, N.T. *Bur. Miner. Resour. Aust. Rep.* 124.

HINDE, G. J., 1889—On *Archaeocyathus,* Billings, and on other genera, allied to or associated with it, from the Cambrian strata of North America, Spain, Sardinia, and Scotland. *Quart. J. geol. Soc. Lond.,* 45.

LAUBENFELS, M. W. de, 1955—Archaeocyatha, Porifera. TREATISE ON INVERTEBRATE PALAEONTOLOGY, Part E, pp. 21-112. *Geol. Soc. Amer.* and *Univ. Kansas Press.*

LLOYD, A. R., 1967—*In* Smith, K. G., et al.—Stratigraphic drilling, Georgina Basin, N.T. *Bur. Miner. Resour. Aust. Rep.* 124.

MILLIGAN, E. N., 1963—The Bureau of Mineral Resources Georgina Basin core drilling programme. *Bur. Miner. Resour. Aust. Rec.* 1963/86 (unpubl.).

PLATE 7

Arborella mors gen. nov. et sp. nov.

Fig. 1. Type I spicule, CPC 7244, x 120. BMR 13 Sandover, core 11 (2579-2582½ feet), Arthur Creek Beds.

Fig. 2. As for Fig. 1, CPC 7245, x110.

Fig. 3. As for Fig. 1, CPC 7336, x100.

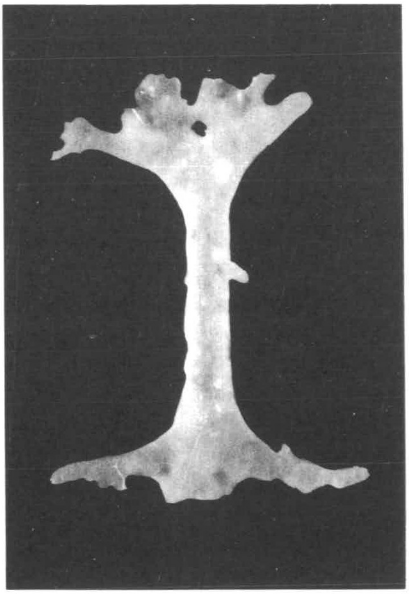
Fig. 4. Type I spicule, CPC 7246, x40. Gidyea 1, cuttings from 145 feet; Ranken Limestone.

Fig. 5. Type I, CPC 7247, x90; Gidyea 1, cuttings from 120 feet; Ranken Limestone.

Fig. 6. Type III spicule, CPC 7248, x100; BMR 13 Sandover, core 11, (2579-2582½ feet), Arthur Creek Beds.

Fig. 7. Type II spicules, CPC 7249, x130; BMR 13 Sandover, core 11 (2579-2582½ feet), Arthur Creek Beds.

Fig. 8. Type II spicule, CPC 7250, x100; Gidyea 1, cuttings from 120 feet. Ranken Limestone.



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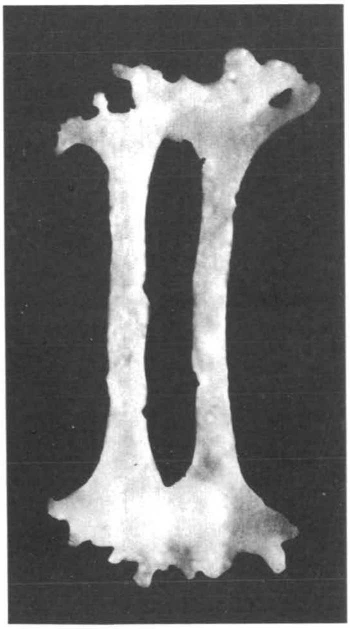

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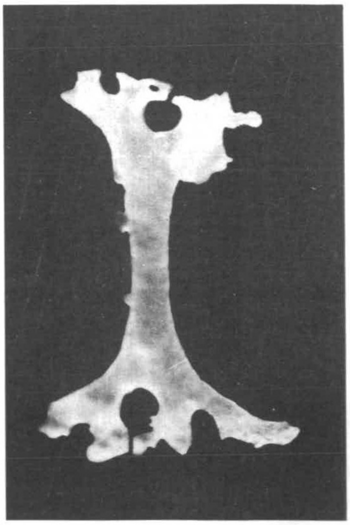

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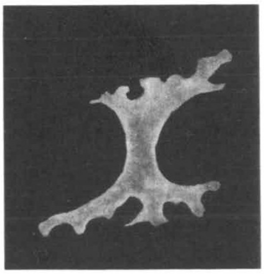

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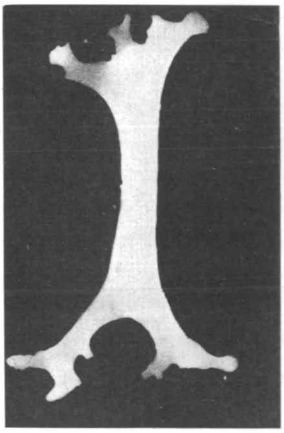

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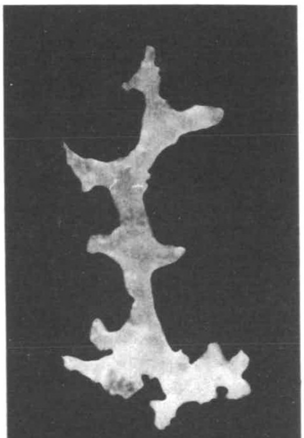

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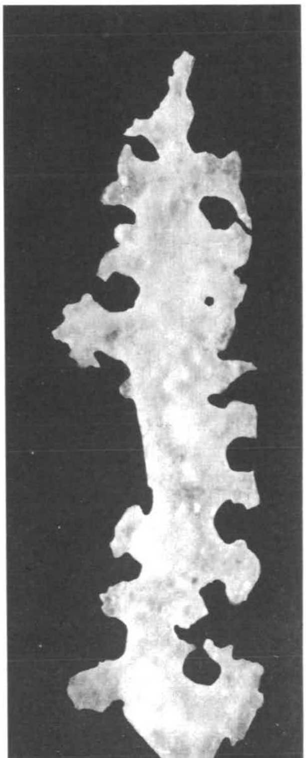

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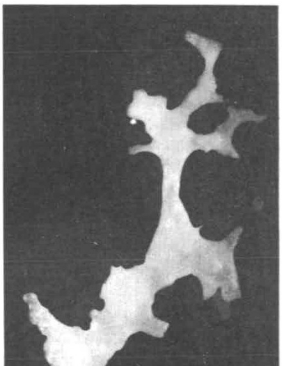


8

Lithistid sponges

PLATE 8

Fig. 1. Type III spicule, CPC 7251, x70; BMR 13 Sandover, core 11 (2579-2582½ feet), Arthur Creek Beds.

Fig. 2. Type III spicules, CPC 7252, x130; Gidyea 1, cuttings from 145 feet, Ranken Limestone.

Fig. 3. Type III spicules, CPC 7253, x160; Gidyea 1, cuttings from 120 feet, Ranken Limestone.

Fig. 4. Type IV spicule, CPC 7254, x140; Gidyea 3, cuttings from 55-60 feet, Ranken Limestone.

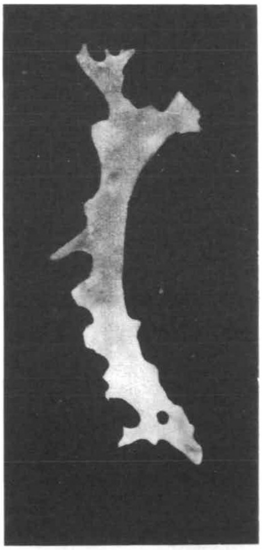
Fig. 5. Type III spicules; CPC 7255, x90. As for Fig. 4.

Fig. 6. Type V spicule; CPC 7256, x120. As for Fig. 4.

Fig. 7. Type IV spicule, CPC 7257, x80; Gidyea 1, cuttings from 145 feet, Ranken Limestone.

Fig. 8. Type IV spicule, CPC 7258, x130. As for Fig. 7.

Fig. 9. Type V spicule, CPC 7259, x70; Gidyea 1, cuttings at 120 feet, Ranken Limestone.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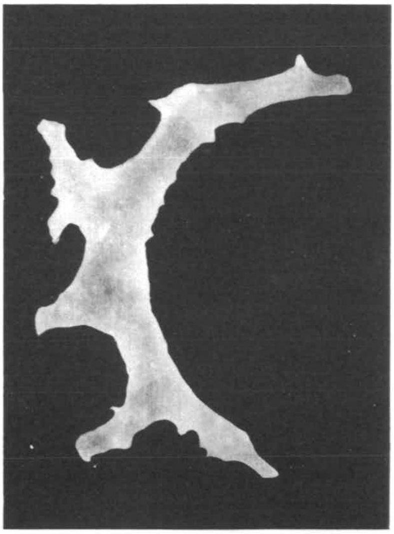
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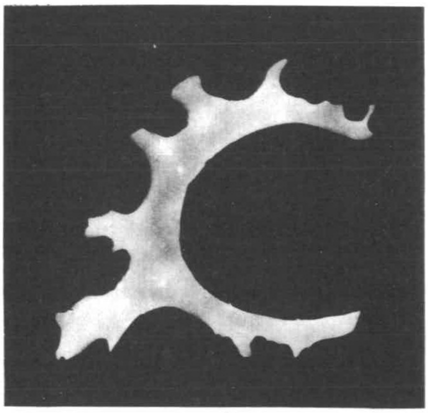
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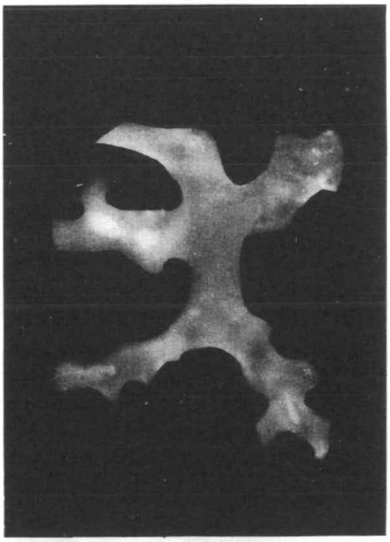
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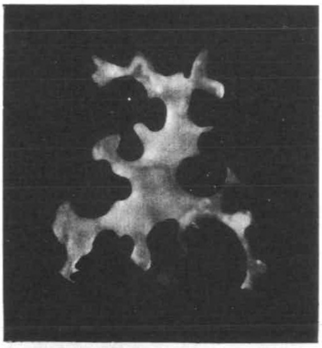
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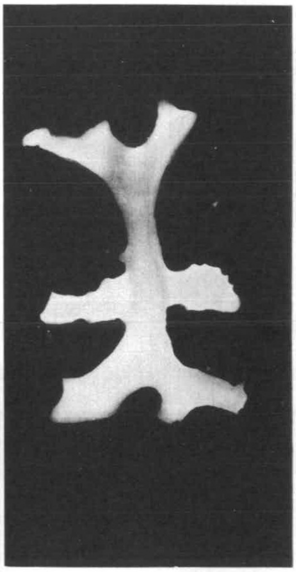
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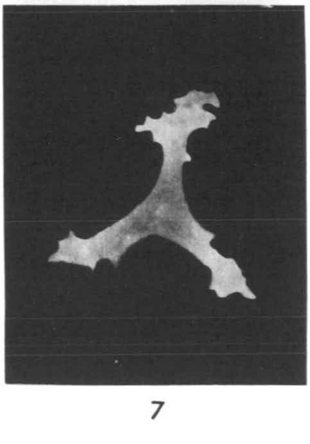
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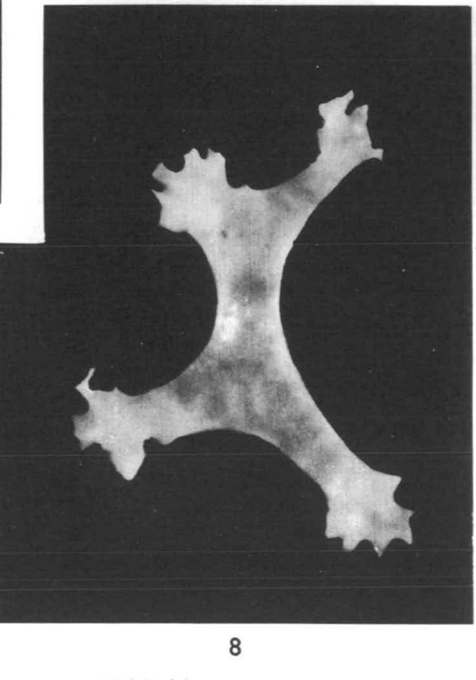
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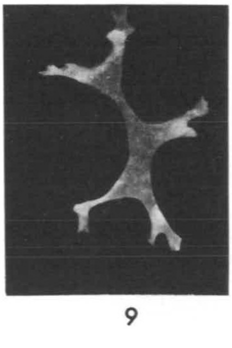
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Lithistid sponges

FORAMINIFERA FROM HBR WRECK ISLAND No. 1 WELL AND HERON ISLAND BORE, QUEENSLAND: THEIR TAXONOMY AND STRATIGRAPHIC SIGNIFICANCE.

1 — LITUOLACEA AND MILIOLACEA

by A. R. Lloyd

SUMMARY

Twenty-five species belonging to 13 genera of the superfamilies Lituolacea and Miliolacea are described from the Miocene rocks of the Wreck Island No. 1 Well and the Miocene and younger rocks of the Heron Island Bore. They are poorly represented in the Heron Island Bore, but occur in quantity between 530 feet and 1795 feet in Wreck Island No. 1. No samples were recovered above 530 feet.

One species, *Cubanina victoriensis,* has been elevated from varietal to specific rank.

Most of the species found are widespread, and in particular the assemblage can be readily correlated with Miocene assemblages in Victoria, Indonesia, and New Zealand.

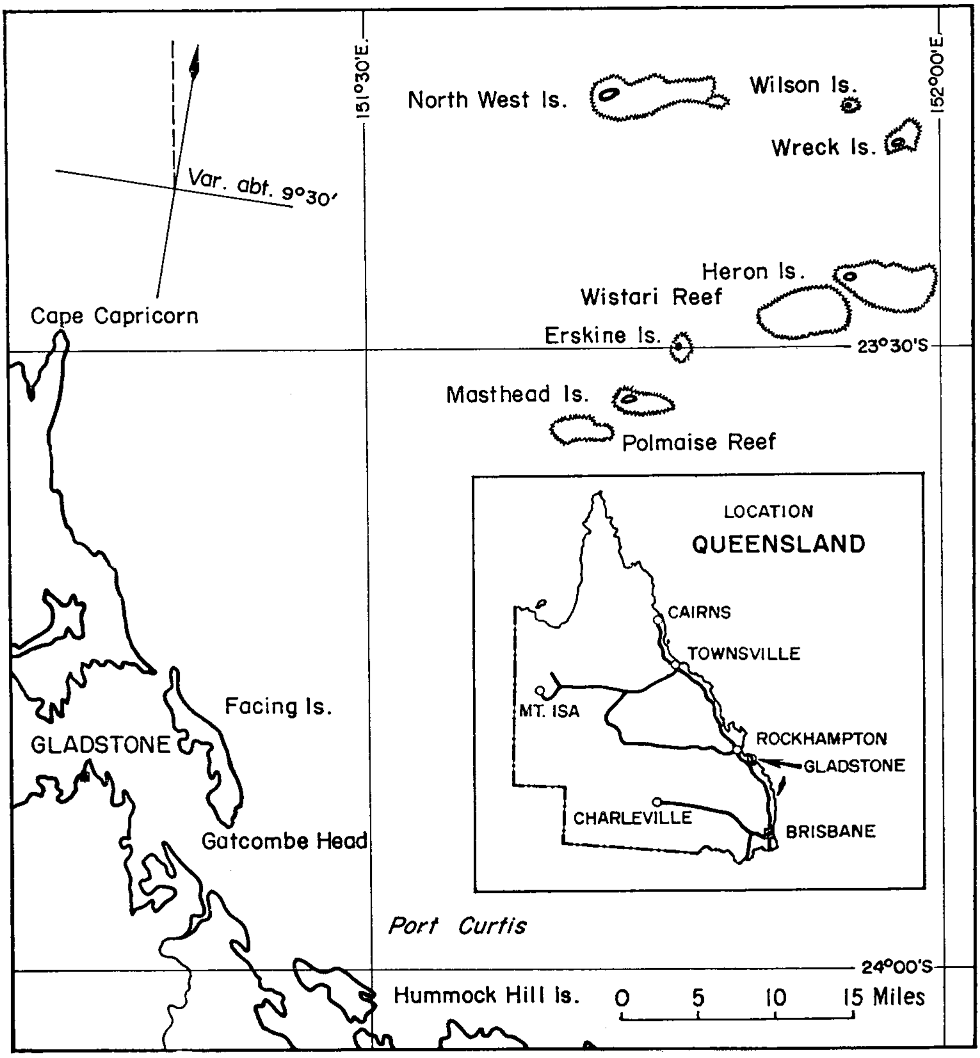

Fig. 1: Locality map.

INTRODUCTION

This is the first of a series of papers on the taxonomy, distribution, and stratigraphic significance of the foraminiferal faunas from Wreck Island No. 1 and Heron Island Bore and their correlation with other sections.

Wreck Island is situated at Latitude 23°20'S., Longitude 151°57'E., 58 miles north-east of Gladstone at the southern extremity of the Great Barrier Reef, Queensland (Fig. 1). It was chosen as the site for a bore to test for the presence of oil in the marine Tertiary strata which were thought to underlie the Reef. Mines Administration Pty Ltd drilled the hole on behalf of Humber Barrier Reef Oil Pty Ltd in 1959. Samples of cuttings were taken at 5-foot intervals from 505 feet to final depth of 1898 feet, and cores were cut at regular intervals, but the recovery was often poor. Casing was run to 480 and 1110 feet.

Heron Island is situated at Latitude 23°26'S., Longitude 151°57'E., 51 miles north-east of Gladstone and 7 miles south of Wreck Island. It was chosen as the site for a deep bore to obtain scientific data on the Great Barrier Reef by the Great Barrier Reef Committee in 1938. Samples were taken at irregular intervals to total depth of 721 feet. Cores were also taken at irregular intervals but with little success. Casing was run to 31, 131, 340, 512, and 672 feet.

From Wreck Island, cuttings and cores covering the interval from 535 to 1795 feet were examined at 25-foot intervals, and closer where considered necessary. Except for cores 7 and 10, which were examined in thin sections, the fauna was freed by washing. The preservation of the foraminifers is variable: from 535 to 1500 feet most tests are well preserved except for breakages to the last chambers; from 1500 to 1795 feet the foraminifers, especially the orbitoids, are infilled or replaced by glauconite, and are ironstained and badly worn, although around 1750 feet the preservation is fairly good.

Most of the samples covering the interval from 69 to 721 feet in Heron Island Bore were washed and the fauna examined. The foraminifers are not as well preserved as in the Wreck Island material.

For early publications which were not available, reliance is placed on the Catalogue of Foraminifera (Ellis & Messina, 1940 et seq.); they are marked * in the bibliography.

All figured specimens and assemblage slides will be housed in the Department of Geology, University of Queensland, whose registry numbers are shown.

Acknowledgments

Thanks are extended to Mr A. K. Denmead of the Geological Survey of Queensland for permission to work on the Wreck Island material and for the supply of some of the Wreck Island samples; to Dr O. A. Jones of the Great

Barrier Reef Committee for the supply of some of the Wreck Island and all of the Heron Island samples and his interest in the project; to Professor Dorothy Hill of the Department of Geology, University of Queensland, for her efforts in gaining permission for me to work on the Wreck and Heron Island material and her interest in the work; to Professor M. F. Glaessner, Dr Mary Wade, and Dr B. McGowran of the School of Geology, University of Adelaide, for their guidance and loan of valuable reprints while I was at the University of Adelaide; to Dr Irene Crespin while she was with the Bureau of Mineral Resources and Mr Allen of the Geological Survey of Queensland for their assistance with material and information. Special thanks are extended to Dr D. J. Belford of the Bureau of Mineral Resources for his valuable guidance and encouragement and the loan of comparative material.

Previous Work

Richards (1938) and Richards & Hill (1942) set out the history of the Heron Island Bore and gave petrological descriptions of the samples. Cushman (1942) listed the foraminifers he identified from the Heron Island Bore samples and illustrated some of them. He did not discuss any age significance of the fauna. Iredale (1942) discussed the molluscs from the Heron Island Bore samples and stated that they indicated a Recent age for the complete section. Maxwell (1962, p. 222) discussed the lithology of both.

Derrington (1960) discussed the history of Wreck Island No. 1 and briefly described the rock types, and Crespin (1960) gave a very brief preliminary account of the foraminifers. Derrington and Crespin ascribed tentative ages of lower Miocene to Recent to the sequence. Traves (1960, p. 369) briefly described the history and rocks of Wreck Island No. 1. Lloyd (1961), in a preliminary study of the 'smaller' foraminifers, considered that the sequence from 530 to 1795 feet is Miocene and is unconformably overlain by a Pleistocene to Recent sequence from 530 feet to surface.

Age of the Faunas

The ages of the faunas will be discussed in more detail in the final paper of this series. At this stage of the investigation it is tentatively considered that in the Wreck Island well, the sequence from surface to about 530 feet is Recent to Pleistocene and rests unconformably on a Miocene sequence from about 530 to 1795 feet. Samples are absent, however, above 530 feet, so the age of this section and the upper limit of the Miocene are uncertain. In Heron Island Bore the fauna by itself does not permit an age determination. With the drilling of Wreck Island No. 1 the faunas can be compared and the sections correlated, and it is tentatively considered that the Heron Island sequence from surface to about 445 feet is Recent to Pleistocene and rests unconformably on a Miocene sequence from about 445 to 721 feet.

Table 1 sets out the distribution and frequencies of the species belonging to the superfamilies Lituolacea and Miliolacea in Wreck Island No. 1. These two superfamilies are not well represented in Heron Island Bore and a distribution chart has not been drawn up.

In Wreck Island No. 1 the agglutinating foraminifers are best represented at 940 feet, but occur throughout most of the section. The miliolids are not abundant but are scattered throughout the section. Of the other foraminiferal groups the fauna at 1750 feet is characterized by an abundance of *Operculina victoriensis* and a new species of *Parrellina;* up to 965 feet the fauna is dominated by *Lepidocyclina* and has smaller numbers of other forms which include *Miogypsina, Operculina bartschi, Amphistegina quoyi, Parrellina* spp., and *Cycloclypeus* sp. Planktonic species occur in core 7 at 965 feet with the highest appearance of *Lepidocyclina,* become abundant from 950 to 900 feet, and then more rare above 900 feet. *Globoquadrina altispira altispira* is abundant from 950 to 940 feet and has its highest occurrence at 930 feet. Other planktonic species present include *Orbulina universa, Globorotalia menardii, Pulleniatina obliquiloculata, Globigerinoides trilobus, G. obliquus,* and *G. ruber.* The main benthonic species which occur within the sequence from 950 to 535 feet are *Operculina bartschi, Cibicides victoriensis, C. mediocris, C. refulgens, C.* sp. nov., *Parrellina* spp., *Elphidium* spp., *Amphistegina quoyi, A. gibbosa, Uvigerina flintii,* and *U. peregrina.*

The Heron Island samples examined yielded only one agglutinated foraminifer, *Vulvulina arenasuturata,* at 693 to 696 feet, but Cushman (1942) identified *Reophax scorpiurus* at 668 feet; *Rhabdammina* sp. at 526 and 528½ feet; *Clavulina pacifica* at 40 feet; *Textularia rugosa* at 506 and 510 feet; and *Textularia* sp. at 673 and 683 feet. The miliolids are also poorly represented in Heron Island Bore; Cushman identified *Triloculina tricarinata* at 514½ feet, *Marginopora* sp. at 704 feet, and *Marginopora vertebralis* at 12 and 17 feet. The overall fauna up to 445 feet is similar to that found in Wreck Island No. 1 with some restricted species in common.

SYSTEMATIC DESCRIPTIONS

The classification used is based on Loeblich & Tappan (1964).

Where reference is made to Barker (1960), it is understood that the specimens referred to were originally figured and described by Brady in his report on the foraminifers dredged by HMS *Challenger* during the years 1873-1876.

All dimensions are approximate and in millimetres.

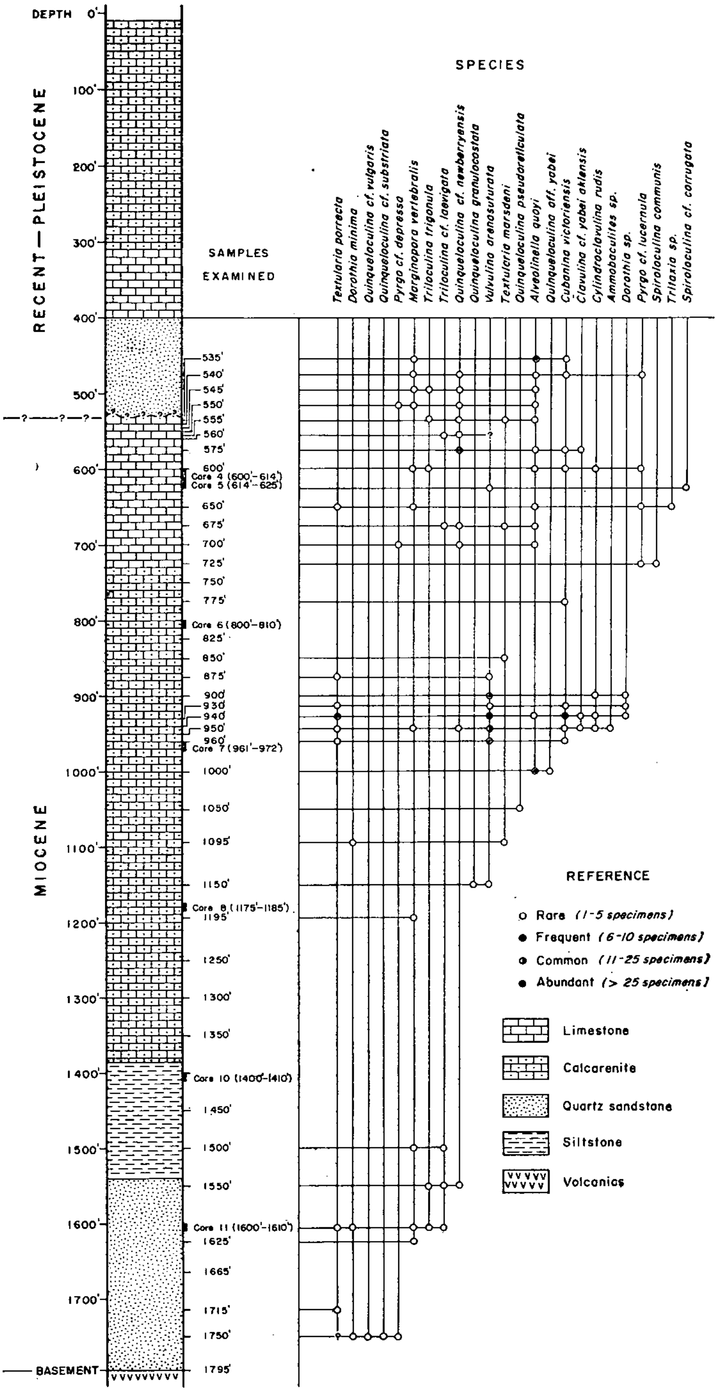

Table 1: Distribution chart H.B.R. Wreck Island No. 1 Well

Order FORAMINIFERIDA

Suborder TEXTULARIINA Delage & Herouard, 1896

Superfamily LITUOLACEA de Blainville, 1825

Family LITUOLIDAE de Blainville, 1825

Subfamily LITUOLINAE de Blainville, 1825

Genus AMMOBACULITES Cushman, 1910

Type Species: *Spirolina agglutinana* d'Orbigny, 1846.

AMMOBACULITES sp.

(Pl. 9, fig. 1)

Description. Test elongate, twice as long as wide, broadening gradually distally, broadest part formed by last chamber, circular in transverse section; periphery acute in planispiral part with small keel, rounded in uniserial part; chambers distinct, planispirally coiled and compressed initially, rapidly becoming uniserially arranged; uniserial chambers 4, enlarging rapidly, a little wider than high, compressed initially, becoming inflated distally; sutures distinct, depressed, concave; wall coarsely agglutinated, rough; aperture terminal, rounded.

Remarks. No species with which the only specimen belonging to *Ammobaculites* sp. could be compared could be found. It may belong to a new species.

Distribution. At 950 feet in Wreck Island No. 1 only.

Dimensions of figured specimen:	*Length*	*Diameter*
F48917	1.40	0.55

Family TEXTULARIIDAE Ehrenberg, 1838

Subfamily SPIROPLECTAMMININAE Cushman, 1927

Genus VULVULINA d'Orbigny, 1826

Type Species: *Vulvulina capreolus* d'Orbigny, 1826.

VULVULINA ARENASUTURATA (LeRoy, 1939)

(Pl. 9, figs 2-10; Pl. 10, figs 1-3)

1939 *Spiroplectammina arenasuturata* LeRoy, p. 229, pl. 4, figs 17-19.
1944a *Spiroplectammina arenasuturata;* LeRoy, p. 14, pl. 1, figs 54, 55.
1949 *Vulvulina dermouti* Boomgaart, p. 53, pl. 3, figs 9a, b.

Description. Test flaring to elongate, 1¼ to twice as long as wide, gradually broadening distally, widest part formed by last two biserially arranged chambers;

compressed initially and towards periphery, thickest along medial section; rhomboidal to elliptical in transverse section; periphery acute with small keel; slightly lobate initially, becoming more so distally; outline broadly rounded at proximal end in megalospheric forms, but more sharply rounded in microspheric forms, rounded distally in mature specimens; chambers distinct, initially planispirally coiled, rapidly becoming biserially arranged, last chamber uniserially arranged in mature specimens; planispiral coil large and distinct in megalospheric forms but small and hard to distinguish in microspheric forms; biserial chambers about 22, increasing gradually in size, fairly constant in shape, narrow, about three times as wide as high; uniserial chamber about four times as wide as high, overlapping the last two biserial chambers completely or partly; sutures distinct, depressed, concave, broad, almost straight, recurving near periphery; medial ridge broad, distinct, raised, with a coarse granular layer which continues along sutures and keels; wall finely agglutinated, smooth; aperture a low interiomarginal rectangular opening in immature specimens lacking uniserial chamber, becoming a terminal elongate slit in mature specimens with uniserial chamber, but sometimes having an elongate vertical interiomarginal aperture intermediate between the two apertural types.

Remarks. Most of the Queensland specimens placed in *V. arenasuturata* are microspheric forms and do not have the final uniserial chamber (Pl. 9, figs 2-4), and without the presence of the few specimens which have the final uniserial chamber (Pl. 9, figs 5, 6), with which they are undoubtedly conspecific, they would have been placed in the genus *Spiroplectammina.* Only rare megalospheric forms (Pl. 9, figs 7, 8) are present in the fauna. The *Spiroplectammina* forms compare closely with the holotype of LeRoy's species and are considered to be conspecific with it. Although LeRoy evidently found no *Vulvulina* forms his species is placed in the genus *Vulvulina* on the new evidence. This complies with the description of *Vulvulina* in the Treatise (Loeblich & Tappan, 1964, p. 251), in which the descriptions of *Textularia* and *Spiroplectammina* would fit the immature forms.

The figures of LeRoy's holotype show it to possess a horizontal interiomarginal aperture similar to that possessed by the majority of the Queensland specimens (Pl. 9, figs 2-4). LeRoy (1944*a,* pl. 1, figs 54, 55) figured a specimen as *Spiroplectammina arenasuturata* which has a vertical interiomarginal aperture similar to that found in two specimens from 960 feet in Wreck Island No. 1 (Pl. 9, figs 9, 10); these cannot be otherwise separated from the other forms placed in this species. LeRoy does not discuss the apertural differences.

Boomgaart (1949, p. 53, pl. 3, fig. 9) described and figured the species *Vulvulina dermouti* from Java; this is considered to be conspecific with the Queensland specimens and hence with LeRoy's specimens. He did not mention any coarse granular layers on the sutures or medial ridge, but the feature is not always pronounced, and could be missed. Boomgaart mentions, but does not figure, the occurrence of textularian forms which he considered to be immature specimens.

A picked sample from 'hilly country east of Semarang, Java, upper course of Ngembrak River between Larip and Karangarem' of Miocene f3 age in the W. J. Parr collection at the Bureau of Mineral Resources was found to contain *Spiroplectammina* forms which are conspecific with the Wreck Island specimens.

Distribution. The immature *Spiroplectammina* form occurs from core 5 (614-625 feet) to 960 feet, with a possible occurrence at 560 feet, in Wreck Island bore and at 693-696 feet in Heron Island Bore. The mature *Vulvulina* form occurs from 900 to 950 feet, and the intermediate form occurs at 960 feet, only in Wreck Island No. 1. LeRoy recorded his species from the lower and middle Miocene of Sumatra; Boomgaart recorded his from the Miocene of Java; and the species has been observed from the Miocene, f3, of Java.

Dimensions of figured specimens:	*Length*	*Width*	*Thickness*
F48918	1.20	0.55	0.30
F48919	0.93	0.55	0.38
F48920	0.75	0.55	0.40
F48921	1.10	0.63	0.40
F48922	0.80	0.55	0.35
F48923	0.90	0.55	0.32
F48924	0.82	0.55	0.30
F48925	1.05+	0.75	0.50
F48926	0.80	0.55	0.35
F48927	0.90	0.55	—
F48928	1.13	0.55	—
F48929	0.90	0.55	—

Subfamily TEXTULARIINAE Ehrenberg, 1838

Genus TEXTULARIA de France, 1824

Type Species: *Textularia sagittula* de France, 1824.

TEXTULARIA MARSDENI Finlay, 1939

(Pl. 10, figs 4a-c)

1939b *Textularia marsdeni* Finlay, p. 90, pl. 14, fig. 67.
1961 *Textularia marsdeni* Finlay; Hornibrook, p. 28, pl. 2, fig. 27.

Description. Test elongate, one and a half times as long as wide, gradually broadening distally, widest part formed by last two chambers, rectangular with small sides rounded in transverse section; compressed with flattened faces; periphery acute to subacute initially, becoming broadly rounded distally with small keel; chambers distinct, flattened initially, becoming inflated and bar-like distally, biserial throughout, about 20 in number, enlarging gradually, about three times as wide as high; sutures depressed, becoming strongly depressed and concave distally; medial line depressed, wall finely agglutinated, smooth; aperture a narrow interiomarginal slit.

Remarks. The Queensland specimens are very close to this New Zealand species, the bar-like chambers being quite characteristic. The species is also present in samples in the W. J. Parr collection from the Bairnsdale district and from Newmerella near Orbost in Victoria.

Distribution. From 1095 to 555 feet in Wreck Island No. 1; lower Oligocene to upper middle Miocene in New Zealand; lower and middle Miocene in Victoria.

Dimensions of figured specimen:	*Length*	*Width*	*Thickness*
F48930	1.25	0.90	0.50

TEXTULARIA PORRECTA Brady, 1884

(Pl. 10, figs 5a, b)

1884	*Textularia agglutinana* d'Orbigny var. *porrecta* Brady, p. 364, pl. 43, figs 4a, b.
1915	*Textularia porrecta* Brady; Heron-Allen & Earland, p. 627.
1921	*Textularia porrecta* Brady; Cushman, p. 109, pl. 22, fig. 1.
1941a	*Textularia porrecta* Brady; LeRoy, p. 19, pl. 2, figs 62, 63.
1944b	*Textularia porrecta* Brady; LeRoy, p. 75, pl. 1, figs 5, 6.
1960	*Textularia porrecta* Brady; Barker, pl. 43, fig. 4.

Description. Test very elongate, narrow, three times as long as wide, gradually broadening distally, widest part formed by last two chambers, elliptical in transverse section; periphery acute to subacute initially, becoming rounded distally; chambers distinct, biserially arranged throughout, about 26 in number (22 in largest specimen with initial chambers damaged), constant in shape about twice as wide as high, enlarging gradually, moderately inflated; sutures distinct, depressed, gently curved; medial line depressed; wall coarsely agglutinated, rough; aperture, a low interiomarginal arch.

Remarks. The Queensland specimens compare closely with the specimens described and figured by Brady, Cushman, and LeRoy, and are considered to be conspecific with them. Collins (1958, p. 353) recorded *T. porrecta* from the Recent of the Great Barrier Reef but did not figure or describe his specimens.

Distribution. The species occurs from 650 to 1715 feet, with a possible occurrence at 1750 feet, in the Wreck Island well; in the lower and middle Miocene in Sumatra; in the Recent of Torres Strait and Great Barrier Reef, Queensland, and around the Philippines and the Kerimba Archipelago off south-east Africa.

Dimensions of figured specimen:	*Length*	*Width*	*Thickness*
F48931	2.75+	0.90	0.75

Family ATAXOPHRAGMIIDAE Schwager, 1877

Subfamily VERNEUILININAE Cushman, 1911

Genus TRITAXIA Reuss, 1860

Type Species: *Textularia tricarinata* Reuss, 1844.

TRITAXIA sp.

(Pl. 10, fig. 6)

Description. Test elongate, small, triangular in transverse section; chambers initially triserially arranged, rapidly becoming uniserial, moderately distinct; uniserial chambers compressed and distorted, 4 in number, about twice as wide as high; sutures moderately distinct, slightly depressed, straight across the faces; periphery acute; faces flat to gently concave where not distorted; triserial part bulbous, uniserial part tapering gently distally; where not distorted edges nearly parallel; walls coarsely agglutinated, smooth; aperture terminal, circular at end of small neck with serrated rim.

Distribution. At 650 feet in Wreck Island No. 1 only.

Dimensions of figured specimen:	*Length*	*Width*
F48932	0.75	0.15 - 0.23

Subfamily GLOBOTEXTULARIINAE Cushman, 1927

Genus DOROTHIA Plummer, 1931

Type Species: *Gaudryina bulletta* Carsey, 1926

DOROTHIA sp.

(Pl. 10, figs 7, 8)

Description. Test conical, one and a half times as high as wide, broadening rapidly distally, widest part formed by last two chambers, circular in transverse section; periphery rounded; chambers moderately distinct, initially trochospirally arranged with 4 chambers per whorl, reducing to 3 and finally becoming biserially arranged; biserial chambers about 4 in number, three times as wide as high; chambers internally undivided; sutures moderately distinct, raised, gently curved, with coarse granular layer; wall coarsely agglutinated, smooth, not labyrinthic; aperture a narrow interiomarginal slit.

Remarks. In one specimen (Pl. 10, fig. 7) the chambers are initially trochospirally coiled with 4 chambers per whorl, reducing to 3 chambers per whorl and finally becoming biserial. The second specimen (Pl. 10, fig. 8) has no biserial stage and is considered to be a more immature form of the species. Internally the chambers are not partitioned and the walls are not labyrinthic, so the specimens are placed in the genus *Dorothia.*

They fit the description of *Tritaxilina suturanodosa* given by LeRoy (1944a, p. 16) and externally closely resemble one figured specimen (pl. 1, figs 60, 61); another specimen figured by LeRoy (pl. 5, figs 1, 2) appears to have internal partitions, although he did not describe any internal features. LeRoy (1941a, p. 70, pl. 7, figs 19, 20) figured a specimen as *Textulariella simplex* Cushman which seems to resemble more closely the Queensland specimens and the holotype of *Tritaxilina suturanodosa* than the figures of *Textulariella simplex* given by Cushman (1936, p. 45, pl. 6, figs 20a, b; 1937a, p. 67, pl. 7, fig. 14). LeRoy does not describe the external or internal features of the specimens he figured as *T. simplex,* and Cushman did not describe the nature of the sutures of his specimens; the two forms appear to differ in this feature, which seems to be specifically diagnostic. Without direct comparative material the Queensland specimens cannot be positively identified.

Distribution. From 900 to 940 feet in Wreck Island No. 1 only. LeRoy recorded his specimens from the Miocene of Sumatra.

Dimensions of figured specimens:	*Length*	*Diameter*
F48933	1.50	1.0
F48934	1.40	0.63

DOROTHIA MINIMA (Karrer, 1865)

(Pl. 11, figs 1a, b)

1865	*Textularia minima* Karrer, p. 79, pl. 16, fig. 9.
1865	*Plecanium karreri* Stache, p. 178, pl. 21, fig. 17.
1865	*Plecanium granosissimum Stache,* p. 179, pl. 21, fig. 18.
1865	*Plecanium eurystoma* Stache, p. 179, pl. 21, fig. 19.
1937b	*Dorothia karreri* (Stache); Cushman, p. 92, pl. 10, fig. 9.
1961	*Dorothia minima* (Karrer); Hornibrook, p. 28, pl. 2, fig. 27.

Description. Test small, short and broad, broadening rapidly distally, broadest part formed by last two chambers, rounded in transverse section, periphery broadly rounded, initial end rounded and globular, faces becoming flattened distally; chambers moderately distinct, initially trochospirally coiled with about 5 chambers in the first whorl reducing to 3 chambers in the second whorl and then becoming biserial in the adult; biserial chambers 2 to 4 in number, enlarging rapidly, inflated peripherally, constant in shape, about as wide as high; sutures moderately distinct, depressed, narrow, strongly oblique; walls coarsely agglutinated, smooth; aperture a narrow interiomarginal slit.

Remarks. The Queensland specimens are considered to be conspecific with *D. minima* as figured by Hornibrook. Karrer's figures of the holotype of *Textularia minima* are very idealized and are unsuitable for comparative purposes. Hornibrook placed the three species *Plecanium karreri, P. granosissmium,* and *P. eurystoma* of Stache in synonymy with *Dorothia minima;* the Queensland specimens are very like Stache's figured holotypes (vide Ellis & Messina, 1940 et seq.), which are not too idealized, and they are also placed in synonymy here. Hornibrook (1965, pp. 530-536) subsequently studied the original material of Stache and Karrer and confirmed the synonymy of these species.

The Queensland specimens are also very similar to the specimen figured as *Dorothia gibbosa* by Agip Mineraria (1957, pl. 4, fig. 6) from the Pliocene of Italy, but differ from this species as figured by Cushman (1937b, p. 92, pl. 10, figs 11-13).

Dorothia minima was also found in samples in the Bureau of Mineral Resources collections from the new quarry at Batesford; at 495 feet in No. 1 bore, Parish of Stratford, in Gippsland; and from Bairnsdale and Newmerella near Orbost in Victoria.

Distribution. At 1905 and 1750 feet and in core 11 (1600-1610 feet), in Wreck Island No. 1; upper Eocene to lower Miocene in New Zealand and lower Miocene in Victoria.

Dimensions of figured specimen:	*Length*	*Width*	*Thickness*
F48935	1.0	0.63	0.63

Subfamily VALVULININAE Berthelin, 1880

Genus CLAVULINA d'Orbigny, 1826

Type Species: *Clavulina parisiensis* d'Orbigny, 1826

CLAVULINA sp. cf. C. YABEI AKIENSIS Asano, 1936

(Pl. 11, figs 2, 3)

1936 *Clavulina yabei akiensis* Asano, p. 944, pl. 52, figs 4, 5.
1937b *Clavulina yabei* Asano, var. *akiensis* Asano; Cushman, p. 21, pl. 2, figs 18, 19.
1950 *Clavulina yabei akiensis* Asano, 1936; Asano, p. 2, figs 7, 8.

Description. Test elongate; initial end with chambers triserially arranged, triangular in cross section, broadening rapidly distally, periphery subacute; chambers rapidly becoming uniserially arranged, with diameter less than the width of the final three triserially arranged chambers, giving the initial end a knob-like appearance;

uniserial chambers 4 in number, triangular in transverse section, becoming rounded in last chamber, enlarging slowly, about twice as wide as high; periphery subangular to subrounded; sutures moderately distinct, slightly depressed, narrow, at right angles to direction of growth in uniserial part, gently arched across the faces; wall coarsely agglutinated, rough; aperture terminal, rounded with valvular tooth.

Remarks. The Wreck Island specimens are close to *C. yabei akiensis* Asano from the Pliocene of Japan, but are inadequate to permit a positive identification.

Distribution. At 575, 940, and 950 feet in Wreck Island No. 1.

Dimensions of figured specimens:	*Length*	*Diameter*
F48936	1.0+	0.38
F48937	1.10	0.38

Genus CYLINDROCLAVULINA Bermudez & Key, 1952

Type species: *Clavulina bradyi* Cushman, 1911 (=*Glandulina rudis* Costa, 1857), by original designation.

A study of topotype material of *'Clavulina bradyi'* from Fiji and specimens from Victoria, New Guinea, and Wreck Island, together with a study of the literature, leads to the conclusion that Cushman's species is a junior synonym of *C. rudis* Costa.

Costa (1855, p. 142, pl. 1, figs 12, 13) (vide Ellis & Messina, 1940 et seq.) figured two specimens, an external and an internal view. The external view shows a coarsely agglutinated test which is cylindrical throughout and has indistinct chambers and a thick wall. The internal section has not been cut centrally and therefore does not exhibit the early biserial or triserial chambers.

Hantken (1875, p. 18, pl. 1, fig. 8) figured two external views and an internal view when he erected his species *Clavulina cylindrica,* which he later (1889, p. 383) renamed *C. rudislosta* because the name was preoccupied by *C. cylindrica* d'Orbigny, 1826. The external views show that the species is cylindrical throughout and the chambers indistinct, while the internal view shows the chambers to be biserially arranged and undivided. Hantken's species is therefore placed in synonymy with Costa's species.

Brady (1884, p. 396, pl. 48, figs 32-38) identified specimens from Challenger station 174C off Fiji as *Clavulina cylindrica* Hantken. Cushman (1911, pp. 73-74, tfs. 118, 119) erected a new species *Clavulina bradyi,* designating Brady's specimens as types, but Cushman apparently had not examined Brady's material and had mistakenly stated in the synonymy that Brady had used *C. cylindrica* d'Orbigny, whereas Brady had actually used Hantken's species.

Chapman (1926, p. 36, pl. 8, fig. 11) figured a specimen he identified as *Clavulina rudis* from the Tertiary of New Zealand. He placed *Clavulina cylindrica* of Hantken and Brady in synonymy with *C. rudis,* but made no mention of Cushman's previous work.

Cushman (1937b, pp. 169-170, pl. 20, figs 17-22) placed the species *rudis* and *bradyi* in the genus *Liebusella.* In his discussions on *Liebusella rudis* he stated that the Recent material of the Pacific and tropical Atlantic have been referred to Costa's species, but that the two species seem to be distinct. Cushman did not elaborate the differences. Chapman (1906, p. 88) recorded *Clavulina rudis* and *C. soldanii* from the Recent of Great Barrier Island off the west coast of New Zealand, but did not describe or figure the specimens. Cushman (loc. cit.) placed Chapman's *C. soldanii* in synonymy with *Liebusella bradyi.* Assemblage slides picked from Chapman's material in the W. G. Parr collection contain Chapman's *Clavulina rudis* and *C. soldanii,* which are both conspecific with the Queensland specimens. The *C. rudis* is the typical form, whereas the *C. soldanii* differs in the walls, which are thinner and made up of finer organic particles, and in the distinct and more depressed sutures. The differences are due to their being of different generations and having different wall texture and thickness.

In their description of *Cylindroclavulina,* Bermudez & Key (1952, p. 76) (vide Ellis & Messina, 1940 et seq.) stated that Colom (1945, pp. 28-30, pl. 11, figs 151-157) figured 6 specimens which he identified as *Liebusella? rudis* from the lower Miocene of Spain but which Bermudez & Key placed in synonymy with *C. bradyi,* their designated type species.

Barker (1960, p. 98, pl. 48, figs 32-38) placed Brady's specimens in *Cylindroclavulina bradyi* (Cushman). Hornibrook (1961, p. 30) recorded *Liebusella bradyi* from the lower Oligocene to Recent in New Zealand and, like Cushman, placed Chapman's *Clavulina soldanii* in synonymy.

The Wreck Island specimens were compared with specimens from Challenger station 174C near Fiji in the Bureau of Mineral Resources collections and were found to be conspecific. In his discussions on *Liebusella rudis,* Cushman (1937b, p. 169) recorded the species from the Miocene of Western Beach, Geelong, and from the 'upper Oligocene' (now Miocene) Balcombian of Balcombe Bay, Mornington, and a single specimen from Altona coal shaft near Port Phillip in Victoria. Specimens which had been identified as *Liebusella rudis* from Tambo River cliffs and Altona coal shaft and as *Clavulina cylindrica* Hantken from 433 feet in No. 9 bore, Parish of Colquhoun, Gippsland, Victoria, in the Bureau of Mineral Resources collections were found to be conspecific with the Queensland specimens. The species was also seen in a lower Miocene sample from 22 miles south-west of Laiagam and 15 miles south-south-east of Porgera in the Wabag area of the Western Highlands of New Guinea. Large specimens up to 5.22

mm long and 3 mm across were also identified in samples 7/1946 and 8/1946 dredged during the voyage of FIS. 'Endeavour' in 1912 from the Great Australian Bight and housed in the W. J. Parr collection.

It is evident from the literature that two species *rudis* and *bradyi* have been thoroughly confused. The present study confirms the opinion that they are one and the same species, and *Cylindroclavulina bradyi* is therefore a junior synonym of *C. rudis*.

CYLINDROCLAVULINA RUDIS (Costa, 1855)

(Pl. 11, figs 4-10; Plate 12, figs 1a-c)

1855	*Glandulina rudis* Costa, p. 142, pl. 1, figs 1, 2.
1875	*Clavulina cylindrica* Hantken, p. 18, pl. 1, fig. 8.
1884	*Clavulina cylindrica* Hantken; Brady, p. 396, pl. 48, figs 32-38.
1889	*Clavulina rudislosta* Hantken, p. 383.
1906	*Clavulina rudis* Costa; Chapman, p. 82.
1906	*Clavulina soldanii* Chapman, p. 88. (*non* Parker & Jones).
1911	*Clavulina bradyi* Cushman, p. 73, text-figs 118, 119.
1921	*Clavulina bradyi* Cushman; Cushman, p. 155, pl. 31, fig. 4.
1926	*Clavulina rudis* (Costa); Chapman, p. 36, pl. 8, fig. 11.
1937b	*Liebusella rudis* (Costa); Cushman, p. 168, pl. 20, figs 17-21.
1937b	*Liebusella bradyi* (Cushman); Cushman, p. 169, pl. 20, fig. 22.
1956	*Clavulina rudis* (Costa); Agip Mineraria, pl. 4, fig. 1.
1960	*Cylindroclavulina bradyi* (Cushman); Barker, p. 98, pl. 48, figs 32-38.

Description. Test elongate, cylindrical, circular in transverse section, gradually broadening distally, widest part formed by last chamber; chambers not discernible in the large megalospheric specimens but moderately distinct in the smaller microspheric specimens, initially triserially arranged, rapidly becoming biserial and then uniserial in the adult; uniserial chambers 2 to 5 in number, of constant shape, enlarging slowly, about as wide as high; internally, chambers undivided throughout; sutures where visible are depressed, concave; wall thick, coarsely agglutinated, smooth, formed almost entirely of bolivinid and globigerine foraminifers with some rotaline and miliolid forms; aperture terminal, at end of short neck with serrated rim, small tooth projecting from one margin.

Remarks. One of the main features of the species is the formation of the wall with small foraminiferal tests.

In longitudinal section (Pl. 11, fig. 9) the initial triserial and biserial chambers are not easy to distinguish from the chambers of incorporated foraminifers, and the extremely thick walls also tend to obliterate the chambers. The second longitudinal section (Pl. 12, figs 1b, c) does not show the initial triserial chambers clearly because of their small size, but the undivided biserial and uniserial chambers are clearly shown. The transverse section (Pl. 11, fig. 10) shows only the early biserial chambers; the triserial chambers could not be observed during the sectioning, possibly because of their small size and the thick wall.

Distribution. At 600 and 900 to 950 feet in Wreck Island No. 1; lower Miocene of Spain, Victoria, and New Guinea; lower Miocene to upper Pliocene of Italy; Miocene of Austria, Hungary, and Egypt; Recent of Atlantic Ocean, Philippines, Fiji, Malay Archipelago; lower Oligocene to Recent of New Zealand; 'upper Eocene' of south-east Borneo.

Dimensions of figured specimens:	*Height*	*Diameter*
F48938	3.0	1.5
F48939	1.95	0.7
F48940	2.2	0.85
F48941	1.95	0.75
F48942	1.5	0.5
F48943	1.45	0.65
F48944	—	0.65
F48945	1.55	0.5

Subfamily ATAXOPHRAGMIINAE Schwager, 1877

Genus CUBANINA Palmer, 1936

Type Species: *Cubanina alavensis* Palmer, 1936

CUBANINA VICTORIENSIS (Cushman, 1936)

(Pl. 12, figs 2-13)

1907 *Clavulina angularis* Chapman, p. 29, pl. 4, figs 68-73. (non d'Orbigny).
1936 *Clavulinoides szaboi* (Hantken) var. *victoriensis* Cushman, p. 22, pl. 3, figs 19, 22.
1937a *Clavulinoides szaboi* (Hantken) var. *victoriensis* Cushman; Cushman, p. 134, pl. 18, figs 35, 36.

Description. Test elongate, initial end rapidly broadening distally, edges becoming almost parallel in most specimens but broadening throughout in some specimens, widest part formed by last chamber, triangular in transverse section; chambers initially triserially arranged, rapidly becoming uniserially arranged; uniserial chambers distinct, 6 in number, enlarging gradually, twice as wide as high, mainly uniform in shape but last chamber sometimes becoming globular, becoming more embracing distally, triangular in transverse section but last chamber sometimes circular; periphery in the triserial part acute, becoming subacute to subrounded in the uniserial part and sometimes rounded in last chamber; internally the chambers are partly subdivided by 3 narrow vertical partitions projecting somewhat inwards from the agglutinated wall, but not extending above the previous aperture; sutures distinct, depressed, slightly arched across the faces; faces flat to gently concave; walls coarsely agglutinated, rough; aperture terminal, circular opening at end of small neck with serrated rim.

Remarks. The Wreck Island specimens were compared with specimens of *'Clavulinoides szaboi* var. *victoriensis'* from 253 to 270 feet in Dimboola No. 1 bore in the Murray Basin of Western Victoria and the base of Rock Cliff, Torquay, Victoria (the type locality of the species) and found to be conspecific, having the internal partitions of the chambers, which were not seen by Cushman. Most of the Wreck Island specimens (such as those figured on Pl. 12, figs 2, 3a) are similar to Cushman's figured paratype, having near-parallel sides, but some (Pl. 12, figs 4, 5) are broadening throughout as in his holotype. Externally there are close similarities with the specimens figured as *Clavulinoides szaboi* by LeRoy (1941a, p. 20, pl. 1, figs 55, 56) from the Miocene of Borneo, Cushman (1937a, pl. 18, figs 33, 34) from the Oligocene of Hungary, and Agip Mineraria (1957, pl. 3, fig. 10) from the Eocene and Oligocene of Italy; these differ externally only in the more rounded periphery. In Cushman's description of his variety, he mentioned that his specimens did not possess as definite a neck as *C. szaboi,* but the Wreck Island and the Victorian specimens examined possess necks as well developed as *C. szaboi.* The internal characters of the chambers of *C. szaboi* are not described; in the absence of this information it is considered that Cushman's variety should be elevated and treated as a separate species. The types designated by Cushman in establishing his variety are the designated types of *Cubanina victoriensis.*

Distribution. From 535 to 960 feet in Wreck Island No. 1; Oligocene to lower Miocene of Victoria; and middle Oligocene to lower Miocene of the Mount Gambier area, South Australia.

Dimensions of figured specimens:	*Height*	*Width*
F48946	2.70	0.75
F48947	3.40	0.80
F48948	2.05	1.13
F48949	1.50	0.75
F48950	1.20	0.75
F48951	0.75	0.50
F48952	0.95	0.63
F48953	1.60	0.60
F48954	1.20	0.60
F48955	—	0.50
F48956	—	0.60
F48957	—	0.75

Suborder MILIOLINA Delage & Herouard, 1896

Superfamily MILIOLACEA Ehrenberg, 1839

Family NUBECULARIIDAE Jones, 1875

Subfamily SPIROLOCULININAE Wiesner, 1920

Genus SPIROLOCULINA d'Orbigny, 1826

Type Species: *Spiroloculina depressa* d'Orbigny, 1826

SPIROLOCULINA COMMUNIS Cushman & Todd, 1944

(Pl. 13, figs 1a-c)

1884	*Spiroloculina excavata* Brady, p. 151, pl. 9, figs 5, 6. (*non* d'Orbigny).
1944	*Spiroloculina communis* Cushman & Todd, p. 63, pl. 9, figs 4, 5, 7, 8.
1951	*Spiroloculina communis* Cushman & Todd, 1944; Asano, p. 13, figs 87, 88.
1960	*Spiroloculina communis* Cushman & Todd; Barker, p. 18, pl. 9, figs 5, 6.

Spiroloculina communis was found at 725 feet in Wreck Island No. 1 only. It has been recorded from the Pliocene of Japan and the Recent of the Pacific.

Dimensions of figured specimen:	*Height*	*Width*	*Thickness*
F48958	0.68	0.33	0.2

SPIROLOCULINA sp. cf. S. CORRUGATA Cushman & Todd, 1944

(Pl. 13, figs 2a-c)

cf.

1944	*Spiroloculina corrugata* Cushman & Todd, p. 61, pl. 8, figs 22-25.
1951	*Spiroloculina corrugata* Cushman & Todd, 1944; Asano, p. 13, figs 91, 92.

One specimen close to *S. corrugata* was found in core 5 (614-625 feet) in Wreck Island No. 1. It differs from the species as described and figured by Cushman & Todd from the Recent of the Philippines in having a simple tooth and costae which are oblique to the periphery. The specimen figured by Asano from the Pliocene of Japan has a single tooth similar to the Wreck Island specimen and not bifid as in the holotype.

Dimensions of figured specimen:	*Height*	*Width*	*Thickness*
F48959	0.60	0.40	0.15

Subfamily QUINQUELOCULININAE Cushman, 1917

Genus QUINQUELOCULINA d'Orbigny, 1826

Type Species: *Serpula seminulum* Linné, 1758

QUINQUELOCULINA sp. aff. Q. YABEI Asano, 1936

(Pl. 13, figs 3, 4)

aff.

1936	*Quinqueloculina yabei* Asano, p. 942, pl. 51, figs 1a-c.
1951	*Quinqueloculina yabei* Asano, 1936; Asano, p. 8, figs 57-59.

Two specimens were found which are close to *Q. yabei.* Both specimens have a simple tooth as against a bifid tooth in *Q. yabei* and one specimen (fig. 4) has its apertural end slightly produced.

Distribution. From 1000 feet in Wreck Island No. 1 and 704 to 712 feet in Heron Island Bore. *Q. yabei* has been recorded from the Pliocene to Recent of Japan.

Dimensions of figured specimens:	*Height*	*Width*	*Thickness*
F48960 …… …… …… …… ……	0.75	0.6	0.45
F48961 …… …… …… …… ……	0.5	0.3	0.2

QUINQUELOCULINA PSEUDORETICULATA Parr, 1941

(Pl. 13, figs 5a-c)

1884	*Miliolina reticulata* Brady, p. 177, pl. 9, figs 2, 3. (*non* d'Orbigny).
1941	*Quinqueloculina pseudoreticulata* Parr, p. 305.
1941a	*Quinqueloculina reticulata* LeRoy, p. 22, pl. 3, figs 1, 2. (*non* d'Orbigny).
1941b	*Quinqueloculina reticulata* LeRoy, p. 71, pl. 5, figs 1, 2. (*non* d'Orbigny).
1941b	*Quinqueloculina reticulata* (d'Orbigny) var. *elongata* LeRoy, p. 71, pl. 5, figs 13, 14. (*non* d'Orbigny).
1946	*Quinqueloculina reticulata* Germeraad, p. 63, pl. 1, figs 10, 11. (*non* d'Orbigny).
1951	*Quinqueloculina reticulata* Asano, p. 6, figs 35, 36. (*non* d'Orbigny).
1960	*Quinqueloculina pseudoreticulata* Parr; Barker, p. 18, pl. 19, figs 2, 3.

Only a single specimen which is considered to be conspecific with Brady, Asano, Germeraad, and LeRoy's specimens was found.

The specimen is slightly damaged and the sutures are not all distinct; outwardly it appears to be triloculine, but it could as easily be a result of the preservation as actually a triloculine form. As the specimen resembles Brady's specimens in every other way it was placed in this species and genus.

Brady and LeRoy followed d'Orbigny (1826) in the identification of their species. Soldani had previously described and figured as *Frumentaria reticulata* a form which d'Orbigny placed in synonymy with his species *Triloculina reticulata.*

Parker, Jones, & Brady (1871, pl. 18, fig. 18) refigured Soldani's figures, which are very idealized and of little value in identifying the species. Parr, in erecting his species, used Brady's figured specimen as the holotype and had not examined the original specimens of d'Orbigny. D'Orbigny's species is poorly figured and not described and may be best allowed to lapse unless his original specimens are re-examined; until this is done and adequately described and illustrated it is thought best to use Parr's species. LeRoy's variety comes within the normal variations of the species.

Distribution. From 1050 feet in Wreck Island No. 1 only; from the 'late Tertiary' of Indonesia, Pliocene of Japan, and the Recent of the Great Barrier Reef and the Great Australian Bight of Australia.

Dimensions of figured specimen:	*Height*	*Width*	*Thickness*
F48962	1.0	0.8	0.6

QUINQUELOCULINA sp. cf. Q. VULGARIS d'Orbigny, 1826

(Pl. 13, figs 6, 7)

cf.

1917	*Quinqueloculina vulgaris* d'Orbigny; Cushman, p. 46, pl. 11, fig. 3.
1951	*Quinqueloculina vulgaris* d'Orbigny, 1826; Asano, p. 8, figs 54-56.
1957	*Quinqueloculina vulgaris* d'Orbigny; Agip Mineraria, pl. 6, fig. 8.

The four specimens placed here occur at 1750 feet in Wreck Island No. 1. They are damaged and partly abraded, and have a pitted surface; the sutures are not distinct and only 3 or 4 chambers can be seen. They have similar outlines, chamber shapes, aperture, and tooth to the specimen figured by Asano from the Pliocene of Japan, but the preservation prevents a positive identification. The Wreck Island specimens, like the Japanese specimen, have a long simple tooth and bluntly angular peripheries, whereas the holotype figured by d'Orbigny (vide Ellis & Messina, 1940 et seq.) has a bifid tooth and acute peripheries. They are also closely comparable with this species as figured by Cushman (1917) from the Recent of the Northern Pacific.

Dimensions of figured specimens:	*Height*	*Width*	*Thickness*
F48963	1.30	1.14	0.60
F48964	1.25	1.20	0.75

QUINQUELOCULINA GRANULOCOSTATA Germeraad, 1946

(Pl. 13, figs 8a-c)

1884	*Miliolina linnaeana* (d'Orbigny); Brady, p. 174, pl. 6, figs 15, 20.
1946	*Quinqueloculina granulo-costata* Germeraad, p. 63.
1960	*Quinqueloculina granulo-costata* Germeraad; Barker, p. 12, pl. 6, figs 15-20.

One specimen belonging to *Q. granulocostata* from the Recent of the Pacific was found at 1150 feet in Wreck Island No. 1. Although the specimen was broken the species is easily recognized from its very strong costae.

Dimensions of figured specimen:	*Height*	*Width*	*Thickness*
F48965	1.25	0.60	0.40

QUINQUELOCULINA sp. cf. Q. SUBSTRIATA Bandy, 1949

(Pl. 13, figs 9a-c; Pl. 14, figs 1a-c)

1949 *Quinqueloculina substriata* Bandy, p. 21, pl. 2, fig. 3.

Two specimens found from 1750 feet in Wreck Island No. 1 compare very closely with *Q. substriata* from the upper Eocene of Alabama, U.S.A. One specimen is smaller and more compressed than the other, but they are considered to be conspecific.

Dimensions of figured specimens:	*Height*	*Width*	*Thickness*
F48966	1.50	0.70	0.38
F48967	1.0	0.45	0.20

QUINQUELOCULINA sp. cf. Q. NEWBERRYENSIS Puri, 1957

(Pl. 14, figs 2, 3)

cf.
1957 *Quinqueloculina newberryensis* Puri, p. 107, pl. 3, figs 6a-c.

Several specimens compare closely with *Q. newberryensis* in chamber arrangement and shape and the nature of the sutures, but differ from it in having a smooth surface and an aperture which is indistinct but appears to be a simple arched slit.

Distribution. From 540 to 1550 feet in Wreck Island No. 1 and 386 to 712 feet in Heron Island Bore. *Q. newberryensis* was described from the upper Eocene of Florida, U.S.A.

Dimensions of figured specimens:	*Height*	*Width*	*Thickness*
F48968	1.20	0.80	0.63
F48969	0.38	0.30	0.20

QUINQUELOCULINA AKNERIANA d'Orbigny, 1846

(Pl. 14, figs 4a-c)

1846 *Quinqueloculina akneriana* d'Orbigny, p. 290, pl. 18, figs 16-21.
1941b *Quinqueloculina akneriana* d'Orbigny; LeRoy, p. 71, pl. 5, figs 15, 16.
1944 *Quinqueloculina* aff. *akneriana* d'Orbigny; LeRoy, p. 16, pl. 3, figs 21-23.
1951 *Quinqueloculina akneriana* d'Orbigny, 1846; Asano, p. 2, figs 6-8.

Q. akneriana is rare in the Heron Island Bore. The specimen identified as *Q.* aff. *akneriana* by LeRoy (1944a) is so close to the Queensland specimens that it is considered to belong to this species.

Distribution. From 386 to 712 feet in Heron Island Bore with a possible occurrence between 180 to 200 feet; Pliocene of Japan; lower and middle Miocene and 'late Tertiary' of Indonesia; and the Tertiary of Vienna.

Dimensions of figured specimen:	*Height*	*Width*	*Thickness*
F48970	0.55	0.40	0.25

Genus PYRGO Defrance, 1824

Type Species: *Pyrgo laevis* Defrance, 1824

PYRGO sp. cf. P. LUCERNULA (Schwager, 1866)

(Pl. 14, figs 5a, b)

cf.

1866	*Biloculina lucernula* Schwager, p. 202, pl. 4, fig. 17.
1917	*Biloculina lucernula* Schwager; Cushman, p. 79, pl. 32, figs 2a-c.
1921	*Biloculina lucernula* Schwager; Cushman, p. 475, pl. 98, figs 1a-c.
1941	*Pyrgo lucernula* (Schwager); LeRoy, p. 72, pl. 2, figs 27, 28; pl. 5, figs 17, 18.

The Queensland specimens have very inflated rounded chambers and depressed sutures, and compare closely with *P. lucernula* as described and illustrated by Schwager, Cushman, and LeRoy. The aperture is damaged on the Queensland specimens and this prevents positive identification.

Distribution. From 545 to 725 feet in Wreck Island No. 1; 'younger Tertiary' of Kar Nikobar, India; 'late Tertiary' of Indonesia; and Recent of the Philippines.

Dimensions of figured specimen:	*Height*	*Width*	*Thickness*
F48971	0.5	0.35	0.4

PYRGO sp. cf. P. DEPRESSA (d'Orbigny, 1826)

(Pl. 14, figs 6, 7)

1826	*Biloculina depressa* d'Orbigny, p. 298.
1871	*Biloculina depressa* d'Orbigny; Parker, Jones, & Brady, pp. 247, 263, pl. 8. fig. 5.
1884	*Biloculina depressa* d'Orbigny; Brady, pp. 145-146, pl. 2, figs 12, 16, 17; pl. 3, figs 1, 2.
1917	*Biloculina depressa* d'Orbigny; Cushman, p. 174, pl. 28, figs 1, 2.
1921	*Biloculina depressa* d'Orbigny; Cushman, pp. 469-470, pl. 96, fig. 2, text-figs 45-47.
1929	*Pyrgo depressa* (d'Orbigny); Cushman, p. 71, pl. 19, figs 4, 5.
1951	*Pyrgo depressa* (d'Orbigny, 1826); Asano, p. 18, figs 122, 123.
1960	*Pyrgo depressa* (d'Orbigny); Barker, pp. 4-6, pl. 2, figs 12, 16, 17, pl. 3, figs 1, 2.

Strongly compressed specimens closely comparable with this widespread Pliocene to Recent species as figured by Brady, Cushman, and Asano were found at 550, 700 and 1750 feet in Wreck Island No. 1 and at 693 to 696 feet in Heron Island Bore. The preservation of the specimens was not good enough to permit a positive identification.

Dimensions of figured specimens:	*Height*	*Width*	*Thickness*
F48972	0.70	0.63	0.38
F48973	0.70	0.63	0.50

Genus TRILOCULINA d'Orbigny, 1826

Type Species: *Miliolites trigonula* (Lamarck, 1804)

TRILOCULINA TRIGONULA Lamarck, 1804

(Pl. 14, figs 8, 9)

1804 *Miliolites trigonula* Lamarck, p. 351, pl. 17, fig. 4.
1884 *Miliolina trigonula* (Lamarck); Brady, p. 164, pl. 3, figs 15, 16.
1917 *Triloculina trigonula* (Lamarck); Cushman, p. 15, pl. 25, fig. 3.
1929 *Triloculina trigonula* (Lamarck); Cushman, p. 56, pl. 12, figs 10, 11; pl. 13, figs 1, 2.
1941a *Triloculina trigonula* (Lamarck); LeRoy, p. 22, pl. 3, figs 26-28.
1949 *Triloculina trigonula* (Lamarck); Boomgaart, p. 66, pl. 5, fig. 13.
1951 *Triloculina trigonula* (Lamarck 1804); Asano, p. 17, text-figs 116, 117.
1957 *Triloculina trigonula* (Lamarck); Agip Mineraria, pl. 8, fig. 3.
1960 *Triloculina trigonula* (Lamarck); Barker, p. 6, pl. 3, figs 15, 16.

This widespread late Tertiary to Recent species was found at 545 to 575 and 1545 feet and in core 11 (1600-1610 feet) in Wreck Island No. 1.

One specimen (Pl. 14, fig. 8) appears to differ from typical forms of the species in the sizes of the chambers and the position of the sutures, but it is considered to be an immature form. In the second specimen (Pl. 14, fig. 9) an apparent short neck has been accentuated by damage to the apertural region.

Dimensions of figured specimens:	*Height*	*Width*	*Thickness*
F48974	0.40	0.25	0.25
F48975	0.60	0.40	0.45

TRILOCULINA sp. cf. T. LAEVIGATA d'Orbigny, 1878

(Pl. 15, figs 1-4)

cf.
1878 *Triloculina laevigata* d'Orbigny; Terquem, p. 57, pl. 5, figs 20, 21.
1955 *Triloculina laevigata* d'Orbigny, 1826; Asano. p. 15, figs 103-105.

A number of specimens, varying slightly from one another, are well similar to *T. laevigata.* They also show some similarities with *T. oblonga* as figured by Pezzani (1963, p. 603, pl. 35, fig. 1) and Cushman (1917, p. 69, text-figs 35, 36, pl. 26, fig. 3; 1929; p. 57, pl. 13, figs 4, 5), from the Pliocene of Italy and the Recent of the Atlantic Ocean respectively; and with *T. longissima* of Galloway & Heminway from the Oligocene of Puerto Rico.

Distribution. At 560, 675, 1500, and 1545 feet and in core 11 (1600-1610 feet) in Wreck Island No. 1, *T. laevigata* has been recorded from the Pliocene of Japan and France and the Recent of the Mediterranian.

Dimensions of figured specimens:	*Height*	*Width*	*Thickness*
F48974	1.3	0.65	0.45
F48975	0.38	0.20	0.13
F48976	0.70	0.33	0.22
F48977	0.45	0.25	0.15

TRILOCULINA LITTORALIS Collins, 1958

(Pl. 15, figs 5a-c)

1958 *Triloculina littoralis* Collins, p. 369, pl. 3, figs 12a-c.

A single specimen belonging to *Triloculina littoralis* was found at 704 to 712 feet in Heron Island Bore. The species was originally described from the Recent of the Great Barrier Reef, Queensland.

Dimensions of figured specimen:	*Height*	*Width*	*Thickness*
F48978	0.40	0.25	0.18

Family SORITIDAE Ehrenberg, 1839

Subfamily SORITINAE Ehrenberg, 1839

Genus MARGINOPORA de Blainville, 1830

Type Species: *Marginopora vertebralis* Quoy & Gaimard *in* de Blainville, 1830

MARGINOPORA VERTEBRALIS Quoy & Gaimard *in* de Blainville, 1830

(Pl. 15, fig. 6)

1830 *Marginopora vertebralis* Quoy & Gaimard *in* de Blainville, p. 377, pl. 69, figs 6, 6a-c.
1884 *Orbitolites complanata* Lamarck; Brady, p. 218, pl. 16, figs 1-6.
1917 *Orbitolites complanata* Lamarck; Cushman p. 95, pl. 39, fig. 2.
1924 *Marginopora vertebralis* Quoy & Gaimard; van der Vlerk, pp. 26-27, pl. 4. figs 14, 15.
1942 *Marginopora vertebralis* Blainville; Cushman, pl. 12, fig. 6,
1954 *Marginopora vertebralis* Quoy & Gaimard; Cole, pp. 582-583, pl. 210, figs 10-13, pl. 211, figs 3-29.
1960 *Marginopora vertebralis* Blainville; Barker, p. 32, pl. 16, figs 1-6.
1964 *Marginopora vertebralis* Quoy & Gaimard *in* de Blainville, 1830; Loeblich & Tappan, p. 498, fig. 384 (3, 4).
1965 *Marginopora vertebralis* Quoy & Gaimard; Jell, Maxwell, & McKellar, pl. 44, fig. 1.

This widespread middle Miocene to Recent species occurred from 535 to 1625 feet in Wreck Island No. 1 and from 252 to 258 feet in Heron Island Bore. Cushman (1942) recorded *M. vertebralis* from 0 to 17 feet and a *Marginopora* sp. at 704 feet in the Heron Island Bore.

Dimensions of figured specimen:	*Diameter*	*Thickness*
F48979	1.75	0.35

Family ALVEOLINIDAE Ehrenberg, 1839

Genus ALVEOLINELLA Douville, 1906

Type Species: *Alveolinella quoii* d'Orbigny, 1826

ALVEOLINELLA QUOYI (d'Orbigny, 1826)

(Pl. 15, fig. 7)

1826 *Alveolina quoii* d'Orbigny, p. 307, pl. 17, figs 11-13.
1884 *Alveolina boscii*, Defrance; Brady, p. 222, pl. 17, figs 7-12.
1917 *Alveolina boscii* (Defrance); Cushman p. 98, pl. 39, fig. 3.
1921 *Alveolina boscii* (Defrance); Cushman, p. 487, pl. 99, figs 2-5.
1958 *Alveolinella quoyi* (d'Orbigny); Todd & Post, p. 558, pl. 202, figs 5, 8.
1960 *Alveolinella quoyi* (d'Orbigny); Barker, p. 34, pl. 17, figs 7-12.

This middle Miocene to Recent species was found from 535 to 1000 feet in Wreck Island No. 1; and from 552 to 567 feet in Heron Island Bore.

Dimensions of figured specimen:	*Length*	*Thickness*
F48980	3.0	1.0

BIBLIOGRAPHY

AGIP MINERARIA, 1957—Foraminifera Padani (Tersiario e Quaternario). Atlante iconografico e Distribuzione stratigrafica. *Agip Mineraria, Milan.*

ASANO, K., 1936—New species of Foraminifera from Aki-gun, Tosa Province, Japan. (Studies on the fossil Foraminifera from the Neogene of Japan; Part 7). *J. geol. Soc. Japan,* 43(519), 942-946.

ASANO, K., 1950—Illustrated catalogue of Japanese Tertiary smaller Foraminifera. Part 4; Valvulinidae. *Inst. Geol. Paleont. Tohoku Univ., Sendai, Japan.*

ASANO, K., 1951—*Idem.* Part 6; Miliolidae. *Ibid.*

BANDY, O. L., 1949—Eocene and Oligocene Foraminifera from Little Stave Creek, Clarke County, Alabama. *Bull. amer. Paleont.,* 32(131), 5-211.

BARKER, R. W., 1960—Taxonomic notes on the species figured by H. B. Brady on the Foraminifera dredged by H.M.S. Challenger during the years 1873-1876. *Spec. Publ. Soc. econ. Paleont. Miner.,* 9.

*BERMUDEZ, P. J., and KEY, C. E., 1952—Tres géneros nuevos de foraminíferos de las familias Reophacidae y Valvulinidae. *Mem. Soc. Cien. La Salle, Caracas, Venezuela,* 12(31), 71-76.

*BLAINVILLE, H. M. DUCROTAY de, 1830—Zoologie: conchyliologie et malacologie. In: *Dictionnaire des Sciences Naturelles,* 60, 1-631. *Paris, F. G. Levrault.*

BOOMGAART, L., 1949—Smaller Foraminifera from Bodjonegoro (Java). *Geol. Inst., Univ. Utrecht.*

BRADY, H. B., 1884—Report on the scientific results of the voyage of H.M.S. Challenger during the years 1873-76, Zoology, 9.

CARTER, A. N., 1964—Tertiary Foraminifera from Gippsland, Victoria, and their stratigraphical significance. *Mem. geol. Surv. Vic.,* 23.

CHAPMAN, F., 1906—On some Foraminifera and Ostracoda obtained off Great Barrier Island, New Zealand. *Trans. N.Z. Inst.,* (1905), 38, 77-112.

CHAPMAN, F., 1907—Tertiary Foraminifera of Victoria, Australia. The Balcombian deposits of Port Phillip. *J. linn. Soc. Lond., Zool.,* 30, 10-38.

CHAPMAN, F., 1926—The Cretaceous and Tertiary Foraminifera of New Zealand with an appendix on the Ostracoda. *Palaeont. Bull. N.Z. geol. Surv.,* 11.

COLE, W. S., 1954—Larger Foraminifera and smaller diagnostic Foraminifera from Bikini drill holes. *In*: Bikini and nearby Atolls, Pt 4, Paleontology. *Prof. Pap. U.S. geol. Surv.,* 260-0, 569-608.

COLLINS, A. C., 1958—Foraminifera. *Sci. Rep. Brit. Mus. (nat. Hist.) Great Barrier Reef Exped. 1928-1929,* 6(6), 335-437.

*COLOM, C., 1945—Los foraminiferos de 'concha arenacea' de las margas burdigalienses de Mallorca. *Inst. Invest. geol. 'Lucas Mallada', Estud. geol., Madrid,* 2, 3-33.

*COSTA, O. S., 1855—Foraminiferi fossili della marne Terziarie di Messina. *Mem. R. Accad. Sci. Napoli,* 2.

CRESPIN, Irene, 1960—Preliminary note on micropalaeontology. *In* Completion report H.B.R. No. 1 Wreck Island. *Bur. Miner. Resour. Aust. Petrol. Search Subs. Acts Publ.* 4, 12.

CUSHMAN, J. A., 1911—A monograph of the Foraminifera of the North Pacific Ocean. Part 2; Textulariidae. *Bull. U.S. nat. Mus.* 71.

CUSHMAN, J. A., 1917—Part 6; Miliolidae. *Ibid.,* 71.

CUSHMAN, J. A., 1937b—A monograph of the foraminiferal family Valvulinidae. *Ibid.* 8.

CUSHMAN, J. A., 1942—A report on samples obtained by the boring at Heron Island, Great Barrier Reef, Australia. *Rep. Gt Barr. Reef Comm.,* 5, 112-119.

CUSHMAN, J. A., and TODD, R., 1944—The genus *Spiroloculina* and its species. *Spec. Publ. Cushman Lab.,* 11.

DERRINGTON, S. S., 1960—Completion Report, H.B.R. No. 1, Wreck Island. *Bur. Miner. Resour. Aust. Petrol. Search Subs. Acts Publ.,* 4.

ELLIS, B. F., and MESSINA, A. M., 1940 et seq.—Catalogue of Foraminifera. *Amer. Mus. nat. Hist.*

FINLAY, H. J., 1939a—New Zealand Foraminifera: Key species in stratigraphy—No. 1. *Trans. Roy. Soc. N.Z.,* 68, 504-543.

FINLAY, H. J., 1939b—New Zealand Foraminifera: Key species in stratigraphy—No. 2. *Ibid.,* 69(1), 89-128.

*GALLOWAY, J. J., and HEMINWAY, C. E., 1941—The Tertiary Foraminifera of Porto Rico. *N.Y. Acad. Sci., sci. Surv. Porto Rico and Virgin Islands,* 3 (1920-1941) (4), 275-491.

GLAESSNER, M. F., 1945—PRINCIPLES OF MICROPALAEONTOLOGY. *Melbourne, Univ. Press.*

*HANTKEN, M. von, 1875—Die Fauna der *Clavulina szaboi*—Schichten; Theil 1—Foraminiferen Hungary. *K.ung. geol. Anst., Mitt. Jb., Budapest,* 4(1), 1-93.

HANTKEN, M. von, 1889—*In* Posewitz, T., BORNEO. Berlin, *Friedlander.*

HERON-ALLEN, E., and EARLAND, A., 1914—The Foraminifera of the Kerimba Archipelago (Portuguese East Africa), Part 1. *Trans. zool. Soc. Lond.,* 20, pt 12.

HILL, D., and DENMEAD, A. K. (eds), 1960—The geology of Queensland. *J. geol. Soc. Aust.,* 7.

HORNIBROOK, N. de B., 1961—Tertiary Foraminifera from Oamaru District (N.Z.). Part 1—Systematics and distribution. *Palaeont. Bull. N.Z. geol. Surv.,* 34(1).

HORNIBROOK, N. de B., 1965—A preliminary statement on the type of the New Zealand Tertiary Foraminifera described in the reports of the Novara Expedition in 1865. *N.Z. J. Geol. Geophys.,* 8(3), 530-536.

IREDALE, T., 1942—Report on molluscan content of Heron Island reef boring samples. *Rept. Gt Barrier Reef Comm.*, 5, 120-122.

JELL, J. S., MAXWELL, W. G. H., and MCKELLAR, R. G., 1965—The significance of the larger Foraminifera in the Heron Island reef sediments. *J. Paleont.*, 39(2), 273-279.

*KARRER, F., 1865—Die Foraminiferen-Fauna des tertiären Grunsandsteines der Orakei-Bay bei Auckland. *Novara-Exped., geol. Theil,* 1(2), 69-86.

*LAMARCK, J. B., 1804—Suite des mémoires sur les fossiles des environs de Paris. *Ann. Mus. nat. Hist. nat., Paris,* 5, 349-357.

LEROY, L. W., 1939—Some small Foraminifera, ostracoda and otoliths from the Neogene ('Miocene') of the Rokan-Tapanoeli area, Central Sumatra. *Natuurk. Tijdschr. Nederl.-Indie.*

LEROY, L. W., 1941a—Small Foraminifera from the late Tertiary of the Sangkoelirang Bay area, east Borneo, Nederlands East Indies. *Colo. Sch. Min. Quart.*, 36(1), pt 1, 1-62.

LEROY, L. W., 1941b—Small Foraminifera from the late Tertiary of Siberoet Island, off the west coast of Sumatra, Netherlands East Indies. *Ibid.*, 36(1), pt 2, 63-105.

LEROY, L. W., 1944a—Miocene Foraminifera of Central Sumatra, Netherlands East Indies. *Ibid.*, 39(3), pt 1, 1-69.

LEROY, L. W., 1944b—Small Foraminifera from the Miocene of West Java, Netherlands East Indies. *Ibid.*, 39(3), pt 2, 71-113.

LLOYD, A. R., 1961—Foraminifera from the subsurface Miocene of Wreck Island, Queensland. *Thesis, Univ. Adelaide* (unpubl.).

LOEBLICH, A. R., Jr, and TAPPAN, Helen, 1964—TREATISE ON INVERTEBRATE PALEONTOLOGY. Part C. SARCODINA, *Geol. Soc. Amer.* and *Univ. Kansas Press.*

MAXWELL, W. G. H., 1962—Lithification of carbonate sediments in the Heron Island reef, Great Barrier Reef. *J. geol. Soc. Aust.*, 8(2), 217-238.

*ORBIGNY, A. d', 1826—Tableau méthodique de la classe des Céphalopodes. *Ann. Sci. nat., Paris, ser.* 1, 7, 96-314.

*ORBIGNY, A. d', 1846—Foraminifères fossiles du bassin tertiaire de Vienne (Autriche) (Die fossilen foraminiferen des tertiaeren Beckens von Wien). *Paris, Gide et Comp.*, 1-303.

*PARKER, W. K., JONES, T. R., and BRADY, H. B., 1871—On the nomenclature of the Foraminifera; Part XIV. The species enumerated by d'Orbigny in the 'Annales des Sciences Naturelles', 1826, vol. 7 (continued from Ann. Mag. nat. Hist., ser. 3, vol. XVI, p. 41). *Ann. Mag. nat. Hist., ser.* 4, 8, 145-179.

PARR, W. J., 1941—A new genus, *Planulinoides,* and some species of Foraminifera from southern Australia. *J. Min. Geol. Vic.* 2, 305.

PEZZANI, F., 1963—Studio micropaleontologico di un Campione della Serie Messiniana di Tabiano Bagni (Parma). *Riv. ital. paleont.*, 69(4), 559-662.

*PURI, H. S., 1957—Stratigraphy and zonation of the Ocala group. *Bull. Florida geol. Surv.*, 38.

RICHARDS, H. C., 1938—Scientific investigations on the Great Barrier Reef, Australia. *Rep. Gt Barr. Reef. Comm.*, 2.

RICHARDS, H. C., and HILL, Dorothy, 1942—Great Barrier Reef bores, 1926 and 1937—descriptions, analyses, and interpretations. *Ibid.*, 5.

*SCHWAGER, C., 1866—Fossile Foraminiferen vom Kar Nikobar. *Novara Exped., Geol. Theil* 2.

*STACHE, G., 1865—Die Foraminiferen der tertiären Mergel des Whaingaroa-Hafens (Prov. Auckland). *Novara-Exped., geol. Theil,* 1(2), 159-304.

*TERQUEM, O., 1878—Les foraminifères et les entomostraces ostracodes du Pliocène superieur de l'Ile de Rhodes. *Mem. Soc. geol. Fr., ser.* 3, 1(3), 1-135.

TODD, Ruth, 1958—Smaller Foraminifera; *in* Geology of Saipan, Mariana Islands. *Prof. Pap. U.S. geol. Surv.*, 280-H, 265-320.

TODD, R., and LOW, D., 1960—Smaller Foraminifera from Eniwetok drill holes. *Ibid.*, 260-X, 799-861.

TODD, R., and POST, R., 1954—Smaller Foraminifera from Bikini drill holes: *in* Bikini and nearby atolls, Part 4, Paleontology. *Ibid.*, 260-N, 547-565.

TRAVES, D. M., 1960—Wreck Island, subsurface. *J. geol. Soc. Aust.*, 7, 369-371.

VLERK, I. M. van der, 1924—Foraminiferen uit het Tertiair van Java; 1. *Dienst Mijnb., wetensch. Meded., Ned.-O-Ind.*, 1, 16-35.

PLATE 9

All figures except thin sections are retouched photographs; magnifications approximate.

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4a, b. F 48920, (a) side view (b) edge view. x45.
4. F 48921, side view. x30.
6a-c. F 48922, (a) side view (b) edge view (c) end view. x42.
7. F 48923, side view. x42.
8. F 48924, side view. x42.
9a, b. F 48925, (a) side view (b) end view. x32.
10a, b. F 48926, (a) side view (b) end view. x30.
F 48918-20, 48923-24, 940' Wreck Island; F 48921-22, 900' Wreck Island;
F 48925-26, 960' Wreck Island.

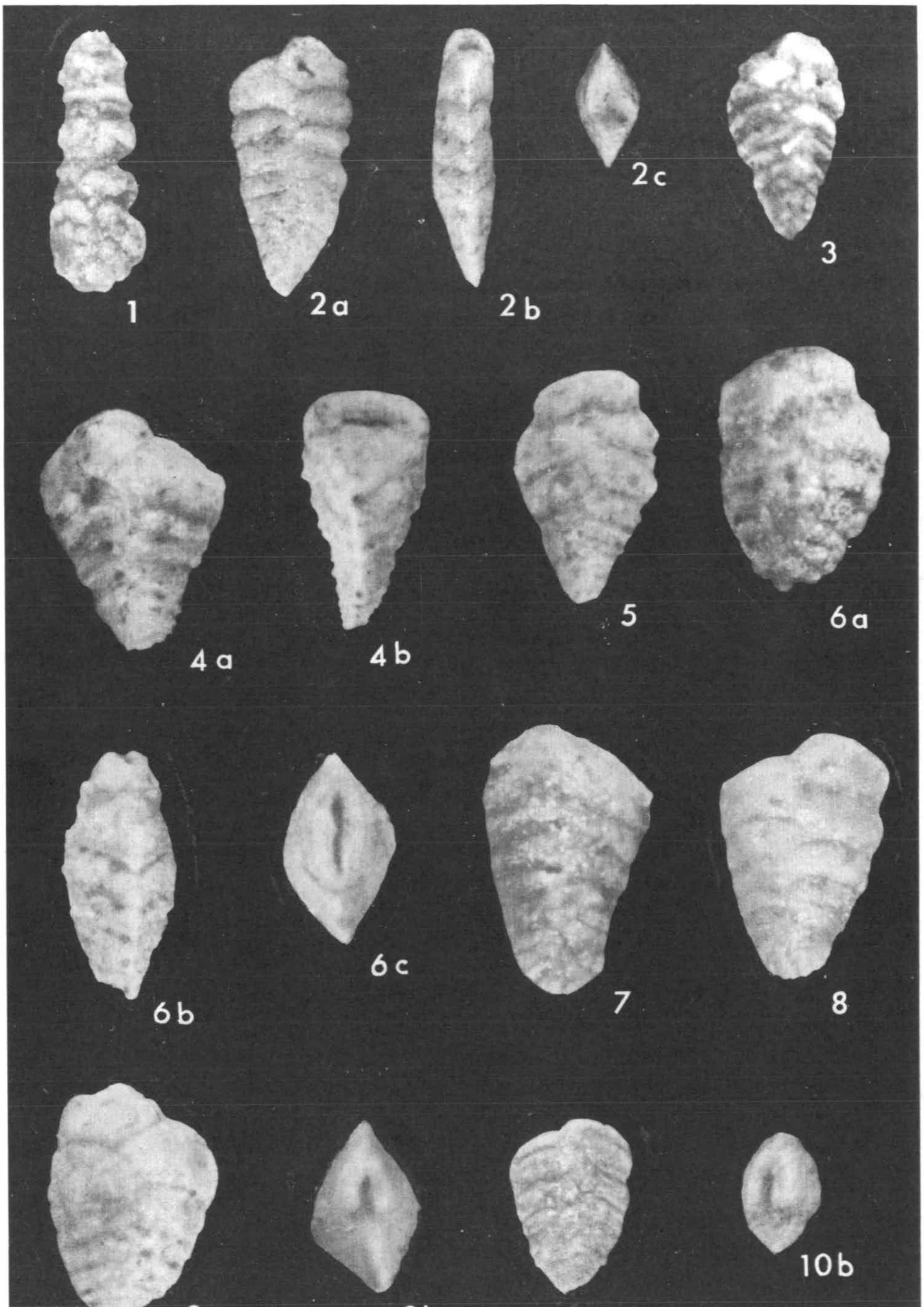

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PLATE 10

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2. F 48928. Vertical thin section, transmitted light, *Spiroplectammina* form showing textularian aperture and foramina, proloculus, and initial coiling. x40. 940′ Wreck Island.
3. F 48929. Vertical thin section, reflected light, *Vulvulina* form showing textularian foramina and *Vulvulina* terminal aperture. x50. Wreck Island.

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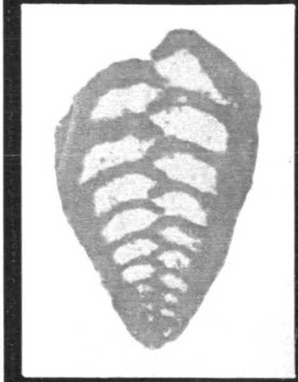

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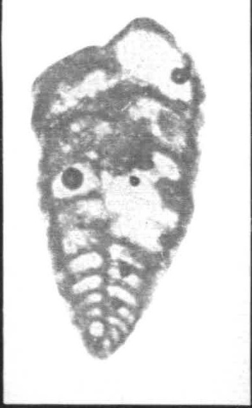

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4a

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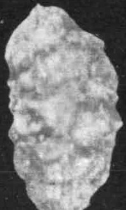
4c

5 a

7 b

5b

6



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7a

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PLATE 11

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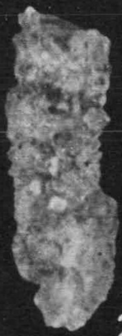
8. F48942, side view. x20.
9. F 48943, vertical thin section, transmitted light. x30.
10. F 48944, horizontal thin section, transmitted light. x50.
F 48938-43, 940' Wreck Island; F 48944, 22 miles S.S.E. Laiagam Airstrip, Wabag area, New Guinea.


1a


1b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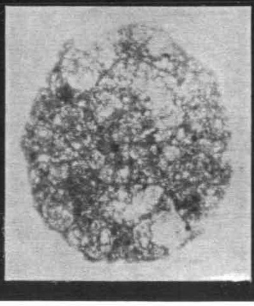
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PLATE 12

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F 48945. (a) external side view of specimen before sectioning. x20.
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5. F 48949, edge view. x18.
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   (b) reverse side of 'a' showing chamber restrictions. x23.
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9. F 48953. Vertical thin section, reflected light, showing biserial and uniserial chambers, foramina and terminal aperture. x23.
10. F 48954. Vertical thin section, reflected light, of broken specimen showing biserial and uniserial chambers. x22.
11. F 48955. Horizontal thin section, transmitted light, of initial triserial chambers. x20.
12. F 48956. Horizontal thin section, transmitted light, of first uniserial chamber showing chamber restrictions and apertural neck. x23.
13. F 48957. Horizontal thin section, transmitted light, of final chamber showing chamber restrictions and apertural neck. x21.

F 48946-57, 940′ Wreck Island.

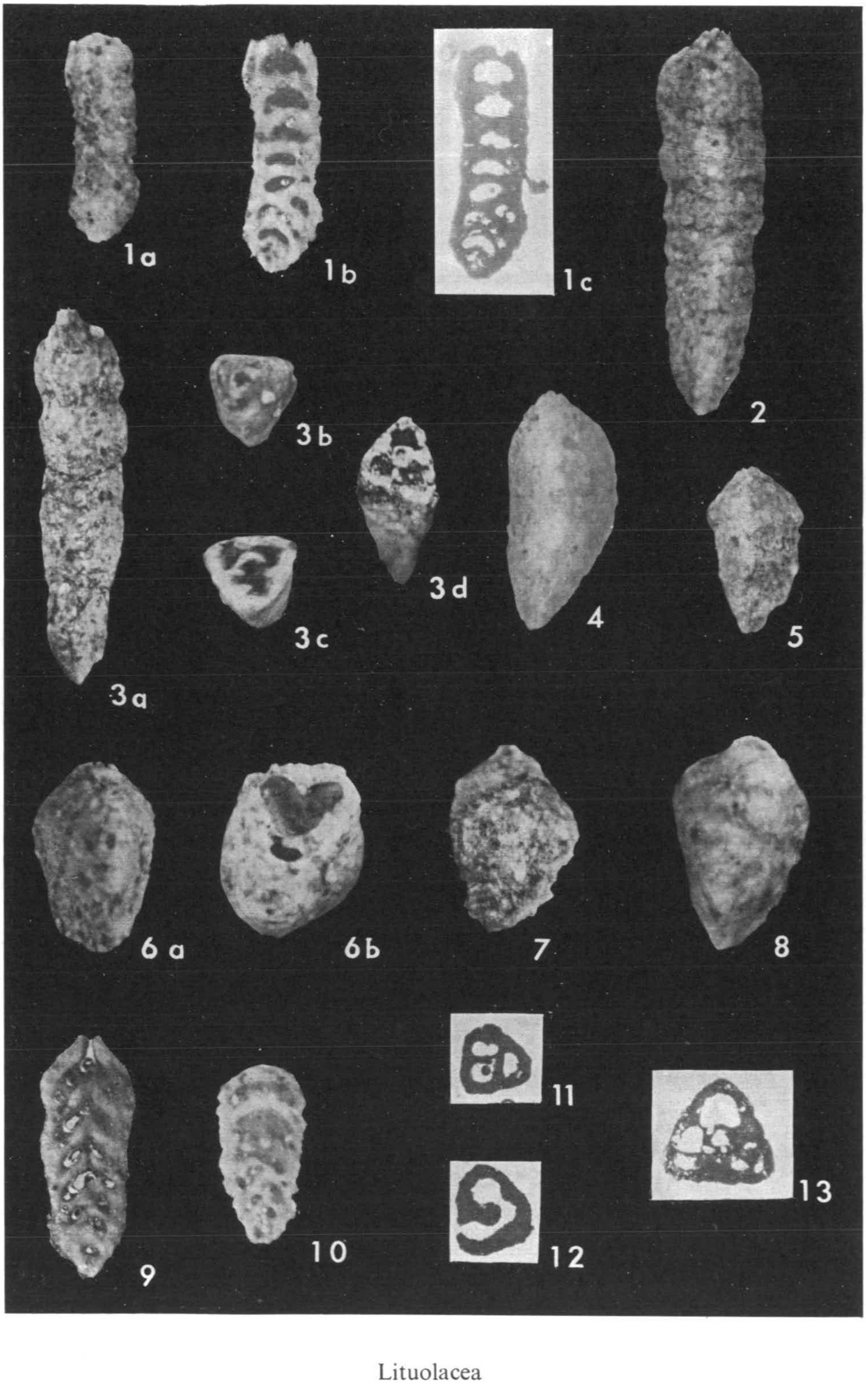

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PLATE 13

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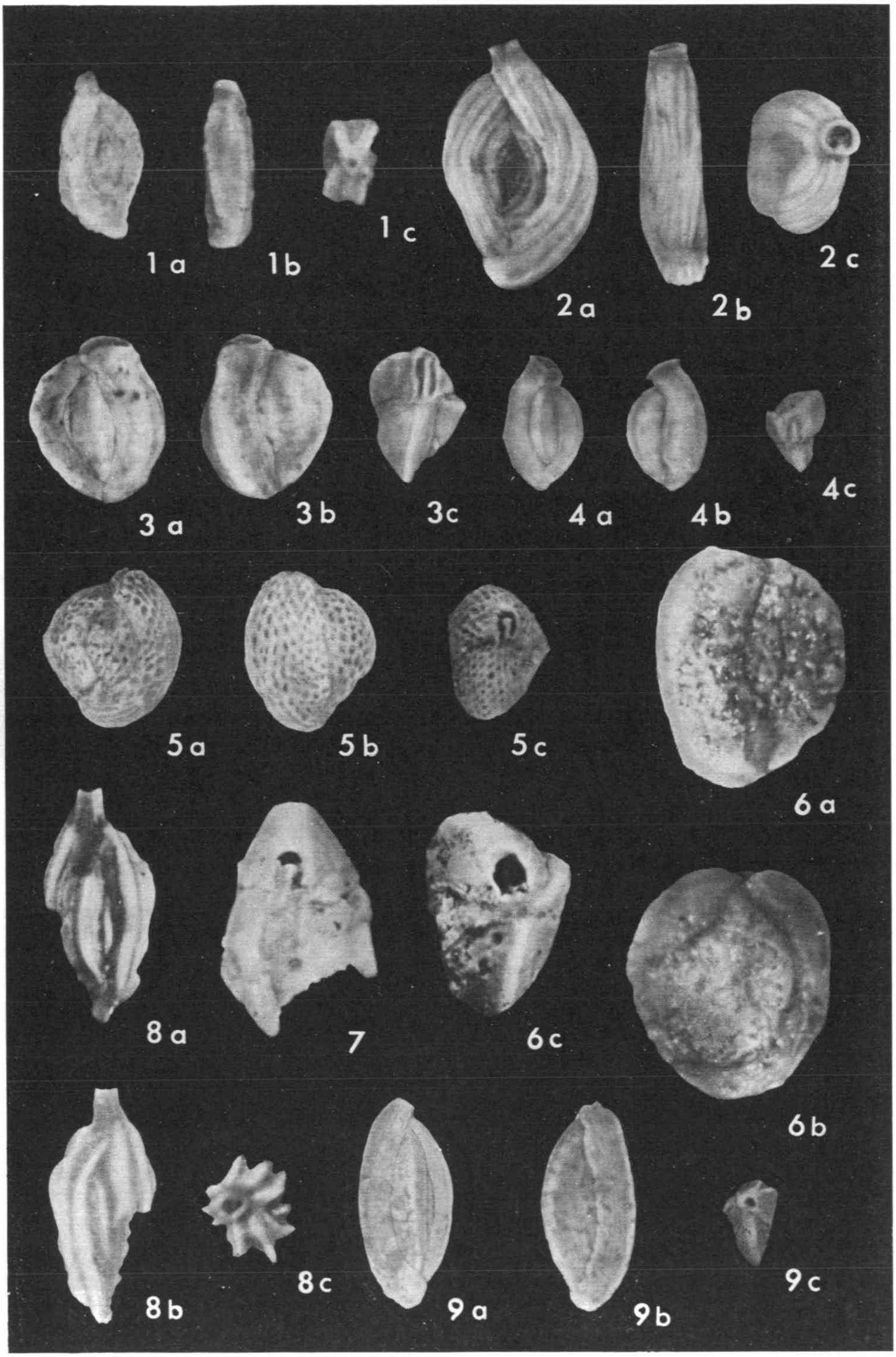

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PLATE 14

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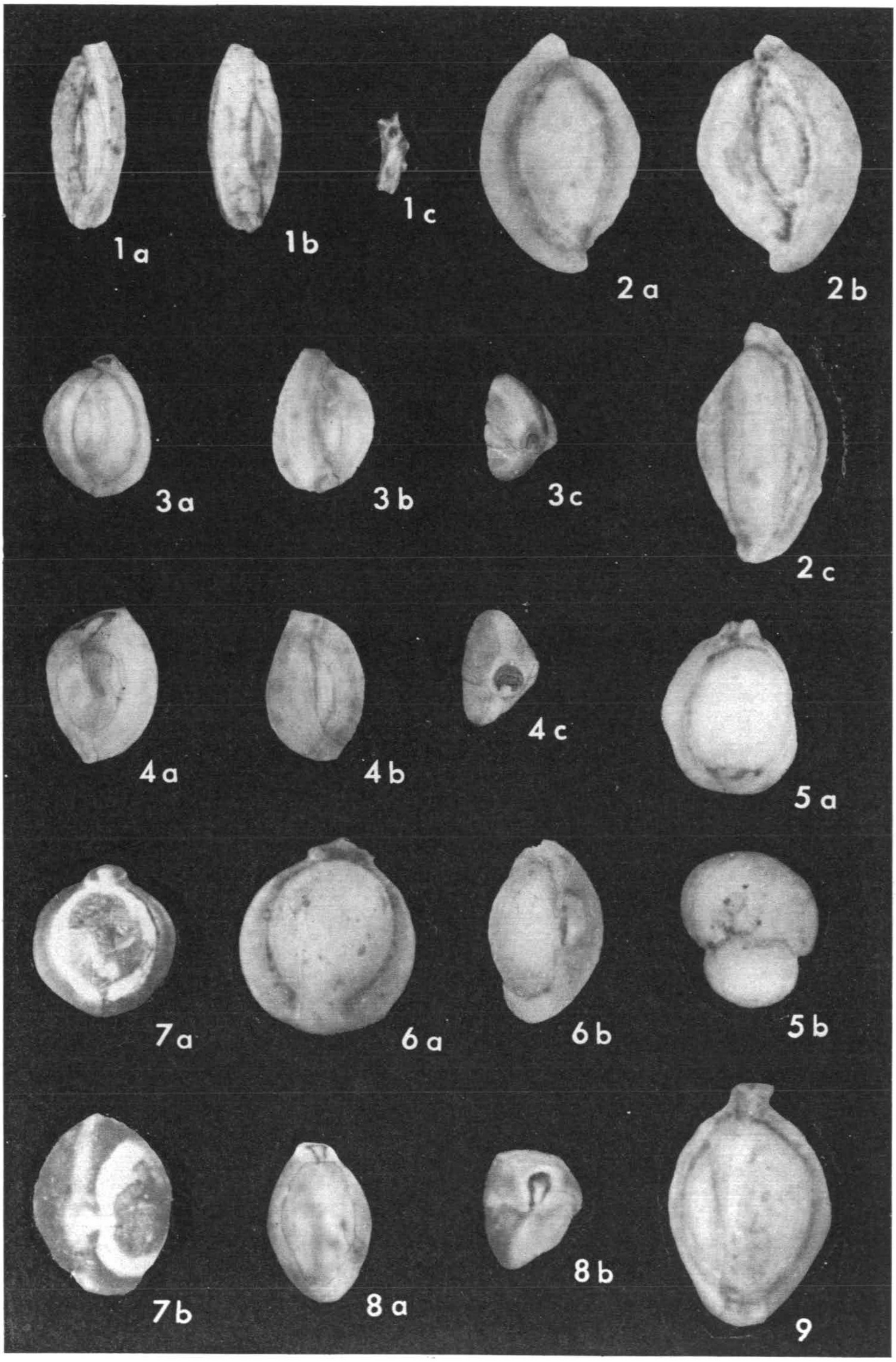
9. F 48975. Edge view. x58. 555′ Wreck Island.



Miliolacea

PLATE 15

Figures 1-4. *Triloculina* sp. cf. *T. laevigata* d'Orbigny, 1878 .... Page 92
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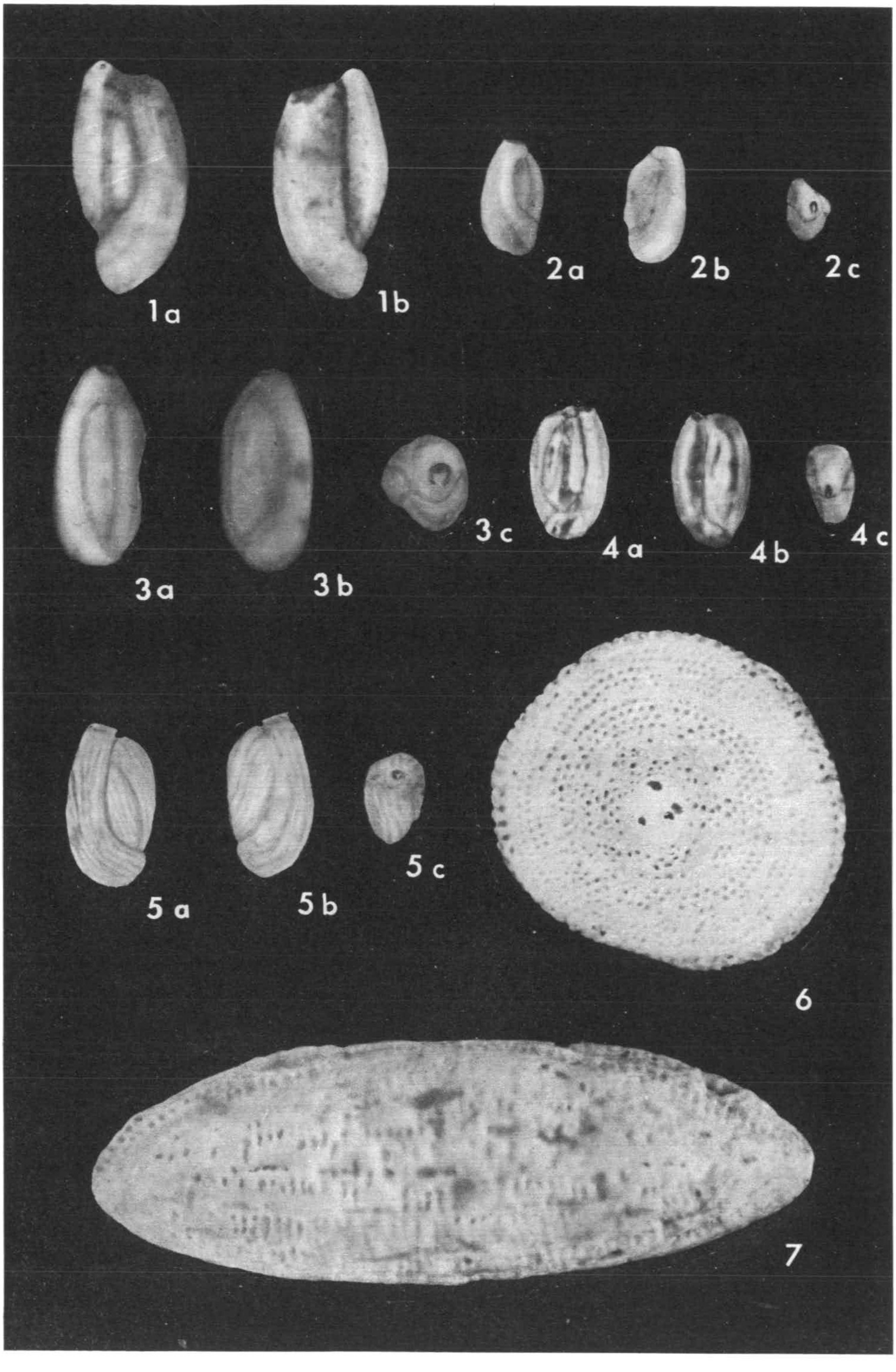
Figure 6. *Marginopora vertebralis*—Quoy & Gaimard *in* de Blainville, 1830 .... Page 93
F 48981. Face view. x30. 1625′ Wreck Island.

Figure 7. *Alveolinella quoyi* (d'Orbigny, 1826) .... Page 94
F 48982. Side view. x34. 1000′ Wreck Island.



Miliolacea

LOWER CRETACEOUS RADIOLARIA FROM THE NORTHERN TERRITORY OF AUSTRALIA

by A. R. Lloyd

SUMMARY

A radiolarian fauna is described from siltstone pebbles in a conglomerate at Lee Point, 10 miles north of Darwin, in the Northern Territory of Australia. The pebbles were derived from the Lower Cretaceous Mullaman Beds which crop out nearby. A similar fauna was found in porcellanites which crop out near Beetaloo and Shandon Downs homesteads, which are respectively 30 miles east-north-east and 92 miles east-south-east of Newcastle Waters, south of Darwin.

The evidence derived from both free specimens and thin sections has thrown new light on the radiolarian fauna described by Hinde (1893), from thin sections of porcellanite from Fanny Bay near Darwin. Except for his species *Lithocyclia exilis,* which has been emended and placed in the genus *Arachnosphaera* Haeckel, 1862, none of his species could be positively identified in the thin sections or related to free specimens.

INTRODUCTION

Samples of siltstone from pebbles in a conglomerate at Lee Point, 10 miles north of Darwin, which is thought to be Recent in age, were collected by the Resident Geologists of the Bureau of Mineral Resources at Darwin early in 1965, and forwarded for phosphate analysis. During the phosphate analysis, I. R. Pontifex noticed numerous circular organic remains in thin sections, which were subsequently identified as Radiolaria. Free specimens were then obtained after washing. The fauna was recognized as similar to the ones previously found in porcellanites from Fanny Bay (Hinde, 1893) and Larrakeyah Quarry near Darwin (Lloyd, 1963).

Porcellanites collected in 1965 by M. C. Brown of the Bureau of Mineral Resources from the vicinity of Beetaloo and Shandon Downs homesteads near Newcastle Waters were found to contain a similar radiolarian fauna.

Hinde (1893) described numerous new species of Radiolaria from thin sections of porcellanite from Fanny Bay near Darwin, but he had no idea of the age of the deposits. Brown (1895) collected ammonites from similar rocks nearby, which Etheridge determined to be indicative of the Cretaceous and (1907) placed in the Lower Cretaceous after studying further fossils collected by Brown. Whitehouse (1926, pp. 278-279) recorded ammonites from Point Charles near Darwin which he considered to be typical of the Upper Albian. Above the ammonite bed he mentioned a 'whitish rock' with belemnite impressions which he thought probably indicated an uppermost Albian or lowermost Cenomanian age. This 'whitish rock' with belemnite impressions is undoubtedly the porcellanite which contains the radiolarian fauna of Hinde. Noakes (1949, p. 28) placed these rocks in his Darwin Formation, the marine part of his Mullaman Group, and quoted Dr I. Crespin as saying that they were possibly Albian in age. Traves (1955, p. 82) recorded that Dr Crespin identified the Radiolaria cf. *Cenosphaera* and *Dictyomitra* in the Mullaman Group near Willeroo homestead, 70 miles south-west of Katherine. Malone (1962, p. 9 and Table 1) placed all the Lower Cretaceous sediments in the Darwin area in the Mullaman Beds. Lloyd (1963) recorded forms similar to *Lithocyclia exilis* Hinde in thin sections of porcellanite which also contains belemnite impressions from Larrakeyah Quarry in Darwin. In his description of Cretaceous strata and fossils of the Northern Territory, Skwarko (1966) suggested that sediments at Darwin, Point Charles, Shoal Bay, and Bathurst and Melville Islands were deposited in a single and distinct area of Cretaceous sedimentation in the Northern Territory. The ammonite faunas at Shoal Bay and Point Charles have not, however, been revised since Whitehouse based his datings on them in 1926, despite the fact that Wright (1963) has recently described the lower Albian-Cenomanian faunas of Bathurst Island. Whitehouse's datings of these beds are now in doubt, as Terpstra (pers. comm.) has identified lower Cenomanian foraminifera in core samples (at 101-143 feet) in a Shoal Bay bore. This implies that the age of the Radiolaria-bearing porcellanite beds at Darwin is younger than lower Cenomanian, and not 'uppermost Albian or lowermost Cenomanian' as suggested originally by Whitehouse (1926) and generally held.

Veevers & Wells (1962, p. 169) and Johnson & Dallwitz (1961, pp. 271-273) recorded that Dr Crespin identified *Lithocyclia exilis* in thin sections of porcellanite from the Bejah Beds in the south-eastern part of the Canning Basin in Western Australia. Lloyd (1963) recorded similar forms in thin sections from the Bejah Beds in the Gibson Desert area of the Canning Basin. Skwarko (1962, 1963) dated pelecypods in the Bejah Beds as Aptian.

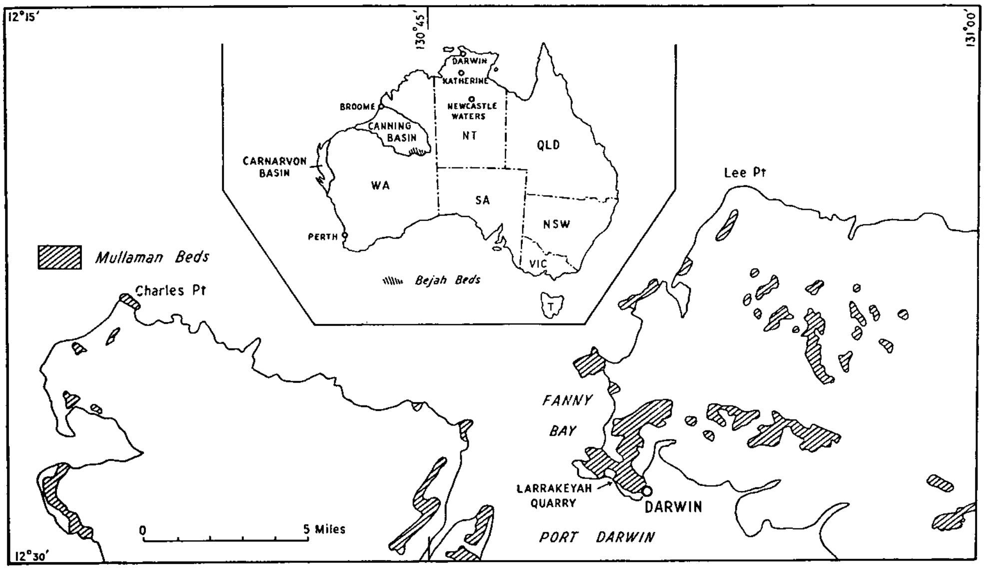


Fig. 1: Locality map.

Hinde's species, based solely on random thin sections, are considered to be unsatisfactory because the few characters available are not sufficient to enable them to be recognized in the free state or to relate them to other described species. Further, one cannot be sure that some of the forms illustrated by Hinde as separate species are not differently oriented sections of the one species. A relationship has been established between free specimens and random thin sections in the case of his species *Lithocyclia exilis,* which has now been emended and placed in the genus *Arachnosphaera* Haeckel.

The preservation of the Radiolaria in the porcellanites is poor because of the strong leaching. The material from Lee Point was not leached and was therefore better preserved and gave rise to the main observations here.

In the taxonomic part of this paper the classification follows Campbell (1954), and the recognition of the various genera is based on Haeckel (1887) and Campbell.

SYSTEMATIC DESCRIPTIONS

Subclass RADIOLARIA Muller, 1858.

Order PORULOSIDA Haeckel, 1887

Suborder SPUMELLINA Ehrenberg, 1875.

Division SPHAERELLARI Haeckel, 1882.

Superfamily LIOSPHAERICAE Haeckel, 1882.

Family STYLOSPHAERIDAE Haeckel, 1882.

Subfamily XIPHOSTYLINAE Haeckel, 1882.

Genus Xiphosphaera Haeckel, 1882.

Type Species: *Xiphosphaera tredecimporata* Rust, 1885.

Xiphosphaera (Xiphosphaera) sp.

(Pl. 17, fig. 7)

Only one specimen of this form was found, in a random thin section from Lee Point to the north of Darwin; it consists of a single circular lattice shell with two similar polar spines. The specimen cannot be determined specifically, but from the observed morphological features it is thought that it comes within *Xiphosphaera* (*Xiphosphaera*).

Dimensions of figured specimen:	*Diameter of Shell*	*Length of Spines*
CPC 6990	150μ	150μ

Family ASTROSPHAERIDAE Haeckel, 1882.

Subfamily ASTROSPHAERINAE Haeckel, 1882.

Genus Diplosphaera Haeckel, 1860.

Type Species: *Diplosphaera gracilis* Haeckel, 1862.

Diplosphaera (Diplosphaerella) sp.

(Pl. 17, fig. 5; Pl. 18, fig. 4)

A number of specimens were observed in random thin sections from Lee Point and 8 miles NNE of Shandon Downs homestead near Newcastle Waters; they consist of an inner and an outer circle connected by simple radial spines. From these characters it appears that the specimens consist of an inner spherical medullary shell and an outer spherical cortical shell connected by a few simple radial spines, which would place them in *Diplosphaera* (*Diplosphaerella*).

Dimensions of figured specimens:	*Diameter of Shells*
CPC 6988	62μ, 125μ
CPC 7190	33μ, 100μ

Subfamily HELIOSPHAERINAE Haeckel, 1882.

Genus COSCINOMMA Haeckel, 1887.

Type Species: *Coscinomma amphisiphon* Haeckel, 1887.

COSCINOMMA (COSCINOMMA) sp.

(Pl. 17, figs 1-4)

In the free state the species consists of a single spherical shell with a fine hexagonal mesh.

A specimen similar to the one illustrated (Pl. 17, fig. 1) was sectioned and found to have only a single shell. Similar, but better preserved, spherical forms with a hexagonal mesh, from a rich radiolarian fauna in the Gearle Siltstone of the Carnarvon Basin, Western Australia, were examined and found to have a single shell. The free specimen illustrated has therefore been related to the single-shell forms illustrated as Figures 2-4 from random thin sections. In thin sections it can be seen that the pores prolong both the inner and outer surfaces. It is therefore considered that the specimens illustrated belong to a species of *Coscinomma* (*Coscinomma*).

The species was observed from Lee Point near Darwin; 8 miles NNE of Shandon Downs homestead and 19 miles NE of Beetaloo homestead near Newcastle Waters; and from the Gearle Siltstone in the Carnarvon Basin of Western Australia. The fauna from the Gearle Siltstone is Albian.

Dimensions of figured specimens:	*Diameter*
CPC 6984	225μ
CPC 6985	125μ
CPC 6986	100μ
CPC 6987	125μ

Subfamily ACTINOMMATINAE Haeckel, 1862.

Genus ACTINOMMA Haeckel, 1862.

Type Species: *Haliomma trinacrium* Haeckel, 1860.

ACTINOMMA (ACTINOMMA) sp.

(Pl. 17, fig. 6; Pl. 18, fig. 5)

In thin section the specimens consist of three concentric circles joined by numerous fine radial spines.

The free specimens would consist of three concentric spherical lattice shells joined by numerous simple radial spines and therefore come within the definition of *Actinomma* (*Actinomma*).

A few specimens were found at Lee Point and 19 miles NE of Beetaloo homestead. Hinde (1893, pl. 5, figs 4, 5) figured similar forms from Fanny Bay as *Astrophacus* sp., but neither Hinde's nor the present specimens can be assigned to this genus because it is discoidal.

Dimensions of figured specimens:	*Diameter of Shells*
CPC 6989	31μ, 62μ, 125μ
CPC 7181	25μ, 60μ, 100μ

Subfamily ARACHNOSPHAERINAE Haeckel, 1862.

Genus ARACHNOSPHAERA Haeckel, 1862.

Type Species: *Arachnosphaera oligacantha* Haeckel, 1862.

ARACHNOSPHAERA EXILIS (Hinde, 1893), em.

(Pl. 16, figs 1, 3-10; Pl. 18, figs 1-3)

1893 *Lithocyclia exilis* Hinde, p. 223, pl. 5, fig. 8.

Description. Shell small, spherical, surface with a very fine hexagonal mesh; internally with eight concentric spherical shells crossed by numerous fine radiating spines. The external diameter of the shells varies between 150 and 175μ.

Discussion. Circular forms consisting of 8 concentric rings crossed by numerous fine radiating 'septa' have been observed previously (Lloyd, 1963) in thin sections of samples from the Bejah Beds in the south-eastern part of the Canning

Basin in Western Australia (Pl. 16, fig. 1) and from the Mullaman Beds at Larrakeyah Quarry in Darwin (Pl. 16, figs 3, 4). They were considered to belong to the form described and figured as *Lithocyclia exilis* by Hinde (1893, p. 223, pl. 5, fig. 8) from a thin section of a porcellanite from Fanny Bay near Darwin. As the forms are invariably circular in cross-sections, they must be spherical in the free state. The genus *Lithocyclia* is defined as having an external lenticular latticed cortical shell, a single medullary shell, and a chambered equatorial girdle, and a species belonging to this genus could not, therefore, give circular cross-sections only. The cross-sections of *'L. exilis'* have a similar structure to a horizontal section of the girdle of *Lithocyclia lenticula* Haeckel as figured by Haeckel (1887, pl. 36, figs 3, 4) and Campbell (1954, p. 84, fig. 39, 1); but here the similarities end.

Material from Lee Point contains numerous free spherical forms, and broken specimens such as that illustrated on Plate 16, figure 7, show that the forms with a very fine hexagonal mesh have the internal concentric structure figured by Hinde and observed in the random thin sections of Lee Point material (Pl. 16, figs 8-10), and the material from near Newcastle Waters (Pl. 18, figs 1, 2). The relationship of the random thin sections and free specimens was thus established.

Some of the random thin sections illustrated (Pl. 16, figs 2, 11, 12; Pl. 18, fig. 3) show a distinct spiral structure; others (Pl. 16, fig. 13) have an interrupted spiral structure. It could not be proved whether these forms belong to *A. exilis* or not. The spiral structure may be the result of the direction in which the sections were cut through specimens of *A. exilis,* but the specimens may belong to one or more different genera and species; they could, for instance, fall within the genus *Spireuma* Haeckel, of the subfamily Litheliinae, family Litheliidae.

The species is placed in the genus *Arachnosphaera* because it has more than five concentric spherical lattice shells with polygonal meshes; the characteristics required for subgeneric determination could not be distinguished. The species bears a close resemblance to *Cromyodruppa concentrica* Lipman as figured in the Russian Treatise on the Protozoa (p. 669, fig. 949b), but differs in being spherical instead of ellipsoidal.

A. exilis is abundant in the Mullaman Beds at Lee Point and Larrakeyah Quarry near Darwin; is abundant in porcellanite 8 miles NNE of Shandon homestead near Newcastle Waters, which is similar and equivalent to the Mullaman Beds; and is common to rare in the Bejah Beds in the south-eastern part of the Canning Basin in Western Australia. It has a known stratigraphic range from Aptian to uppermost Albian or lowermost Cenomanian and therefore extends the range of the genus from Lower Cretaceous to Recent.

Dimensions of figured specimens:	*Diameter* (μ)	
CPC 6972	125	
CPC 6973	100	
CPC 6974	125	
CPC 6975	125	
CPC 6976	150	
CPC 6977	225	
CPC 6978	150	
CPC 6979	150	
CPC 6980	125	
CPC 6981	100	125
CPC 6982	100	
CPC 6983	75	125
CPC 7178	155	
CPC 7179	130	
CPC 7180	100	

Suborder NASSELLINA Ehrenberg, 1875.

Division CYRTELLARI Haeckel, 1882.

Superfamily ARCHIPILIILAE Haeckel, 1882.

Subsuperfamily TRIACARTILAE Campbell, 1954.

Family STICHOCORYTHIDAE Haeckel, 1882.

Genus DICTYOMITRA Zittel, 1876.

Type Species: *Dictyomitra multicostata* Zittel, 1876.

DICTYOMITRA (DICTYOMITRELLA) sp. A

(Pl. 17, fig. 11)

Shell conical, smooth, consisting of five joints of nearly similar length. The species was found at Lee Point only, and is very rare.

Dimension of figured specimen:	*Length*	*Width*
CPC	200μ	50-100μ

DICTYOMITRA (DICTYOMITRELLA) sp. B

(Pl. 17, figs 12-16; Pl. 18, figs 6-8)

Shell conical, smooth, consisting of 8 to 10 joints of nearly similar length, expanding regularly throughout or expanding rapidly until the fourth joint, remaining uniform in width until the seventh joint, then gradually narrowing.

Forms illustrated (Pl. 17, fig. 12; Pl. 18, figs 5-8) may be sections through this species and are included here. The form illustrated by Hinde from Fanny Bay (pl. 5, fig. 14) as *Dictyomitra australis* may also be conspecific with the forms here placed in *D.* (*D.*) sp. B.

Dictyomitra (*Dictyomitrella*) sp. B is rare at Lee Point, 8 miles NNE of Shandon Downs homestead, and 19 miles NE of Beetaloo homestead; it possibly occurs at Fanny Bay.

Dimensions of figured specimens:	*Length* (μ)	*Width* (μ)
CPC 6995	175	25-75
CPC 6996	350	0-175
CPC 6997	250	75-175
CPC 6998	350	50-175-150
CPC 6999	350	75-175
CPC 7182	250	0-75
CPC 7191	300	0-125
CPC 7192	300	0-150

Genus LITHOCAMPE Ehrenberg, 1838

Type Species: *Lithocampe radicula* Ehrenberg, 1838

?LITHOCAMPE (LITHOCAMPE) sp.

(Pl. 17, figs 8, 9)

In thin section the form is conical and consists of about seven similar joints.

It is thought that the two specimens illustrated are related, although this could not be proved. Not many characters can be observed, and they are placed questionably in *Lithocampe* (*Lithocampe*). The form is very rare, at Lee Point only.

Dimensions of figured specimens:	*Length*	*Width*
CPC 6991	100μ	25-50μ
CPC 6992	150μ	25-75-50μ

?LITHOCAMPE (LITHOCAMPIUM) sp.

(Pl. 17, fig. 10)

In thin section the form is conical and consists of about five joints of dissimilar length which widen rapidly until the third joint and then decrease in width to the end. The section appears to be cut along the external surface which shows that it possibly has a smooth lattice shell. The form is placed questionably in *Lithocampe* (*Lithocampium*). It is very rare and was found at Lee Point only.

Dimensions of figured specimen:	*Length*	*Width*
CPC 6993	350μ	100-150-125μ

BIBLIOGRAPHY

ANONYMOUS (Ed. ORLOV, YU.A., RAUZER) CHERNOUSOVA, D. M., and FURSENKO, A. V., 1959—Radiolarians, *in* FUNDAMENTALS OF PALEONTOLOGY, GENERAL PART PROTOZOA, 552-712. *Moscow. Acad. Sci. USSR.* English translation by Israel Programme for Scientific Translations, 1962.

BROWN, H. Y. L., 1895—Government Geologist's report on explorations in the Northern Territory. *S. Aust. parl. Pap.* 82.

CAMPBELL, A. S., (ed. R. C. MOORE), 1954—Radiolaria, *in* TREATISE ON INVERTEBRATE PALEONTOLOGY, Part D, PROTISTA 3, 11-163. *Geol. Soc. Amer.* and *Univ. Kansas Press.*

CRESPIN, I., 1960—Radiolaria in the Lower Cretaceous rocks of Australia. *Int. geol. Cong., 21st Sess., Norden,* 4, 27-34.

ETHERIDGE, R., Jr, 1907—Preliminary report on other fossils forwarded to me by the Government Geologist of South Australia. *S. Aust. parl. Pap.* 55, 15.

HAECKEL, E., 1887—Report on the Radiolaria collected by H.M.S. Challenger, 1873-1876. *Rep. Voyage Challenger, Zool.* 18.

HINDE, G. J., 1893—Note on a Radiolaria rock from Fanny Bay, Darwin, Australia. *Quart. J. geol. Soc. Lond.,* 49, 221-226.

JOHNSON, N. E. A., and DALLWITZ, W. B., 1961—Petrography of selected rocks from the Canning Basin, *in* VEEVERS & WELLS, 1961, 264-276.

LLOYD, A. R., 1963—Probable Radiolaria from the Lower Cretaceous Bejah Beds, Gibson Desert, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1963/30 (unpubl.).

MALONE, E. J., 1962—Darwin, N.T.—1:250,000 Geological Series. *Bur. Miner. Resour. Aust. explan. Notes* D/52-4.

NOAKES, L. C., 1949—A geological reconnaissance of the Katherine-Darwin region, Northern Territory, with notes on the mineral deposits. *Bur. Miner. Resour.. Aust. Bull.* 16.

SKWARKO, S. K., 1962—Notes on Australian Lower Cretaceous palaeogeography. *Bur. Miner. Resour. Aust. Rec.* 1962/11 (unpubl.).

SKWARKO, S. K., 1963—Mesozoic fossils from the Gibson Desert, Central Western Australia. *Ibid.,* 1963/2 (unpubl.).

SKWARKO, S. K., 1966—Cretaceous stratigraphy and palaeontology of the Northern Territory. *Bur. Miner. Resour. Aust. Bull.* 73.

TRAVES, D. M., 1955—The geology of the Ord-Victoria region, Northern Australia. *Bur. Miner. Resour. Aust. Bull.* 27.

VEEVERS, J. J., and WELLS, A. T., 1961—The geology of the Canning Basin, Western Australia. *Bur. Miner. Resour. Aust. Bull.* 60.

WELLS, A. T., 1963—Reconnaissance geology by helicopter in the Gibson Desert, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1963/59 (unpubl.).

WHITEHOUSE, F. W., 1926—The correlation of the marine Cretaceous deposits of Australia. *Rep. Aust. Ass. Adv. Sci.,* 43, 275-280.

WRIGHT, C. W., 1963—Cretaceous ammonites from Bathurst Island, Northern Australia. *Palaeontology,* 6(4), 597-614.

PLATE 16

Figures 1, 3-10. *Arachnosphaera exilis* (Hinde, 1893) .... Page 121

1. CPC 6972. Thin section from Bejah Beds, SE Canning Basin, Western Australia. x300.

3, 4. CPC 6974. Thin sections from Larrakeyah Quarry, Darwin, Northern Territory. 3. x300. 4. x250.

5, 6. CPC 6976. Free specimen from Lee Point. 5. x80. 6. x120.

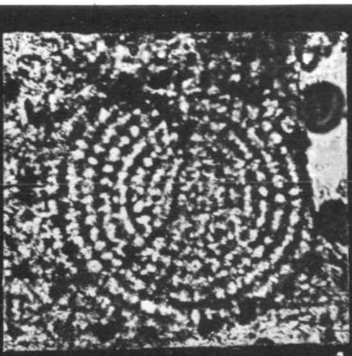
7. CPC 6977. Broken free specimen from Lee Point. x80.

8-10. CPC 6978, 6979, 6980. Thin sections from Lee Point. 8. x130. 9. x200. 10. x320.

Figures 2, 11-13. *?Arachnosphaera exilis* (Hinde, 1893) .... Page 121

2. CPC 6973. Thin section from Bejah Beds, SE Canning Basin, Western Australia. x200.

11-13. CPC 6981, 6982, 6983. Thin sections from Lee Point. 11. x200. 12. x300. 13. x360.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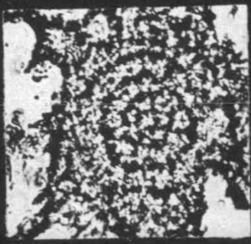
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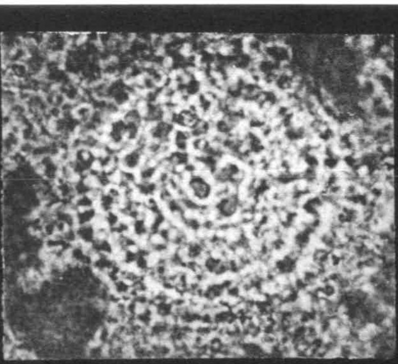
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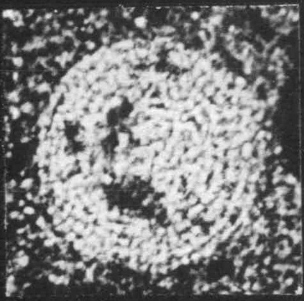
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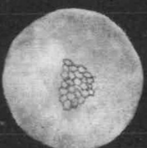
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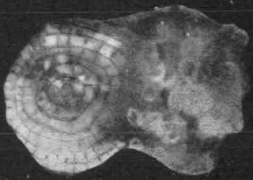
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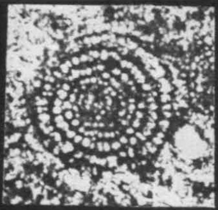
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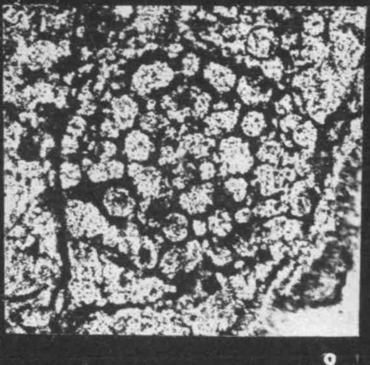
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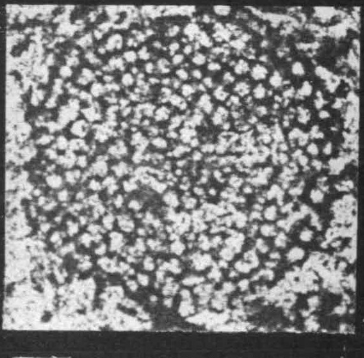
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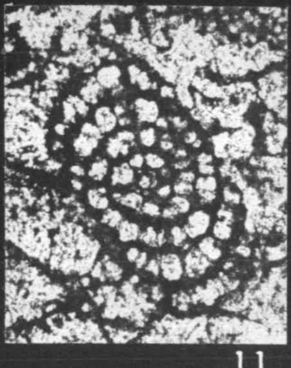
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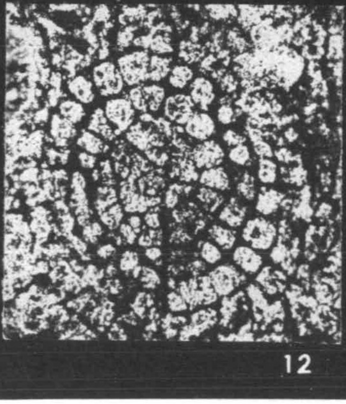
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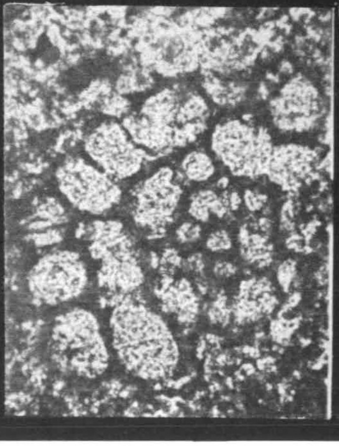
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Lower Cretaceous Radiolaria

PLATE 17

Figures 1-4. *Coscinomma (Coscinomma)* sp. .... Page 120
1. CPC 6984. Free specimen from Lee Point. x120.
2-4. CPC 6985, 6986, 6987. Thin sections from Lee Point. 2. x200. 3. x250. 4. x120.

Figure 5. *Diplosphaera (Diplosphaerella)* sp. .... Page 119
CPC 6988. Thin section from Lee Point. x120.

Figure 6. *Actinomma (Actinomma)* sp. .... Page 121
CPC 6989. Thin section from Lee Point. x250.

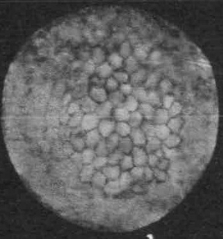
Figure 7. *Xiphosphaera (Xiphosphaera)* sp. .... Page 119
CPC 6990. Thin section from Lee Point. x70.

Figures 8, 9. *?Lithocampe (Lithocampe)* sp. .... Page 124
CPC 6991, 6992. Thin sections from Lee Point. 8. x200. 9. x150.

Figure 10. *?Lithocampe (Lithocampium)* sp. .... Page 124
CPC 6993. Thin section from Lee Point. x100.

Figure 11. *Dictyomitra (Dictyomitrella)* sp. A .... Page 123
CPC 6994. Free specimen from Lee Point. x100.

Figures 12-16. *Dictyomitra (Dictyomitrella)* sp. B .... Page 123
12. CPC 6995. Thin section from Lee Point. x300.
13-16. CPC 6996-6999. Free specimens from Lee Point. 13. x100. 14. x100. 15. x100. 16. x60.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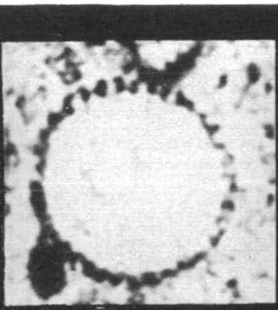
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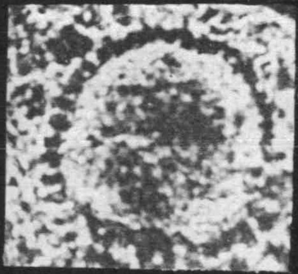
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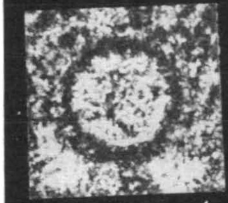
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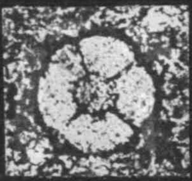
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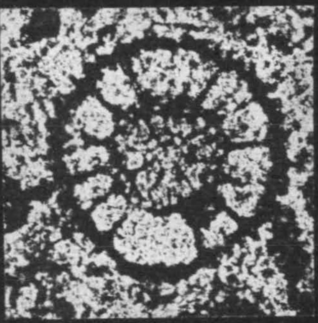
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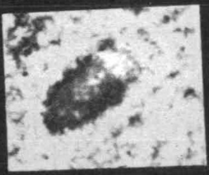
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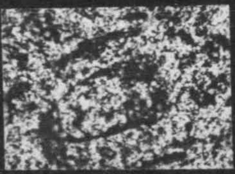
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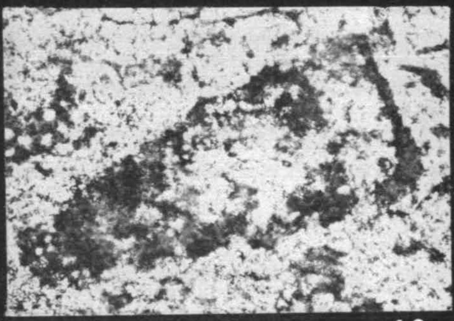
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Lower Cretaceous Radiolaria

PLATE 18

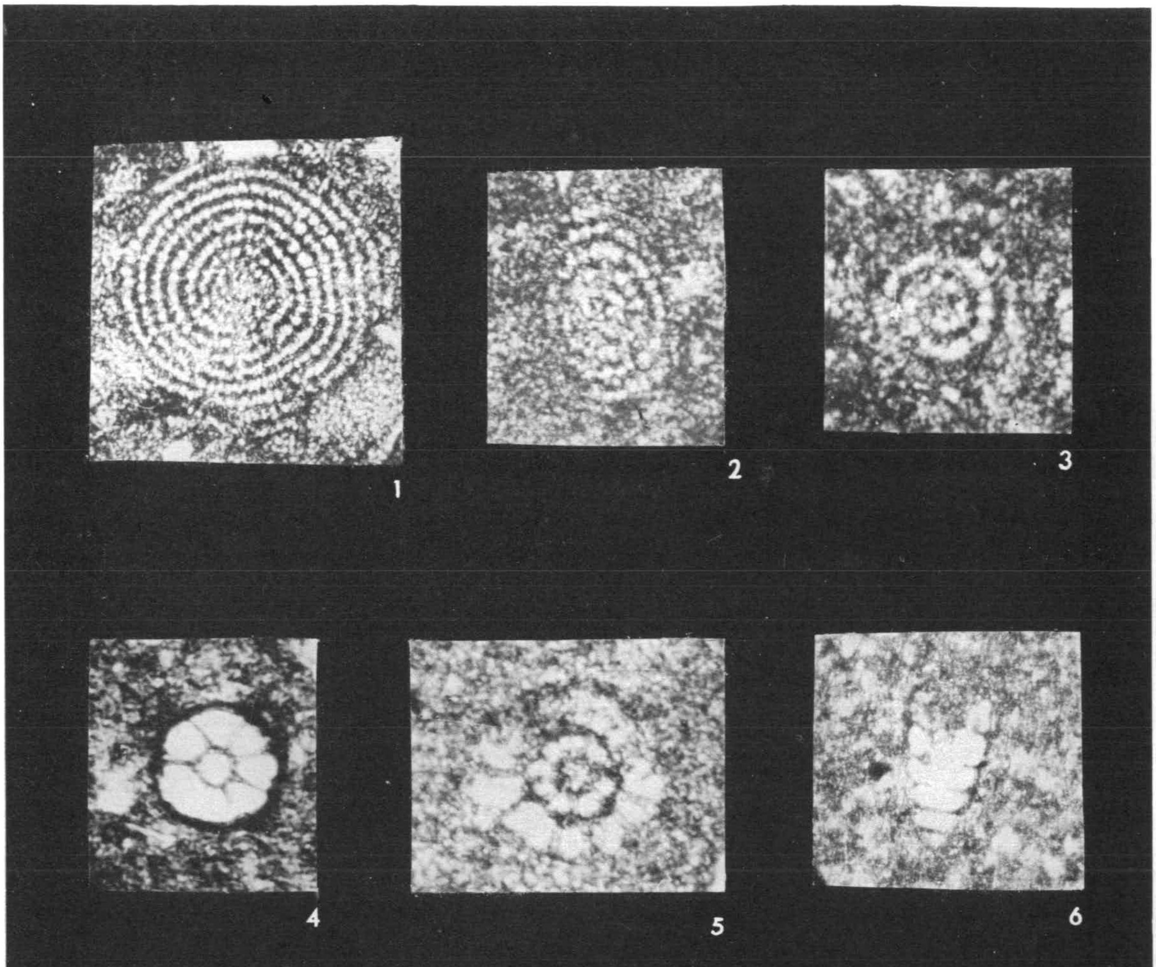
Figures 1, 2. *Arachnosphaera exilis* (Hinde, 1893) .... Page 121
CPC 7178, 7179. Thin section from 19 miles NE of Beetaloo homestead. 1. x200. 2. x175.

Figure 3. *?Arachnosphaera exilis* (Hinde, 1893) .... Page 121
CPC 7180. Thin section from 19 miles NE of Beetaloo homestead. x180.

Figure 4. *Diplosphaera* (*Diplosphaerella*) sp. .... Page 119
CPC 7190. Thin section from 8 miles NNE of Shandon Downs homestead. x160.

Figure 5. *Actinomma* (*Actinomma*) sp. .... Page 121
CPC 7181. Thin section from 8 miles NNE of Shandon Downs homestead. x280.

Figures 6-8. *Dictyomitra* (*Dictyomitrella*) sp. B .... Page 123
CPC 7182, 7191, 7192. Thin sections from 8 miles NNE of Shandon Downs homestead. 6. x72. 7. x80. 8. x100.



Lower Cretaceous Radiolaria

THE ORDIAN STAGE OF THE CAMBRIAN AND ITS AUSTRALIAN METADOXIDIDAE

by A. A. Öpik

SUMMARY

The name Ordian designates the hitherto unnamed stage of the Cambrian referred to in the literature as the '*Redlichia* fauna' or the '*Redlichia* beds', or zone. The Ordian is post-Lower Cambrian (post-Olenellian) and represents therefore the initial, pre-*Paradoxides* stage of the Middle Cambrian. In the Ordian fauna about twenty fossils are named specifically, and some forty more are evident in the undescribed collections. It is a diversified and relatively large fauna. The stage above it—the Templetonian, equated with the upper part of the *Paradoxides oelandicus* stage and the Zone of *Ptychagnostus gibbus*—is also discussed in some detail. The Ordian is a temporal equivalent of the *Protolenus* zone, of the pre-*Glossopleura* American Middle Cambrian, of a substantial part of the Siberian Lena stage, and of the larger, upper part of the *Redlichia* sequence of Asia; these sequences are discussed in a review of stratigraphic charts of Russian, American, and Chinese authors. The modern concept of an 'extended Lower Cambrian, referred to as the 'Leno-Aldanian' in this paper is reviewed and its existence as a standard different from Walcott's classical concept of Lower Cambrian is acknowledged as a *fait accompli* in a part of the literature of recent years; the history of the classical and 'Leno-Aldanian' concepts is reviewed. The correlation of the Ordian in relation to the classical standard and the Leno-Aldanian standard is presented. Sequences of Ordian age are listed, and the recently discovered Cambrian sequences of New South Wales discussed; in this State, in the Mootwingee Range area, the Ordian sequence is seen resting above the Olenellian Lower Cambrian and below the advanced Middle Cambrian Templetonian strata. The name Ordian is derived from the Ord Valley and the Ord River in the northern part of Western Australia.

The trilobite family Metadoxididae Whitehouse appears to belong to a different ordinal taxon from the Redlichiida. The Metadoxididae (hitherto unknown in Australia) are represented here by the Ordian *Onaraspis somniurna* gen. nov. et sp. nov., and *Onaraspis adusta* sp. nov. *Onaraspis* differs from *Metadoxides* by a smaller number of segments in the thorax and a larger pygidium.

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INTRODUCTION

In the course of mapping in central and northern Australia, sequences and faunas have been discovered which belong to the 'earliest Middle Cambrian *Redlichia*-bearing beds'. This cumbersome phrase designates a definite but hitherto unnamed Cambrian stage—the Ordian of the present paper. The name Ordian is used here to designate the age of two species of *Onaraspis* gen. nov., and it will be used further in other taxonomic papers dealing with fossils of the '*Redlichia* fauna'.

THE ORDIAN STAGE

DEFINITION

The time and time-rock division of the Cambrian scale which hitherto has been designated as the '*Redlichia* fauna' or '*Redlichia*-bearing beds, or strata' or the '*Redlichia*-bearing early Middle Cambrian', or '*Redlichia* Zone', etc., stands in need of a geographically derived formal name; the name Ordian is proposed as such a name. The Ordian is regarded here as the initial stage of the Middle Cambrian Series and Epoch because in time it follows the Lower Cambrian—the Olenellian as defined by Walcott in 1890. The fundamental reason for placing the Ordian in the early (earliest) Middle Cambrian is the fact (see Table 1) that it occupies the hiatus below the *Paradoxides oelandicus* stage and above the Olenellian Lower Cambrian.

The designation '*Redlichia* fauna' is inadequate in stratigraphy because species of *Redlichia* occur also in the late Lower Cambrian (Olenellian) in South Australia, as indicated by Daily (1956; 1957) and Pocock (1954), and apparently in South-eastern Asia. So particular species of *Redlichia* rather than the genus as such are significant in identification of Ordian sequences.

FAUNAL CENSUS

The fauna is diversified, but no single site is known as having produced a larger number of items. Unfortunately only few of the fossils have been described taxonomically.

Known Australian Ordian fossils are:

Redlichia forresti (Etheridge)*
Redlichia idonea Whitehouse
Redlichia venulosa (Whitehouse)
Redlichia chinensis Walcott

Xystridura, with four undescribed species (paper in prep.).
Dolichometopidae, gen. nov.
Zacanthoididae? gen. indet.

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* Open nomenclature has been applied to four other species of *Redlichia* (a, b, c, d) by Öpik (1958); these and several others are the subject of a separate paper to be published later. Sixteen species are evident so far.

Dorypygidae (*Kootenia,* more than one species)
Dinesus sp. indet. (cf. *D.* (*Erbia*) *granulatus* Lermontova)
Bathynotus sp. nov. (Őpik, 1956, p. 43: its Ordian or Templetonian age remains inconclusive).
Onaraspis somniurna gen. nov., sp. nov.
Onarapsis adusta sp. nov.
Ptychopariacea, several genera
Proasaphiscidae (one form)
Drepanopyge Lu, 1961, sp. indet.
Pagetia cf. *significans* (Etheridge)
Peronopsis sp.
Bradoriida (several forms, paper in prep.)
Orthoid brachiopods (several genera)
Inarticulate brachiopods (*Arotreta, Acrothele, Lingulella,* Obolidae, and, apparently, *Botsfordia* and *Neobolus*)
Helcionella, several forms
Stenothecoides
Hyolithes (several)
Biconulites hardmani (Etheridge Jr *in* Foord, 1890)
Spongia (*Chancelloria, Eiffelia,* and simpler forms)
Archaeocyathus cf. *atlanticus* Billings
Girvanella

This list covers the bulk of the Ordian fossils known in the literature and in the undescribed collections; earlier reference is given in Őpik (1956, 1957, 1958).

Biconulites hardmani is the most common fossil known from all sites; in places its shells are massed together in coquinas; a related form occurs also in the Templetonian, but not as abundantly. Richter's (1941, p. 24) *Hyolithes* (*Orthotheca*) *kingi* from the Dead Sea is also a *Biconulites,* probably *B. hardmani* itself.

Protolenidae and Ellipsocephalidae have not yet been found in the Ordian of Australia. Eodiscidae are also absent, but should be found sooner or later. A doubtful *Calodiscus* is mentioned below in the faunal list of the locality at Gaylad Dam AS.33. In passing, an eodiscid pygidium (probably *Serrodiscus*) has been found in the Templetonian Beetle Creek Formation (coll. H. O. Fletcher, Australian Museum, Sydney).

THE TEMPLETONIAN

The Ordian spans from the end of the Lower Cambrian (Olenellian) to the beginning of the Templetonian Stage; the concept of the Templetonian (Templeton Series, Whitehouse 1936; compare also Őpik, 1956, 1957) has not been stabilized as yet. It refers here to the *Xystridura templetonensis* (*X. saintsmithi* of authors) fauna in Queensland and *Xystridura browni* fauna in Northern Territory, which is succeeded by a number of Oryctocephalidae and several agnostids; the Zone of *Ptychagnostus gibbus* is taken here as the topmost division of the Templetonian. The Templetonian is therefore an approximate equivalent of the Scandinavian upper part of the *Paradoxides oelandicus* stage followed by the *Ptychagnostus gibbus* Zone.

The name Templetonian Stage is a liberal interpretation of Whitehouse's 'Templetonian series', in which 'series' is supposed to indicate a time-rock division. The concept of the Templetonian Stage is won from the study of the sequences at the headwaters of the Templeton River (Öpik, *in* Öpik, Carter, & Noakes, 1961) in Queensland. Whitehouse's own concept (Whitehouse, 1936, chart, p. 78) of the Templeton 'Series' is quite different and cannot be used for the following reasons: (1) it includes the '*Amphoton* Stage' which is a part of the late Middle Cambrian Zone of *Ptychagnostus nathorsti* (Öpik, 1956, 1957, p. 19); (2) the *Dinesus* Stage (with *Xystridura templetonensis*) is shown as younger than the '*Triplagnostus atavus*' Zone: it is however, older than *atavus,* and separated from the *atavus* zone by the intervening Zone of *Ptychagnostus* ('*Triplagnostus*') *gibbus.* At that time (1939), of course, the correct position of *gibbus* below *atavus* was unknown even in Sweden.

SUMMARY: THE ORDIAN AND ITS EQUIVALENTS

The name Ordian covers the interval between the top of the Olenellian (Georgian, Waucoban, in American terms) and the beginning of the Templetonian (the incoming of the Paradoxidian Middle Cambrian). The Ordian is regarded here as the earliest Middle Cambrian because it is post-Olenellian, and post-Lower Cambrian in the classical sense. Overseas equivalents are the '*Protolenus* zone', a substantial part of the Lena stage of Russian authors and of the *Redlichia* sequence of south-eastern Asia, which are attributed by several authors wholly to the Olenellian Lower Cambrian, as for example by Lu (1960, p. 213). Thus, the Ordian can be regarded either as the pre-*Paradoxides* Middle Cambrian or as the post-*Olenellus* Lower Cambrian, as discussed by Öpik (1966a, 1966b).

APPRAISAL OF THE OLENELLIAN AND THE LENO-ALDANIAN

The status of the Ordian Stage remains unaffected whether it is attributed to the Lower or to the Middle Cambrian; but the concepts and the spans of these epochs are considerably affected: the epoch receiving the Ordian subtracts from the other epoch a substantial part, thus creating two different scale standards in the current literature. Examples are given below in a survey of published stratigraphic charts and correlations, and summarized in Table 1.

In the following discussion 'classic Lower Cambrian' means also 'Olenellian' and 'Leno-Aldanian Lower Cambrian' refers to the extended Lower Cambrian.

It is apparent that a general, unqualified use of the designation 'Lower Cambrian' may be somewhat ambiguous. Unambiguous references to the classic Lower Cambrian in the sense of Walcott's (1890, 1891) Olenellian are applied by Rasetti (1951) and as Georgian and *Olenellus* zone by Shaw (1965; 1958). Shaw (1954, p. 1046) also gives good reasons for the restitution of the earliest name Georgian, which was replaced subsequently by Waucoban (Walcott, 1912).

The second standard, of a Leno-Aldanian Lower Cambrian, is also unambiguous as employed in modern Russian literature (Pokrovskaya, 1961; Vasilenko, 1963); it refers to a Lower Cambrian consisting of the original Lower Cambrian (Aldanian) and the post-Olenellian Lena stage taken together. This concept of the extended Leno-Aldanian Lower Cambrian is consistently applied in Russian taxonomic and geological texts and in lucid stratigraphic charts. The Russian version of Lower Cambrian and its application are discussed in some detail below.

The Ordian *Redlichia* fauna of Australia and the *Redlichia* fauna of China are quite similar and contemporaneous in general terms. The works of Chinese stratigraphers (Lu, 1960; Chang 1953-1966; Chu, 1962) indicate that the Ordian - Lower Cambrian sequence and faunas are developed best in eastern Yunnan, where the following sequence of formations has been adopted as a scale: (1) Lungwangmiao, above (2) Tsanglangpu, and (3) Chiungchussu at the base. Of these the Lungwangmiao fauna is contemporaneous with the *Redlichia idonea* fauna of Queensland, which marks the top of the Ordian. Less accurate is the correlation of the base of the Ordian, which depends on the identification of the late Olenellian fauna and its position in the sequence, as discussed next. Chang (1953, p. 147) in his chart employs an extended Lower Cambrian consisting of the Olenellian and the *Protolenus* zone of north-western Europe, and assigns to the latter an 'Upper *Redlichia* shale' of Shantung and Korea. The older part of the *Redlichia* sequence, however, is equated with the Olenellian, which appears an over-estimation. Chart 2 of Chang (1957) is similar except that the Yunnan sequence is projected downwards beyond the lowermost zone of the Olenellian. I am, however, inclined to regard Chang's *Hsuaspis* - *Hebediscus* zone, which is equated by its author with the lower part of the Olenellian, as not older than the uppermost Olenellian, followed above by the post-Olenellian *Palaeolenus* zone. Chart 3 of Chang shows the position of the *Redlichia* - *Cheiruroides* fauna below the uppermost zone of the 'Lower Cambrian' of Shantung; according to Suvorova (1964), however, *Cheiruroides* in Siberia is represented by several species in the uppermost part of the Lena stage, and, above it, in the Amga stage — which is Middle Cambrian by any standard. So, sufficient palaeontological evidence is now available for placing the *Redlichia* fauna in Shantung, at the earliest, in the late Ordian.

Further development in stratigraphic ideas is evident in the recent charts of Chang (1966, p. 150, 151). In these the *Hsuaspis* zone of the lower Shihpai shale of western Hupei is taken from the Chiungchussu division and placed in the lowermost Tsanglangpu. It appears, therefore, that the larger upper part of the Tsanglangpu formation may be early Ordian in age.

In the chart of Lu (1960, p. 213), in the column 'Europe' the Lower Cambrian includes the '*Protolenus* zone'; the *Paradoxides oelandicus* stage, however, is placed well above the base of the Middle Cambrian in a position seen in chart

2 of Chang (1957), and in the American charts which are discused further below. This is a considerable difference from the Russian Leno-Aldanian standard, where *Paradoxides oelandicus* is taken as the start of the Middle Cambrian, and the Lena sequence (to be equated with the *Protolenus* zone) below is the upward extended part of the Lower Cambrian. In brief, it appears that some of the equivalents of the Lena stage (the *Albertella* and *Plagiura-Poliella* zones) are in the charts of Chang and of Lu placed in the Middle, and others (*Protolenus, Redlichia*) in the Lower Cambrian (see Table 1).

Chang's (1957) *Protolenus* zone of north-western Europe is contemporaneous with the Lungwangmiao, and a part of Tsanglangpu, and with the two *Protolenus* zones of Samsonovicz (1956), and should be placed in the hiatus at the base of the *Paradoxides oelandicus* stage.

In American charts (Howell et al., 1944; Howell, 1947; and Lochman & Wilson, 1958) the Lower Cambrian is interpreted as follows: (1) in the American Cordilleran Province Lower Cambrian means Olenellian, and (2) in the Acado-Baltic Province the Olenellian is augmented by a post-Olenellian *Protolenus* zone.

Howell et al. (1944) show a post-Olenellian *Syspacephalus* zone in the latest Lower Cambrian of the Cordilleran Province; Rasetti (1951, p. 81), however, 'does not recognize a post Olenellian Lower Cambrian zone' (*Kochiella* or *Syspacephalus* zone) in the Cambrian of the Rocky Mountains. The Olenellian as the standard of Lower Cambrian in this region is also accepted by Lochman (1952, p. 73), Lochman (1956, p. 1349), and Lochman & Wilson (1958). In Howell's et al. chart (op. cit.) the post-Olenellian *Syspacephalus* zone is correlated with the *Protolenus* zone of north-western Europe and south-eastern Newfoundland. This correlation is approximate but correct and indicates that the *Protolenus* zone should be also regarded as post-Olenellian and post-Lower Cambrian. Lochman (1956, p. 1350) and Lochman & Wilson (1958), however, have retained the *Protolenus* zone in the Lower Cambrian; this procedure adopted in the Russian Leno-Aldanian standard seems not quite compatible with the standard established for the Pacific, western Province of America.

The interpretations of the age of the *Protolenus* zone have some bearing on the correlation of the *Redlichia* sequences of China and of the Ordian of Australia; hence, the designation '*Protolenus* zone' deserves comment. Species of *Protolenus* have been recorded from the Olenellian, from various '*Protolenus* beds', from the *Protolenus* zone (zones), and from the Middle Cambrian (in everybody's sense). Consequently, the genus *Protolenus* has no magic power in placing a sequence in one or another division of the Cambrian scale. The notion of a Lower (Olenellian or otherwise) Cambrian age is connected with the fauna of the Brigus Formation of eastern Newfoundland as revised by Hutchinson (1962).

The *Protolenus* fauna occurs in the upper half of the Brigus, whose lower half carries a diversified Olenellian fauna; at the time of discovery the species of *Protolenus* were stratigraphically inconclusive and the whole formation was placed, therefore, in the 'Lower Cambrian or *Olenellus* zone' of Walcott. Similarly, the Mount Whyte Formation was once regarded as being wholly Lower Cambrian (see Howell et al., 1944), but is now recognized by Rasetti (1951) as early Middle Cambrian; the correlation of the Mount Whyte formation and the *Protolenus* zone of Newfoundland, however, stands as shown in Howell's chart.

For a better understanding of the disparity of the classical Olenellian and the Leno-Aldanian concepts of the Lower Cambrian, as well as of the correlation of the Ordian and the Asian *Redlichia* faunas, the role of the *Paradoxides oelandicus* stage, and the hiatus below that stage in the Acado-Baltic realm, must be considered.

The *Paradoxides oelandicus* fauna with its approximate equivalents (the early Amgan in Siberia and the Templetonian in Australia, for example) provides a generally recognized reference level. In Russia it is taken as the beginning of the Middle Cambrian and the sequence below it is called Lower Cambrian—the Leno-Aldanian of this paper. In the charts of Howell et al. (1944), Howell (1947), and Lochman & Wilson (1958), the *P. oelandicus* stage occupies a high position in the Middle Cambrian, well above the top of the classic Olenellian Lower Cambrian. In the same charts a wide hiatus separates the *P. oelandicus* zone from the *Protolenus* zone or the Olenellian. It is taken as a Middle Cambrian hiatus; of course, it may extend downward, even to the basement; on the island of Oeland, according to Waern (1952), the hiatus includes also a larger, upper part of the Olenellian Lower Cambrian. In Siberia that part of the hiatus below the *P. oelandicus* level and above the Olenellian (Aldanian) is covered by the strata of the Lena stage and attributed to the Lower Cambrian (Leno-Aldanian). In Australia, in parts of the Northern Territory, Templetonian fossiliferous strata rest on Precambrian, but also on Ordian *Redlichia*-bearing beds. In such places the Ordian passes over into the Templetonian without a break and no hiatus is apparent. The Templetonian fauna in its turn is a temporal equivalent of the upper part of the *Paradoxides oelandicus* stage, passing into the Zone of *Ptychagnostus gibbus* (Öpik, 1956; 1957). In Queensland these relationships are observed in a single formation (the Thorntonia Limestone; Öpik, 1956, chart, p. 15) and also at the passage of two formations (Öpik *in* Noakes, Carter, & Öpik, 1959, stratigraphic chart).

These two examples from Queensland demonstrate in fact that the Ordian *Redlichia* fauna fills the Middle Cambrian hiatus below the *Paradoxides oelandicus* stage of the northern hemisphere and has the same position as the Lena stage of the Leno-Aldanian Lower Cambrian. The continuity of the Ordian and the Templetonian can be regarded as a fact. The relationship of the Ordian with the Lower Cambrian below is insufficiently known, but continuity is already evident in South Australia and Central Australia. In Queensland and in the Barkly Tableland of Northern Australia the Ordian rests with an unconformity on the Precambrian as well as on remnants of early Lower Cambrian strata. An example, however, of the Ordian resting above late Olenellian Lower Cambrian is presented below, from the Mootwingee Range area of New South Wales.

Hill (1965) adheres to the Leno-Aldanian and the Russian stratigraphic nomenclature regarding her concept of Lower Cambrian; the Antarctic Archaeocyatha are presumed by her to have a Lena, i.e. post-Olenellian, age. According to Hill (1964a, p. 137), the Ajax Limestone of South Australia also 'is possibly to be equated to either the upper part of the lower Lena stage or the lower part of the upper Lena stage'—a conclusion based on similarities of the Archaeocyathid faunas. The Ajax Limestone, however, is much older (Daily, 1956; 1957) than the Lena stage; it is probably of a lower Olenellian age, and deep in the Aldanian in Russian terms. The Ajax Limestone rests well below faunal assemblage 12 of the Emu Bay Shale of Daily, and its temporal equivalent at Mount Wright in New South Wales, which is discussed below.

HISTORY OF THE CONCEPTS AND NOMENCLATURE

The terms 'lower', 'middle', and 'upper' designate the objective superpositional order of strata and faunas within a division of the geological scale. The concepts behind such designations, on the other hand, are arbitrary and unstable, because the positions of the boundaries are selected from a number of possible alternatives. A division once defined in this manner eliminates other alternatives and becomes a factor in defining the limits of the division below and above. The designations 'lower', 'middle' and 'upper' are also employed as names of epochs and series (for example Lower Devonian, Middle Devonian, Upper Devonian) with the result that the same 'name' is employed for a number of different and competing concepts. Regarding the Lower and Middle Cambrian, only two alternatives are present in modern literature—an enviable advantage as compared with the Ordovician, whose multitude of concepts under each of these 'names' (Jaanusson, 1960) is rather formidable.

In the sketch that follows, Walcott's concept of the Lower Cambrian is taken as the *a priori* criterion in defining the Middle Cambrian because it has historical priority and a subsequent long tradition in learning. An alternative criterion, however, has also gained popularity: the *Paradoxides oelandicus* stage has become accepted as the beginning of the Middle Cambrian, leading to a concept of Lower Cambrian different from Walcott's. But for a long time the two concepts were not seen to be in conflict, because the Paradoxidian was believed to follow the Olenellian immediately.

Walcott's (1890) concept of Lower Cambrian is evident from the title of his historical monograph: 'The fauna of the Lower Cambrian or the Olenellus Zone', and his comment 'The definition of the title' (ibid., p. 515). Fundamental in recognition of the Lower Cambrian are *Olenellus* and its concomitant fauna. At the same time the fact of the superposition of the *Paradoxides* fauna over *Olenellus* was formally established; *Paradoxides,* which hitherto was believed to be 'primordial' or 'Lower Cambrian', became a symbol of the Middle Cambrian. From the beginning, the application of the criterion '*Olenellus* fauna' became a matter of extrapolations, of trial and error, and identification by insufficient and inconclusive means. Tentative as well as erronous identifications were many, but, in principle, should not have been used in weakening the fundamental concept defined by the *Olenellus* and its concomitant fauna. In the course of decades it became apparent that the *Olenellus* and *Paradoxides* faunas are not in contact, but are separated from each other by a sequence with *Protolenus* containing neither *Olenellus* nor *Paradoxides.*

The number of known sites with the *Protolenus* fauna gradually increased, but its final stratigraphic assignment remained inconclusive. In the meantime the belief that *Olenellus* is replaced immediately in time by the *Paradoxides*-bearing faunas was maintained in the literature, and the oldest known *Paradoxides* fauna—the *Paradoxides oelandicus* stage—was regarded as the initial Middle Cambrian; the pre-*oelandicus* faunas automatically became Lower Cambrian ('Olenellian without *Olenellus*'). The prominent exponents of the concept of a restricted Middle and extended Lower Cambrian were Rudolf and Emma Richter, who implemented it in their studies of the Mediterranean Palaeozoic. Their decision (R. & E. Richter, 1948) regarding the Lower Cambrian age of the Spanish Protolenidae was fully accepted by Lotze & Sdzuy (1961) in a comprehensive monograph of the Cambrian of Spain presented consistently in Richters' terms. Thus, the Leno-Aldanian concept originated in the western Mediterranean regions, and developed into a canon in Russian literature. Hupé (1952) adopted the Richters' stratigraphy in his monograph of the Moroccan Cambrian; he applied, nevertheless, Walcott's name 'Georgian' to the extended Lower Cambrian; but that name should be applied only to the classical Olenellian (Shaw, 1954). The Russian palaeontologists and stratigraphers about 1950-1954 adopted without reservation Richters' standard and formalized it with some finality.

The Russian official school of thought is presented in detail for the Siberian platform by Vasilenko (1963, p. 26-27). In Vasilenko's charts the Aldanian stage, as seen from its fossil lists of some fifteen columns, coincides exactly with the Lower Cambrian as established by Walcott; the Aldanian is followed above by the post-Olenellian Lena stage. An earlier and simplified chart is that of Pokrovskaya (1961). She refers the Olenellian to the Caerfai 'stage', a modification of the name Caerfai group of Hicks (1881). Caerfai group, however, (as well as Caerfai series, Caerfai beds) designates a rock unit in South Wales

(Stubblefield, 1956) and not a scale division; the name Caerfai 'stage', is nevertheless substituted by Pokrovskaya for the names Georgian and Aldanian, which are not mentioned at all. The main part of her Lower Cambrian consists of the post-Olenellian Lena stage. Her correlation of the Lena stage with the '*Redlichia* zone' of Australia and Asia and with the '*Protolenus* zone' of Morocco is plausible. Suvorova (1961) uses Aldanian as a designation of the Olenellian in place of Caerfai. Consequently, as a first approximation, the Lena stage and the Ordian are temporal equivalents, and their names can be regarded as approximate synonyms. But the name 'Lena' (Lenaic, Lenian, Lenan) is inappropriate in Australia because (1) it covers a somewhat wider span, and (2) unlike Ordian, it is not subject to the Australian Code of Stratigraphic Nomenclature (vide Őpik, 1951, p. 31; 1963, p. 7). By the way, the Australian column in Pokrovskaya's chart No. 2 was completely out of date in 1961; the same is, unfortunately, apparent in Tchernysheva (1965, for example p. 22).

ORDIAN CORRELATION

The results of the enquiry regarding the problem of the pre-Paradoxides Middle Cambrian or post-*Olenellus* Lower Cambrian are summarized in Table 1, which also shows the scale position of the Ordian Stage.

The *Paradoxides oelandicus* stage and its temporal equivalents provide a datum of reference which is shown in all charts discussed so far. Column 1 refers to the classic standard according to which Lower Cambrian means Olenellian.

Column 2 refers to the sequence on the island of Oeland (Westergaard, 1936-1946; Waern, 1952). Below the rocks containing *Paradoxides oelandicus* and concomitant trilobites, some 24 metres (about 80 feet) according to Waern, and 20-25 metres (Westergaard) of the sequence contains no trilobites; hence this part is attributed to the *P. oelandicus* stage by extrapolation only; it can just as well be placed in the 'pre-*Paradoxides* Middle Cambrian'. The actual local hiatus on Oeland is very large; the Middle Cambrian rests on strata with *Discinella holsti*—the earliest Lower Cambrian of the Baltic area (Waern, op. cit., p. 227). The hiatus as shown in column 2 corresponds to the *Partoleuus* sequences of the same realm, as for example, of maritime Atlantic Canada.

Column 3, in combination with columns 1 and 2, is extracted from Lochman & Wilson (1958); it is close to the correlation in Howell et al. (1944) and is supported by palaeontological evidence (Őpik, 1956; 1957, p. 44). Rasetti (1956) suggests three zones (*Albertella, Plagiura-Kochaspis,* and *Wenkchemnia*).

Column 4 (Australia) is based on data presented in the present paper.

Column 5 is constructed from Chinese sources which are discussed above; Chinese authors include the Tsanglangpu in the Olenellian.

TABLE 1

Acado-Baltic Realm 1.	2.	Rocky Mountains 3.	Australia 4.	South China (Yunnan) 5.	Siberia 6.	Poland Spain Morocco 7.
Early Middle Cambrian	*Paradoxides oelandicus* stage	*Glossopleura* zone	Templetonian	Time equivalents of *Paradoxides oelandicus*		
	Hiatus	*Albertella* zone *Poliella-Plagiura* zone	Ordian	Lungwangmiao fauna Tsanglangpu fauna	Lena Stage (Leno-Aldanian)	Extended Lower Cambrian = *Protolenus* zones and Olenellian
Lower Cambrian (Olenellian; Georgian)				Chiungshussu fauna	Aldanian stage	

Column 6 summarizes the Leno-Aldanian concept as employed by the Russian authors.

Column 7 refers to the 'Georgian' extended; Morocco refers to Hupé (1952); Spain to Lotze & Sdzuy (1961). According to Samsonovicz (1956) two *Protolenus* horizons above the Olenellian are discernible, followed above by strata with *Paradoxides* cf. *oelandicus,* 'which appears to be here the lowest Middle Cambrian horizon' (op. cit., p. 141).

Norway, however, is omitted in Column 6. In the sections in the Tømten area of Norway (Hennigsmoen, 1956), strata with *Paradoxides oelandicus* are regarded as the base of the Middle Cambrian; below follows a bed of calcareous sandstone with a single trilobite (*Strenuella linnarssoni*), resting on the Lower Cambrian *Holmia* shale. The *Strenuella* bed represents possibly the 'pre-*Paradoxides* Middle' Cambrian *Protolenus* zone; but a definite conclusion cannot be made on the basis of a single trilobite. The possibility that *Strenuella linnarssoni* belongs to the *Protolenus* zone was already visualized by Kiaer (1961, p. 111). The tectonic structure is too complicated for hiatuses to be clearly recognized.

The existence of two standards regarding the concept of Lower Cambrian is an international *fait accompli.* Even a recommendation of the Geological Congress favouring one school of thought will create, if accepted, a rather undesirable discontinuity in mapping and literary practice of the other. Needless to say, the standards should not be confused with each other nor used simultaneously, matters of correlation excepted. The designation 'Lower Cambrian' referring to isotopic age data should be also specified; in hitherto published data it means Olenellian (Georgian, Aldanian).

FAUNAS AND SEQUENCES OF ORDIAN AGE IN AUSTRALIA

The name Ordian is used in the present paper to designate the age of the Australian Metadoxididae; furthermore, it will be used in papers, now in progress, dealing (1) with species of *Redlichia* of northern Australia and New South Wales, (2) with Archaeostraca, (3) with species of *Xystridura,* and (4) with species of the Dolichometopidae. Several established formations are known to have an Ordian age: Yelvertoft Beds and lower part of the Thorntonia Limestone in Queensland; Gum Ridge Formation and Ranken Limestone in Northern Territory; the formations of the Negri Group in Western Australia and Northern Territory; and the Wirrealpa Limestone of South Australia. Some unnamed formations (named in Reports now issued or about to be issued) and new faunas in central Australia, and in some stratigraphic oil wells, are also known to be Ordian. Finally, hiatuses of Ordian age occur also.

The sequence of faunas of the Ordian indicates a succession of several zones. The zoning, however, cannot be presented until the relevant species are described.

The latest Ordian faunas are evident in Queensland (Yelvertoft Beds and Thorntonia Limestone) and in the Barkly Tableland, and are characterized by numerous species of *Redlichia,* including *R. chinensis.* Also late Ordian is the 'first discovery limestone' of New South Wales (q.v. below). The oldest known Ordian fauna is represented by *Onaraspis adusta* sp. nov. of the Blatchford Formation in the Kimberley region and *Onaraspis somniurna* at Deep Well (q.v.) in central Australia. Collections from the Negri Group on the Ord River indicate the presence of at least three zones, and three to four zones are evident in the Gum Ridge Formation in the Tennant Creek area. A detailed correlation of these areas, formations, and zones must be reserved, of course, but a total of some four zones can be accepted as a rough estimation.

CAMBRIAN IN NEW SOUTH WALES

The recently discovered Cambrian sequence in the Mootwingee Range area of New South Wales offers a welcome example of an Ordian sequence with *Redlichia* resting on late Lower Cambrian (Olenellian) and passing upward into the Templetonian.

Fossiliferous Cambrian (Öpik, 1956, 1957, p. 245-248) was unknown hitherto in the State of New South Wales.

The Cambrian sequences and fossils at Mount Wright in the Mootwingee Range area of New South Wales are as follows:

Top: *late Upper Cambrian and Tremadocian*
Unconformity.
Templetonian: unnamed strata with *Xystridura* sp. nov., *Pagetia significans* (Etheridge), Oryctocephalidae, Dolichometopidae, agnostids, etc.
Ordian: unnamed limestone (the 'first discovery limestone' of Warner & Harrison, 1961) with *Girvanella, Redlichia* sp. indet., Dinesidae, *Kootenia, Pagetia, Biconulites,* etc., followed below by a shale with *Redlichia* sp. nov., *Biconulites,* and other fossils.
Late Lower Cambrian (Olenellian): Sediments and volcanics with lenses of archaeocyathid-bearing limestone (Fletcher, 1964); the identified trilobites are: *Estaingia bilobata* Pocock, 1964; *Calodiscus* aff. *helena* (Walcott), *Serrodiscus* aff. *speciosus* (Ford), *Serrodiscus* sp. nov., *Pagetiidae* gen. nov. sp. nov., Dinesidae (*Proerbia?*), Ellipsocephalidae (? gen. nov.), Lermontoviinae(?); several other fossils including *Scenella* cf. *reticulata* Billings.

The co-ordinates of the Mount Wright area are: Lat. 31°12'S, Long. 142°20'E; its position is also evident in the map (Hall et al., 1962), which shows the presence of Cambrian rocks (unspecified) in the same place.

Estaingia bilobata serves in Australian correlation; its late Lower Cambrian age and distribution in South Australia is discussed by Pocock (1964, p. 410).

The eodiscid genera *Calodiscus* Howell, 1935, and *Serrodiscus* R. & E. Richter, 1941, are known members of the later part of the *Olenellus* fauna in the Northern

Hemisphere (including Britain, Lake, 1946; Spain, R. & E. Richter, 1941), and *Scenella reticulata* belongs to the same fauna. The Australian *Calodiscus* aff. *helena* has a pygidium somewhat different from the original *C. helena* (Walcott; see Rasetti, 1952), but is close to Lazarenko's (1964) '*C. helena*' with its six axial annulations in the pygidium, which is the oldest form; Lazarenko's material comes from the upper Aldanian (=upper Olenellian) of Arctic Siberia. According to Hutchinson (1962, p. 60) Walcott's type material of *Calodiscus helena* 'must have been collected from the upper part of Brigus Formation', which (ibid. p. 9, 18) contains *Protolenus?* above the late Lower Cambrian *Callavia* zone fauna.

The Cambrian in New South Wales was identified by Fletcher (in Warner & Harrison, 1961) from fossils found in rocks previously mapped as Upper Devonian. Subsequently Fletcher (1964) indicates briefly that the early Palaeozoic sequence in the Mootwingee Range area is of a Cambrian to Tremadocian age and adds a stratigraphic column by Messrs P. S. Lavers and W. H. Jones 'which is a modified version of that suggested by Dr A. A. Öpik'. I wholly agree with this 'modified version', which presents the local sequence of rock types and strata; my own 'version', however, (a personal communication of field notes) refers to the succession of fossil faunas in the first place. Furthermore, sequences VI (Templetonian, early Middle Cambrian) and VII (late Upper Cambrian) of Lavers & Jones (1964) are separated by an angular unconformity. I also acknowledge with pleasure and gratitude that Messrs Lavers & Jones supplied me subsequently with Lower Cambrian fossils from the volcanics at the Mount Wright fault, that Mr. H. O. Fletcher gave me for study his original material from the 'first discovery limestone', and that at a later date Mr G. A. Brown of Planet Exploration Company supplied the *Redlichia* fauna which he discovered, to satisfy the forecast I ventured to make in my 'field notes'.

NOMENCLATURE

The name Ordian is derived from the Ord River, Ord Valley, and Ord River station in the north of Western Australia. Wade (1924, p. 26) introduced the name Ord River Basin to denote the structure of the Negri series in the Ord River Valley; structures, however, are not stratigraphic units, and therefore the name 'Ord Basin' has no bearing on the availability of the geographic place name 'Ord' for naming of a stage.

The name Ordian as applied here was approved by the Western Australian Stratigraphic Nomenclature Subcommittee on 23 December 1965, and has been entered in the Central Register of Australian Stratigraphic Names.

The *Redlichia* fauna was discovered first on the Ord (Foord, 1890), followed by the Salt Range in Pakistan (Redlich, 1899). The concept and the nomenclature of the Ordian does not conflict with the 'Negri Series' of Chapman 1923-1924 (vide Wade, 1924)—the Negri Group (Traves, 1955) in modern usage—because the Negri Group is a rock unit: it can be dated by means of its fossils, and its age is Ordian. Furthermore, the whole of the Negri Group cannot be attributed yet to the Ordian; some 700 feet of the upper part of the Group in the Ord Basin (the Hudson Shale, by Traves, 1955) are unfossiliferous; the Negri sequence in the Argyle Basin, however, contains a *Redlichia* (not *R. forresti*) close to the top, but its correlation with the sequence on the Ord is inconclusive. The lower half of the sequence, with the Headleys Limestone at base and topped by the Shady Camp Limestone of Traves' section (1955, p. 36), is definitely Ordian in age.

PALAEONTOLOGY

OCCURRENCE AND AGE OF METADOXIDIDAE IN AUSTRALIA

The record of Metadoxididae in Australia is as follows:

1. *Onaraspis somniurna* gen. nov. et sp. nov., near Deep Well, Rodinga area, Northern Territory, locality Rd 10.

2. *Onaraspis* sp. indet., at Gaylad Dam, Ferguson Range, Alice Springs Area, Northern Territory, locality AS 33.

3. *Onaraspis adusta* sp. nov., Ragged Range, Kimberley Division, Western Australia, locality CG51/1.

4. Metadoxididae, indet., Cornford Bore, May Downs, Mount Isa area, Queensland, locality M262.

1. The Deep Well locality Rd 10 (collection number of this Bureau) is about 5 miles south-east of Deep Well homestead and 11 miles east-north-east of the Deep Well railway siding, south of Alice Springs, at about Lat. 24°S and Long. 134°E. The site and its fossils were discovered in 1959 by Mr D. J. Taylor, then of Frome-Broken Hill Co. Pty Ltd, now of Department of Mines, Melbourne, Victoria, who also supplied the necessary field data. According to Taylor, the outcrop is small, about 100 feet long and 20 feet wide; the sequence consists of a dolomite with two chert layers assigned to the 'Pertaoorrta Formation' (quotation marks by D.J.T.); the lower chert, close to the base of the sequence, yielded most of the fossils. The area is described in detail by Wells et al. (1967). The fossils listed below are identified from all available collections mentioned in the description of *Onaraspis somniurna* sp. nov.

The fossils in chert are as follows:

Onaraspis somniurna sp. nov.—present in a large number of fragments; it is the only trilobite of the sequence.
Biconulites hardmani (Etheridge); its shells are present in large numbers.
Brachiopods: *Wimanella*(?) and an indeterminable orthoid.
'Helcionella'—a form related to *'Helcionella' pacifica* (verbal communication by Miss Joyce Gilbert-Tomlinson); it is rare in association with the trilobite, but frequent with echinoderms.
Echinoderm fragments: abundant.

The age of the fossils is Ordian, as concluded from the mass of *Biconulites hardmani,* the brachiopods, and the *'Helcionella';* even an early Ordian age seems to be probable.

2. The Gaylad Dam locality AS33, Alice Springs area, is 65 miles east of Alice Springs at Lat. 23°46'S and Long. 134°50'E. The outcrop is small, covered with red sand; it was discovered by geologists of the Bureau of Mineral Resources in 1964. The fossiliferous rock is a black and smelly phanerocrystalline limestone, apparently an interbed in a dolomitic formation.

The fossils are fragmentary, but otherwise well preserved, and are as follows:

Onaraspis sp. indet., fragments only.
Xystridura sp. nov.
Dinesus sp. indet., granulose.
Kootenia sp., cranidia and pygidia.
Dolichometopidae, sp. nov. of an undescribed genus.
Ptychopariidae, possibly related to *Emmrichella.*
Pagetiidae(?) or *Calodiscus?*—one fragment.
Biconulites sp. (*hardmani?*—the fragments are rare and specifically inconclusive).
Brachiopods: an indeterminable orthoid and fragmentary phosphatic shells.
'Helcionella', two or three species, including a form of the *'Helcionella pacifica'* group.
Echinoderm fragments.

Fossils designated as 'sp. nov.' will be described later.

The age of the fossils is probably late Ordian. It is, however, a hitherto unknown fauna, of new or undescribed species of trilobites none of which is present in the well explored Templetonian fauna of Northern Territory, and Queensland; related but not identical species of the Dolichometopidae sp. nov. are present in the early Templetonian of Northern Territory, Queensland, and New South Wales. The novelty of the species and the presence of *Onaraspis* suggest a pre-Templetonian age, and the late Ordian is indicated by the generic composition and the relatively large number of items in the fauna.

3. The Ragged Range fossils were collected by Mr R. H. Otway, of Nullagine, Western Australia, a camp assistant of the Bonaparte Gulf Party, led by Dr J. J. Veevers in 1964 (see Kaulback & Veevers, 1965). Locality CG51/1 is in the Blatchford Escarpment, Lat. 16°17'S. and Long. 128°18'E. The trilobite remains are embedded in a brick-brown to red dolomite sandstone of the Blatchford Formation which also contains layers of glauconitic dolomite and varicoloured siltstone and shale, and layers with masses of *Biconulites;* the formation rests on the Antrim Plateau Volcanics, presumably of Lower Cambrian age. The Blatchford Formation was previously referred to as a part of the Negri Group (Traves, 1955, p. 77, text-fig. 20).

The fossils are: *Onaraspis adusta* sp. nov. and *Biconulites hardmani* (Etheridge), which occurs in large numbers packed together in several beds.

The fossils are not older than Ordian, in view of the abundance of *Biconulites hardmani.* The slightly younger formation in the same area (Tarrara Formation, Kaulback & Veevers, 1965) contains *Biconulites* and a species (indet.) of *Redlichia,* which are also Ordian.

4. At Cornford Bore (Öpik et al., 1961), 25 miles west-south-west of Mount Isa, in a minor outlier in a chert bed, rare fragments of a large trilobite have been collected; these are reminiscent of a metadoxidid, close to *Onaraspis.* Associated are three new species of *Redlichia* and *Biconulites hardmani.* The age of these fossils is Ordian.

The Ordian (pre-Templetonian) age of the four sites and faunas discussed above is evident from the associated fossils and needs no further discussion. The presumed early Ordian age of *Onaraspis adusta* and *O. somniurna,* however, needs some comment because being novel forms they cannot be dated on their own merit. *Onaraspis adusta* has a stratigraphic position low in a sequence of *Redlichia*-bearing strata; and the highest known fossiliferous part of the Ordian of the Cambridge Gulf/Ord River area in its turn has not reached the contact with the Templetonian, which is missing, but should be the next stage above. *Onaraspis somniurna* occurs in a similar stratigraphic position, but above strata which contain Lower Cambrian fossils.

Family METADOXIDIDAE Whitehouse, 1939

A comment is needed regarding the restitution of the name Metadoxidinae (-dae), which Sdzuy (1951) regards as a junior subjective synonym of the Doleroleninae 1931, published by Kobayashi (1951). Sdzuy's procedure follows Article 39, I.C.Z.N., 1961, according to which the Dolerolenidae retain the date 1931 in replacing the invalid Olenopsidae, whose type genus is a rejected homonym. I think, however, that the names Dolerolenidae and Metadoxididae are not synonyms, but each represents an independent family taxon.

The Metadoxididae have not yet been satisfactorily accommodated in the higher taxa. The family has no place in the Paradoxidacea (vide Harrington et al., 1959), and nothing in common with *Redlichia* and Redlichiacea. A separate order of trilobites can be contemplated including the Metadoxididae, the Dolerolenidae, the 'quasi-redlichiids' *Perrector, Richterops, Gigantopygus,* and *Bathynotellus;* the suborder *Bathynotina* Lochman, 1959, may be such a taxon as a first step in 'purification' of the Redlichiida, but its full scope cannot be defined yet.

In modern classification (Hupé, 1953; Henningsmoen, 1957; Harrington et al. 1959), the above-mentioned 'quasi-redlichiids' and a number of other genera are referred to as Pararedlichiidae (-inae). I think that *Pararedlichia, Neoredlichia,* and *Eoredlichia* (Chang, 1950) (complete specimens in Chang, 1962) belong to the Redlichiidae, which should include therefore also the family groups Pararedlichiidae and Neoredlichiidae; but these names lose their meaning when applied liberally to a diversity of disparate genera.

In passing, *Bigotina* Cobbold was also placed by Sdzuy (1959) in the Dolerolenidae; but the cranidial characters of *Bigotina,* as for example the tiny posterolateral limbs, indicate a close relationship with the ellipsocephalids and protolenids, which themselves are alien to *Redlichia* as well as to the 'quasi-redlichiids'.

The Dolerolenidae differ from the Metadoxididae by the ptychoparioid design of the cephalon of *Dolerolenus* and its Siberian relatives *Sajanaspis* Repina and *Tungusella* Repina, 1960, and the Chinese *Malungia* Lu, 1961. For the same reason they also are unrelated to the redlichiids. The Saukiandidae Hupé are probably related to the Corynexochida ('bathyuriscids', vide Öpik, 1958, p. 35).

The Metadoxididae are common in Sardinia and Spain, and at least one genus (*Bulaiaspis* Lermontova, in Repina, 1956; Sdzuy, 1961, p. 54) of some ten species occurs in Siberia. The immature *Onaraspis somniurna* (Pl. 1, fig. 5) resembles early instars of *Bulaiaspis* as described by Suvorova (1960), but the adults of *Onaraspis* and *Bulaiaspis* are quite different trilobites. Russian authors refer *Bulaiaspis* to the Redlichiidae as well as Neoredlichiidae.

Genus ONARASPIS nov.

The type species of *Onaraspis* is *O. somniurna* sp. nov.

Diagnosis. Onaraspis gen. nov. refers to species of Metadoxididae distinguished by a relatively small number of segments in the thorax (twelve in the type species), well developed pygidium with a concave flange, and only slightly tapering glabella; in the type species the tenth segment is macropleural.

Differential diagnosis. In the known Metadoxididae (*Metadoxides, 'Anadoxides'*) the thorax is multisegmented, with 18 to 22 segments according to Hupé (1953), and the pygidium is half as long as in *Onaraspis. Metadoxides* and *Onaraspis* differ little as regards the structure of the cephalon, and have a similar granulose ornament and axial spines in the thorax.

Realaspis and *Lunolenus,* both by Sdzuy, are also probably related to *Onaraspis.* In *Realaspis,* the pygidium is *Onaraspis*-like, but the cranidial rim is convex, the interocular cheeks are relatively narrow, and the posterolateral limbs are small. *Lunolenus* has a brim, its glabella is conical, and the pygidial pleural lobes are extremely narrow, and are reduced to mere flanges enclosing the axial lobe.

In *Resserops* R. & E. Richter (=*Perrector,* R. & E.R., according to Henningsmoen, 1957), *Richterops* Hupé, 1953, *Despujolsia* Neltner & Poctey, *Bathynotus* Hall, 1860, and *Bathynotellus* Lermontova, 1940, the structure of the thorax and the pygidium recalls *Onaraspis;* their cephala, however, are disparate and further comment is therefore superfluous.

Finally, *Yiliangella forficula* Chang (1966, pl. 6, fig. 1), from the Tsanglangpu formation of Yunnan, has a cephalon slightly reminiscent of *Onaraspis somniurna,* but its multisegmented thorax with long pleural extremities and the small pygidium with lateral spines are very different. *Yiliangella* has been placed by Chang in the family Gigantopygidae Harrington (in Harrington et al., 1959) because of similarities in the pygidial and pleural structures. The cephala of *Yiliangella* and *Gigantopygus* Hupé are, however, rather disparate.

ONARASPIS SOMNIURNA sp. nov.

(Pl. 19, figs 1-8; Pl. 20, fig. 1 and 2; Text-figs 1-4).

Material. Twelve fragmentary specimens are illustrated, representing all parts of the skeleton except for the rostral shield. The cranidium Plate 19, figure 1, and the pygidium Text-figure 3, were collected by Mr D. Taylor, the discoverer of the fossils; and other illustrated specimens were collected by officers of the Bureau of Mineral Resources on several visits to the site Rd 10; material from a collected supplied by Professor M. Glaessner, Adelaide, was also examined.

Holotype. The cranidium Plate 19, figure 3, CPC 7165, is selected as the holotype because it has retained a palpebral lobe; the cranidium Plate 19, fig. 1, the best preserved specimen, is somewhat immature and its glabella is narrower than in the larger cranidia.

Diagnosis. Onaraspis somniurna is a species with a strongly granulose test distinguished by its slightly tapering glabella, broad border of the free cheek, and rather weak glabellar furrows.

Differential diagnosis. See under *Onaraspis adusta* sp. nov.

The reconstruction, Text-figure 1, is based on the illustrated fragmentary specimens, each belonging to a separate individual of a different size; longitudinal proportions were established first, followed by the less complicated transverse proportions. The number of segments in the thorax was somewhat inconclusive, but not less than eleven were apparent; the final, however, with twelve segments presented a grid satisfying the proportions. Subsequently a rather corroded complete exoskeleton some 10 cm long, CPC 7157, with parts of the cephalon and with the pygidium, became available, showing the calculated number of twelve segments of the model.

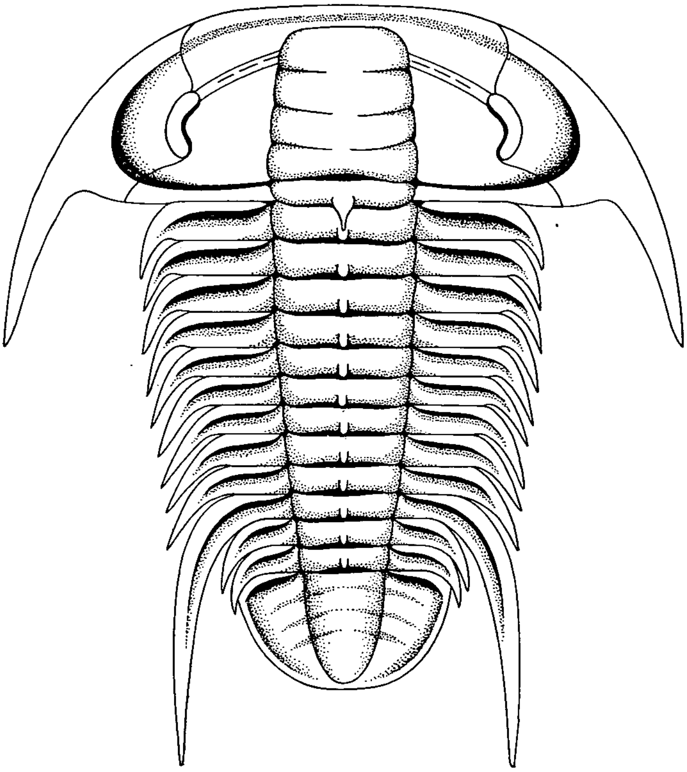


Fig. 1.—*Onaraspis somniurna* sp. nov., restored. The free cheeks are shown as flattened. Compare Text-figure 2.

In the reconstruction the free cheeks and the posterolateral limbs are shown flattened in plan; they are, however, down-sloping, and therefore shortened in projection of a cephalon preserving its convexity as shown in Text-figure 2.

External habit. Onaraspis somniurna is a relatively large trilobite attaining a length of 12-15 cm. The body is strongly convex owing to the down-geniculated flanks, ponderous cephalon, and prominent axial lobe. The transverse semielliptical cephalon is as long as six anterior segments of the thorax; the eyes are relatively small and far apart, the undeflected genal spines are slightly advanced; the glabella reaches the narrow frontal border, is long, broad, and subtruncate in front, and its transverse furrows are ill defined and shallow. The thorax of twelve segments is about as broad as long; the tips of the pleurae are pointed and increase in length retrally; the tenth segment is macropleural, with long free pleurae extending well beyond the rear of the pygidium. The axial (and occipital) annulations are equipped with short spines; the pleural furrows are deep. The pygidium is relatively large—about as long as four posterior segments of the thorax—and almost semicircular; it is concave along the margin; the axial lobe is prominent and long, almost reaching the rear, but the transverse furrows are ill defined. The test is visibly granulose. The proportions of the tagmata and the well developed facets indicate the ability of sphaeroidal coiling.

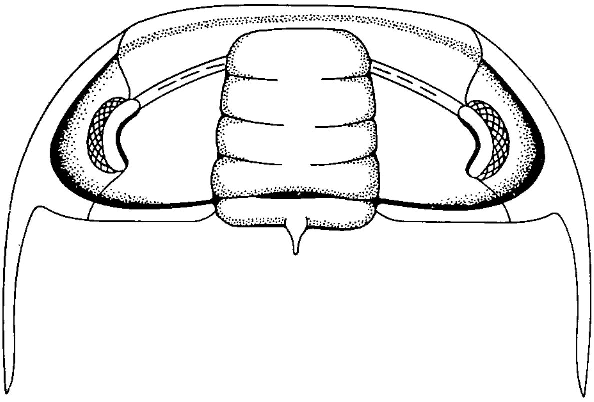


Fig. 2.— ***Onaraspis somniurna*** **sp. nov. Cephalon restored with cheeks down-sloping in original position.**

Description of parts. In the cephalon the relief of lobes and furrows, especially in the glabella, is subdued; it is semielliptical and wide, with a length of about 0.4 of width in the unflattened state (Text-fig. 2). The frontal margin is relatively straight and somewhat arched up in relation to the margins of the free cheeks. The rim in front is narrow and weak, especially in larger specimens, but passing on to the free cheeks it widens rearwards and becomes rather large at the base of the genal spine. The spine itself is curved, broad, and flat. The anterior sutures are slightly divergent and, remaining marginal or almost so, meet in front. The posterior sutures intercept the rear margin well off the genal angles and at the distance of the width of the occipital lobe from the axial furrows in flattened cephala. The cranidium is subrectangular with downsloping posterolateral limbs; these are triangular and moderately large with tips at a fair distance from the genal spines. The rear marginal furrow is deep and the rear cranidial border narrow and prominent. A brim in front of the glabella is absent, and the rim, with a rounded margin, is relatively flat; it is more prominent in younger (Pl. 19, figs 1 and 5) than in large specimens.

The palpebral lobes are relatively small, about half the glabellar length, and placed somewhat behind the glabellar midpoint and separated by wide interocular cheeks which are about half the glabellar width; the glabella is also rather wide. The palpebral lobes in the smaller cranidium are longer than in larger specimens. The ocular ridges are low, broad, and slanting, and in Plate 19, figure 1, they are double.

The occipital lobe is relatively short longitudinally and bears a submarginal axial spine, and the occipital furrow is shallow.

The axial furrows are indistinct, but their position is indicated by the steepness of the glabellar flanks; these flanks are straight and so is the front. The glabella tapers slightly forward, almost reaches the rim, and is about as wide as long in mature specimens; in smaller cranidia it is relatively narrow and therefore longer than wide. Three pairs of rather shallow glabellar furrows are discernible and are transcurrent in some specimens.

The hypostoma is broad in front and narrows rearward to about half its frontal width; its rear is developed into a narrow downward-deflected rim; the maculae are strong, long and narrow, and placed well forward; its median body is relatively short and shallow. The hypostomal test is internally smooth, but ornamented externally by granules and elevated lines. No Cambrian trilobite is known to have a comparable hypostome; but it can be compared with the post-Cambrian Scutellidae.

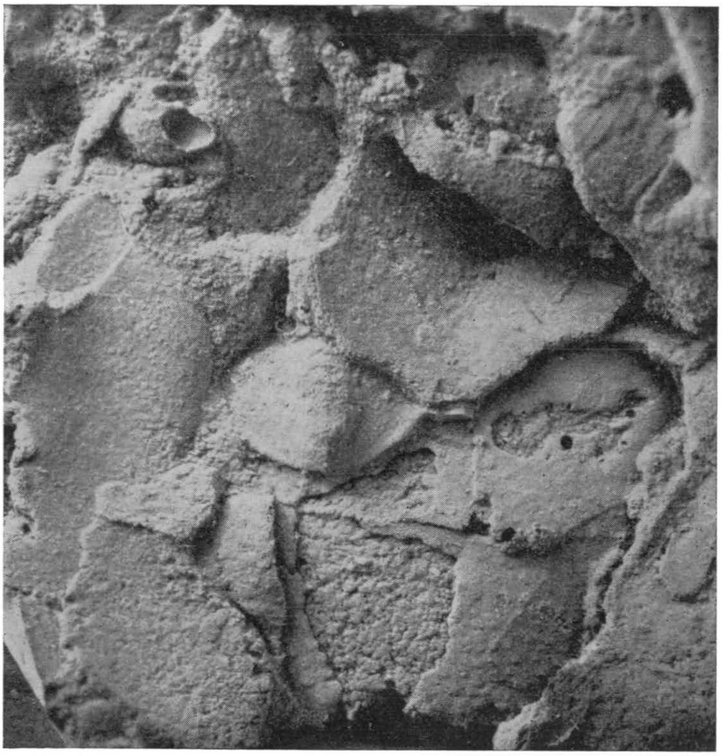


Fig. 3.—*Onaraspis somniurna,* a small pygidium rubber cast of CPC 7160 surrounded by very large fragments; Locality Rd 10; about x8.

In contrast with the cephalon the relief of the thorax is quite strong; the axial furrows are distinct, the pleural furrows deep, and the fulcral points prominent. In frontal segments the axial lobe is slightly wider than a pleura and the pleural tips are slightly advanced; rearward the pleurae are falcate.

The semicircular pygidium is relatively large, as long as about four rear segments of the thorax and about 0.6 of the cephalic length. Its border is concave and the axial lobe is prominent and almost pointed in the rear; in larger specimens the pleural ribs and axial annulations are nearly obsolete, but in small pygidia (Text-fig. 3; Pl. 19, fig. 8) five to six annulations are apparent.

Morphogenesis. Ill preserved meraspid cranidia are present, ranging from 1.5 mm to 4.0 mm in length; in these the palpebral lobes gradually decrease and the transcurrent glabellar furrows shallow as length increases. The cranidial instar 4.0 mm long (Pl. 19, fig. 5) has still a larval appearance which is almost completely lost in the cranidium, Plate 19, figure 5, which is 5.0 mm long. In larger cranidia the growth of the palpebral lobes is visibly retarded and the glabellar and pygidial pleural furrows are becoming effaced. The meraspid cranidia of *Onaraspis somniurna* closely resemble immature instars and even mature shields of *Bulaiaspis* Lermontova.

Comment on illustrated specimens

The following specimens come from locality Rd 10 (near Deep Well, Rodinga 1:250,000 Sheet area, south of Alice Springs); the rock is a chert layer in dolomite.

The cranidium Plate 19, figure 1, CPC 7163, an external mould, is 5.0 mm long; its relatively small size and large palpebral lobes indicate a somewhat immature specimen (see comment on Pl. 19, fig. 5, below). The glabellar furrows are transcurrent but weak; the ocular ridge is double; the front bears terraced lines.

The cranidium Plate 19, figure 2, CPC 7164, is 31.0 mm long; the test is worn, but in the rear on the left side the granulose ornament is visible; fragments of *Biconulites* are associated.

The holotype cranidium, Plate 19, figure 3, CPC 7165, is 18.0 mm long. The middle part of the glabella is missing, but its structure is apparent in other specimens. The right palpebral lobe and the base of the occipital spine are preserved.

The cranidium Plate 19, figure 4, CPC 7166, is 22.0 mm long; its frontal margin is preserved.

The cranidium Plate 19, figure 5, CPC 7167, is 4.0 mm long; it is immature and has large palpebral lobes. It is an internal cast lacking ornament, and is surrounded by fragments of very large specimens.

The hypostoma Plate 19, figure 6, CPC 7168, is 5.0 mm long. Note the large and forward placed maculae and the lineate to granulose ornament preserved on the flanks.

The free cheek Plate 19, figure 7, CPC 7169, is about 36.0 mm long from tip to tip; the frontal doublure is relatively long, indicating that the rostral shield should be quite narrow transversely.

The pygidium Plate 19, figure 8, CPC 7170, is 5.2 mm long; it shows axial annulations and pleural ribs more clearly than the larger pygidium.

The anterior part of the thorax Plate 20, figure 1, CPC 7171, is 38.0 mm long; eight segments are preserved: nos 1 to 8 or 2 to 9.

The posterior part of the thorax with the pygidium Plate 20, figure 2, CPC 7172, is about 30.0 mm long; the tenth macropleural segment is relatively well preserved.

The posterior part of the thorax with the pygidium Text-figure 4, CPC 7161, is 23.0 mm long; it is worn, but the bases of the axial spines of the thorax are visible.

The pygidium Text-figure 3, CPC 7160, is 2.4 mm long; it is associated with the cranidium Plate 19, figure 1, and surrounded by fragments of a very large segment of a thorax.

Fig. 4.— *Onaraspis somniurna,* **rear part of thorax and pygidium, CPC 7161, about x4.**

Occurrence and age: The material of *Onoraspis somniurna* was collected near Deep Well, Rodinga area, Northern Territory, locality Rd 10; its age is Ordian.

ONARASPIS ADUSTA sp. nov.

(Pl. 20, fig. 3-7; Text-fig. 5)

Material. Two cranidia, one pygidium, and a cranidium with the anterior part of the thorax, all from a single locality, are illustrated.

Holotype. The cranidium Plate 2, figures 3 and 4, CPC 7173, is selected as the holotype.

Diagnosis. Onaraspis adusta is distinguished by its parallel-sided glabella, deep glabellar furrows, small palpebral lobes, fine granulation of the test, and relatively delicate border of the free cheeks.

Differential diagnosis: *Onaraspis somniurna* sp. nov. is different in having a tapering glabella, almost obsolete glabella furrows, coarser granulation, and the border of the free cheeks expanded at the genal angle.

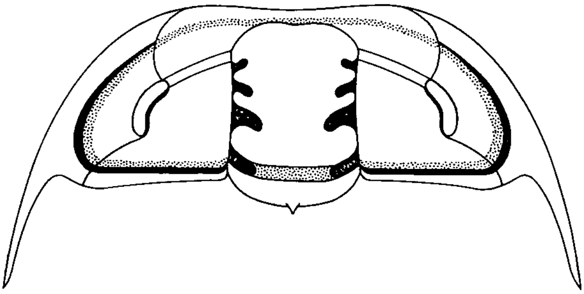


Fig. 5.—*Onaraspis adusta* **sp. nov., cephalon restored; the free cheeks are based on specimens CPC 7158 and 7159, which are not illustrated.**

Description. The cephalon is broadly semielliptical, as long as 0.4 of the width; its frontal margin is arched rearward; the genal spines are undeflected, but moderately advanced. The anterior sutures are curved and convex outward; the posterior sutures intercept the margin at the distance of the width of the occipital lobe. The posterolateral limbs are triangular and relatively large. A brim is absent and the glabella almost contacts the narrow rim. The palpebral lobes are oblique, about 0.4 of glabellar length, and continuous with the slanting ocular ridges. The interocular cheeks are wider than half the glabella. The occipital lobe bears a short marginal spine and the occipital furrow is well defined. The glabella, longer than wide, is almost imperceptibly constricted in the middle and almost parallel-sided, and has its front notched; the three pairs of glabellar furrows are deep and disconnected in the middle. In the thorax the axial and pleural furrows are well impressed, and axial spines are indicated. The pygidium is described below.

Comment on illustrated specimens

The holotype cranidium Plate 20, figures 3 and 4, is 7.6 mm long; its internal cast (Pl. 20, fig. 4) is apparently smooth, but a fine granulation is evident on the latex cast (fig. 3) of its external surface.

The cranidium (latex cast, Pl. 20, fig. 5), CPC 7174, is 9.5 mm long and the largest available; its right posterolateral limb is well preserved.

The pygidium Plate 20, figure 6, CPC 7175, is 6.5 mm long; it is somewhat distorted, but shows the concave pleural flange, and six axial annulations. The axis is long and probably pointed.

The cranidium together with seven segments of the thorax, Plate 20, figure 7, CPC 7176, is 9.1 mm long; abraded axial spines are evident in the thorax.

Occurrence and Age: *Onaraspis adusta* occurs only in the Ragged Range, Kimberley Division, locality CG 51/1, Western Australia; its age is Ordian.

ONARASPIS sp. indet.

(Pl. 20, fig. 8; Text-fig. 6).

Illustrated are a fragment of the cranidium (Pl. 20, fig. 8), CPC 7177, 13.0 mm long, and a fragmentary pygidium (Text-fig. 6), 28.0 mm long; both come from a single bed of limestone, and are selected from a larger number of fragments.

The cranidial fragment consists of the interocular cheek with the palpebral lobe and the adaxial part of the posterolateral limb and the posterior border. The test is visibly granulose. The fragment is close to similar parts of the cranidium of *Onaraspis somniurna* sp. nov. The circular boss seen on the left is an imprint of an echinoderm fragment.

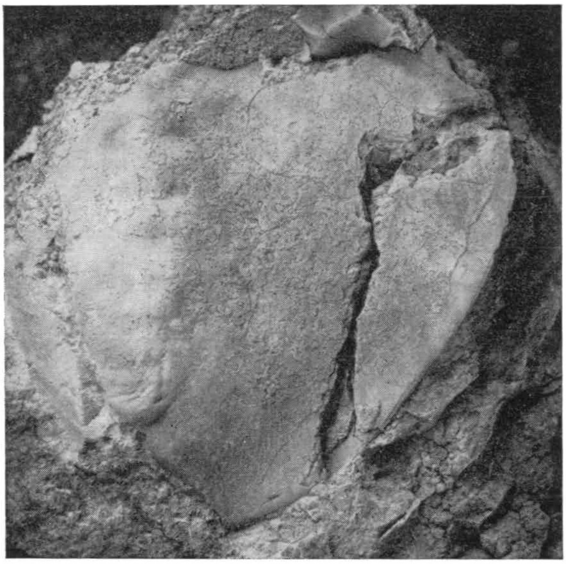


Fig. 6.— *Onaraspis* sp. indet, large fragmentary pygidium, CPC 7162, from locality AS 33 (at Gaylad Dam); x2.

The pygidium is very large, corresponding to a cephalon 6 to 7 cm long. Less than half the pygidium is preserved, and it is therefore unsuitable for reconstruction. The concave flange, absence of pleural ribs, and weak axial annulation indicate that it belongs to *Onaraspis* gen. nov. Its pygidial axis does not reach the rear border and is shorter than in *O. somniurna*.

Occurrence and age: The described specimens came from a limestone bed, locally AS/33, at Gaylad Dam, Alice Springs area; the age is Ordian.

Explanation of new names of fossils

adusta (*Onaraspis*): Lat. burned red, brick red; alludes to the colour of the matrix—red-brown dolomitic sandstone.

Onaraspis: Fem.; 'dream-shield' (Greek).

somniurna: Lat. 'of the dream time'.

The names *Onaraspis* and *somniurna* refer to the folklore of Australian aboriginals.

REFERENCES

Chang, W. T., 1953—Some Lower Cambrian trilobites from Western Hupei. *Acta palaeont. sinica,* 1(3), 121-149.

Chang, W. T., 1957—Preliminary note on the Lower and Middle Cambrian stratigraphy of Poshan, central Shantung. *Ibid.,* 5(1), 13-31.

Chang, W. T., 1962—On the genus *Eoredlichia. Ibid.,* 10(1), 36-44.

Chang, W. T., 1966—On the classification of Redlichiacea with description of new families and new genera. *Ibid.,* 14(2), 136-184.

Chapman, F, 1923-1924—See Wade, 1924.

Chu Chao-ling, 1962—On the occurrence of *Palaeolenus* in Fengyang, Anwhei. *Acta paleont. sinica,* 10(3), 386-391.

Cooper, G. A., et al., 1952—Cambrian stratigraphy and paleontology near Caborca, northwestern Sonora, Mexico. *Smiths. misc. Coll.,* 119 (1).

Daily, B., 1956—The Cambrian in South Australia. *In* Cambrian Symposium. *20th int. geol. Congr., Mexico,* 2, 91-147.

Daily, B., 1957—See Őpik et al., 1957.

Demokidov, K. K., and Lazarenko, N. P., 1964—Stratigraphy of the Upper Precambrian and Cambrian and Lower Cambrian trilobites of northern part of middle Siberia and islands of the Soviet Arctic. *Trudy Inst. geol. Arktiki,* 137 (in Russian).

Fletcher, H. O., 1964—New linguloid shells from Lower Ordovician and middle Palaeozoic rocks of New South Wales. *Rec. Aust. Mus.,* 26 (10), 283-294.

Foord, A. H., 1890—Notes on the palaeontology of Western Australia. *Geol. Mag.,* n.s. dec. III, 3, 97.

Harrington, H. T., et al., 1959—TREATISE ON INVERTEBRATE PALEONTOLOGY: TRILOBITA. *Univ. Kansas Press.*

Henningsmoen, G., 1956—The Cambrian of Norway. *In* Cambrian Symposium. *20th int. geol. Cong., Mexico,* 1, 45-57.

Henningsmoen, G., 1957—Los trilobites de las capas de Saukianda, Cambrico inferior, en Andalucia. *Estud. geol.,* 14, 253-271.

Hill, Dorothy, 1964a—Archaeocyatha from the Shackleton Limestone of the Ross System, Nimrod Glacier area, Antarctica. *J. Roy. Soc. N.Z.,* 2(9), 137-146.

Hill, Dorothy, 1964b—The phylum Archaeocyatha. *Biol. Rev.,* 39, 232-258.

Hill, Dorothy 1965—Archaeocyatha from Antarctica and a review of the phylum. *Transantarctic expedition 1955-1958, sci. Rep.,* 10(3), 1-151.

HOWELL, B. F., et al., 1944—Correlation of the Cambrian formations of North America. *Bull. geol. Soc. Amer.*, 55, 993-1003.

HOWELL, B. F., 1947—Cambrian correlation between China and North America. *Bull. geol. Soc. China*, 27, 141-162 (Grabau Memorial Volume).

HUPE, P., 1952—Contribution à l' étude du Cambrien inférieur et du Précambrien III de l'Anti-Atlas marocain. *Mém. Serv. géol. Maroc.*, 103.

HUPE, P., 1953—Classification des trilobites. *Ann. Paléont.*, 39, 61-168.

HUTCHINSON, R. D., 1956—Cambrian stratigraphy, correlation, and paleogeography of eastern Canada. *In* Cambrian Symposium. *20th Int. geol. Cong. Mexico*, 2, 289-314.

HUTCHINSON, R. D., 1962—Cambrian stratigraphy and trilobite faunas of south-eastern Newfoundland. *Geol. Surv. Can. Bull.* 88.

JAANUSSON, V., 1960—On the series of the Ordovician System. *21st int. geol. Cong., Norden, Reps.* VIII.

KAULBACK, J. A., and VEEVERS, J. J., 1965—The Cambrian and Ordovician geology of the south-eastern part of the Bonaparte Gulf Basin and the Cambrian and Devonian geology of the outliers, Western Australia. *Bur. Miner. Resour. Aust. Rec.* 1965/49 (unpubl.).

KIAER, J., 1916—The Lower Cambrian *Holmia* fauna at Tømten in Norway. *Vidensk.-selsk. Skr., I Kl.*, 10.

LAKE, Ph., 1946—Monograph of the British Cambrian trilobites, Part XIV, 333-350. *Palaeontogr. Soc., Lond.*

LAVERS, P. S., and JONES, W. H., 1964—*In* Fletcher, 1964.

LOCHMAN, Christina, 1952—Trilobites *in* Cooper et al., 60-159.

LOCHMAN, Christina, 1956—Stratigraphy, paleontology and paleogeography of the *Elliptocephala asaphoides* strata in Cambridge and Hoosick quadrangles, New York. *Bull. geol. Soc. Amer.*, 67, 1331-1396.

LOCHMAN-BALK, Christina, and WILSON, J. L., 1958—Cambrian biostratigraphy in North America. *J. Paleont.*, 32(2), 312-350.

LAZARENKO, N. P., 1964—See Demokidov & Lazarenko.

LOTZE, F., and SDZUY, K., 1961—Das Kambrium Spaniens. *Akad. Wiss. Literat. Mainz, math.-naturw. Kl., Abh.*, 6-8.

LU YEN-HAO, 1960—Cambrian deposits of China. *Acad. sinica sci. Rec.*, n.s. 4 (4), 199-216.

LU YEN-HAO, 1961—New Lower Cambrian trilobites from Eastern Yunnan. *Acta paleont. sinica*, 9, 299-320.

MATHESON, R. S., and TEICHERT, C., 1948—Geological reconnaissance in the eastern portion of the Kimberley Division, Western Australia. *Rep. Dep. Min. W. Aust.* for 1945.

NOAKES, L. C., CARTER, E. K., and ŐPIK, A. A., 1959—Urandangi—4 mile geological series. *Bur. Miner. Resour. Aust. explan. Notes* 1, 2nd Edn.

ŐPIK, A. A., 1956—Cambrian geology of Queensland; Cambrian geology of the Northern Territory; Cambrian palaeogeography of Australia. *In* Cambrian Symposium. *20th Int. geol. Congr. Mexico,* 2, 1-24, 25-24, 239-284.

ŐPIK, A. A., et al., 1957—The Cambrian geology of Australia. *Bur. Miner. Resour. Aust. Bull.* 49. (Extract from Symposium, Part II—see Őpik, 1956).

ŐPIK, A. A., 1958—The Cambrian trilobite *Redlichia*: organization and generic concept. *Bur. Miner. Resour. Aust. Bull.* 42.

ŐPIK, A. A., 1960—Cambrian and Ordovician geology (of Queensland). *J. geol. Soc. Aust.,* 7, 91-103.

ŐPIK, A. A., 1961—The geology and palaeontology of the headwaters of the Burke River, Queensland. *Bur. Miner. Resour. Aust. Bull.* 53.

ŐPIK, A. A., 1963—Early Upper Cambrian fossils from Queensland. *Bur. Miner. Resour. Aust. Bull.* 64.

ŐPIK, A. A., 1966—Cambrian. *Bur. Miner. Resour. Aust. Rec.* 1966/6 (unpubl.).

ŐPIK, A. A., 1966b (in press).—Cambrian *in* ENCYCLOPEDIA OF EARTH SCIENCE, ed. R. W. Fairbridge. *N.Y., Reinhold Press.*

ŐPIK, A. A., CARTER, E. K., and NOAKES, L. C., 1961—Mount Isa—4-mile geological series. *Bur. Miner. Resour. Aust. explan. Notes* 20.

POCOCK, K. J., 1964—*Estaingia,* a new trilobite genus from the Lower Cambrian of South Australia. *Palaeontology,* 7(3), 453-471.

POKROVSKAYA, N. V., 1961—O yarussnom raschlenenii Kembria (Concerning the stage subdivision of Cambrian). The Cambrian System etc. Symposium, Part III, 256-273, *20th int. geol. Congr. (Mexico),* Publ. in Moscow, U.S.S.R. (Russian).

RASETTI, F., 1951—Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains. *Smiths. misc. Coll.,* 116(5), 1-210.

RASETTI, F., 1952—Revision of the North American trilobites of the family Eodiscidae. *J. Paleont.,* 26(3), 434-451.

RASETTI, F., 1956—The Middle and Upper Cambrian of western Canada. *In* Cambrian Symposium. *20th Int. geol. Cong., Mexico,* 2, 735-750.

REDLICH, K., 1899—The Cambrian fauna of the eastern Salt Range. *Palaeont. indica,* n.s., 1(1).

REPINA, L. H., 1960—Kompleksy trilobitov nishnego i srednego Kembria Zapadnoi chasti vostochnogo Sayana (Russian: Complexes of trilobites of the Lower and Middle Cambrian of the western part of the Eastern Sayan). *Regional stratigraphy of USSR,* vol. 4, *Acad. Sci. USSR.*

RICHTER, R. and E., 1941a—Die Fauna des Unter-Kambricums von Cala in Andalusien. *Abh. senck. naturf. Ges.,* 455, 1-90.

RICHTER, R. and E., 1941b—Das Kambrium am Toten Meer und die älteste Tethys. *Ibid.*, 460, 1-50.

RICHTER, R. and E., 1948—Zu Frage des Unter-Kambricums in Nordost Spanien. *Senckenbergiana*, 29(1/6), 23-39.

SAMSONOWICZ, J., 1956—Cambrian palaeogeography and the base of the Cambrian system in Poland. *In* Cambrian Symposium. *20th int. geol. Cong., Mexico,* 1, 127-160.

SDZUY, K., 1959—Die Unter-Kambrische Trilobiten-Familie Dolerolenidae. *Senck. Leth.*, 40, 389-407.

SDZUY, K., 1961—Trilobiten. *In* Lotze, F., and Sdzuy, K., Part II.

SHAW, A. B., 1954—Lower and Middle Cambrian faunal succession in north-western Vermont. *Bull. geol. Soc. Amer.*, 65, 1033-1046.

SHAW, A. B., 1958—Stratigraphy and structure of the St Albans area, north-western Vermont. *Ibid.*, 69, 519-568.

STUBBLEFIELD, C. J., 1956—Cambrian palaeogeography in Britain. *In* Cambrian Symposium. *20th int. geol. Cong., Mexico,* 1, 1-43.

SUVOROVA, N. P., 1960—Trilobity Kembria vostoka sibirskoi platformy (Russian: Trilobites of the Cambrian of the eastern Siberian platform). *Trudy palaeont. Inst. AN USSR*, 84, 3.

SUVOROVA, N. P., 1961a—Review of trilobites of the Lower Cambrian of Siberia. *In* Cambrian Symposium, Part III, 133-154. *20th int. geol. Cong., Mexico,* publ. in Moscow, USSR. (Russian).

SUVOROVA, N. P., 1961b—Trilobity Korineksokhidy i ikh istoricheskoye rasvitie (Corynexochid trilobites and their historical development). *Trudy palaeont. Inst. AN USSR,* 103.

TCHERNYSHEVA, N. E., et al., 1965—The Cambrian system, p. 1-596. *Stratigraphy of USSR, Acad. Sci. USSR* (Russian).

TRAVES, D. M., 1955—The geology of the Ord-Victoria Region, northern Australia. *Bur. Miner. Resour. Aust. Bull.* 27.

VASILENKO, V. K. (Chief Editor), 1963—Reshenia meshvedomstvennogo sovestchaniya po razrabotke unifitsirovannykh stratigrafitcheskikh skhem Yakutskoi A.S.S.R. (Decisions of the interdepartmental council for preparation of unified stratigraphic scales (charts) of the Yakutian ASSR). *Governmental Geol. Committee et al., USSR.*

VEEVERS, J. J., ROBERTS, J., KAULBACK, J. A., and JONES, P. J., 1964—New observations on the Palaeozoic geology of the Ord River area, Western Australia and Northern Territory. *Aust. J. Sci.*, 26(11), 352-354.

WADE, A., 1924—Kimberley District of Western Australia and Northern Territory. Petroleum prospects. *Cwlth Aust. parl. Pap.*

WALCOTT, Ch. D., 1890—The fauna of the Lower Cambrian or the *Olenellus* Zone. *Ann. Rep. U.S. geol. Surv.*, 10.

Walcott, Ch. D., 1891—Correlation Papers: Cambrian. *Bull. U.S. geol. Surv.*, 81.

Walcott, Ch. D., 1912—Group terms for the Lower and Upper Cambrian series of formations. *Smiths. misc. coll.*, 57(10), 305-307.

Wells, A. T., Ranford, L. C., Cook, P. J., Stewart, A. J., and Shaw, R., 1967—Geology of the north-eastern Amadeus Basin, Northern Territory. *Bur. Miner. Resour. Aust. Rep.* 113.

Westergaard, A. H., 1936—*Paradoxides oelandicus* beds of Øland. *Avh. sver. geol. Unders.*, ser. C, 394.

Westergaard, A. H., 1946—Agnostidea of the Middle Cambrian of Sweden. *Ibid.*, 477.

Whitehouse, F. W., 1936—The Cambrian faunas of north-eastern Australia: Part 1, stratigraphic outline; Part II, Trilobita (Miomera). *Mem. Qld Mus.*, 11, 59-112.

Whitehouse, F. W., 1939—The Cambrian faunas of north-eastern Australia: Part III, the polymerid trilobites. *Ibid.*, 11(3), 179-282.

Waern, B., 1952—Palaeontology and stratigraphy of the Cambrian and lowermost Ordovician of the Bodahamn core. *Bull. geol. Inst. Uppsala*, 34, 233-250.

PLATE 19

Onaraspis somniurna sp. nov.

Fig. 1.—Small cranidium, rubber cast of CPC 7163, x12.

Fig. 2.—Cranidium, CPC 7164, x1.3.

Fig. 3.—Cranidium, CPC 7165—the **holotype,** x1.8.

Fig. 4.—Cranidium, CPC 7166, x1.8.

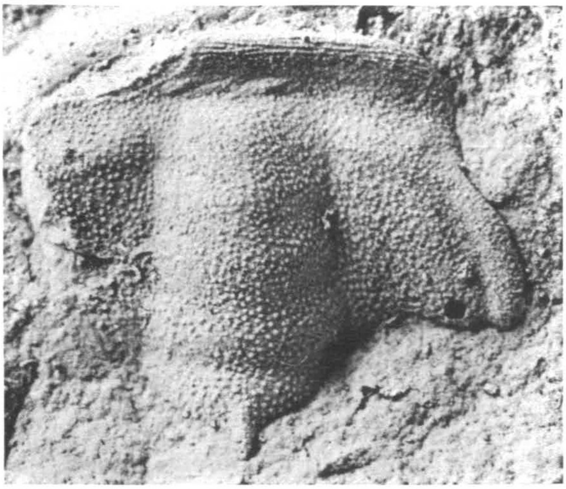
Fig. 5.—Fragmentary immature cranidium, CPC 7167, x3.5, and large granullose fragments.

Fig. 6.—Hypostoma, CPC 7168, x7.

Fig. 7.—Free cheek, CPC 7169, x1.3.

Fig. 8.—Small pygidium, CPC 7170, x3.

All specimens are from locality Rd 10, near Deep Well, Rodinga area, Northern Territory.



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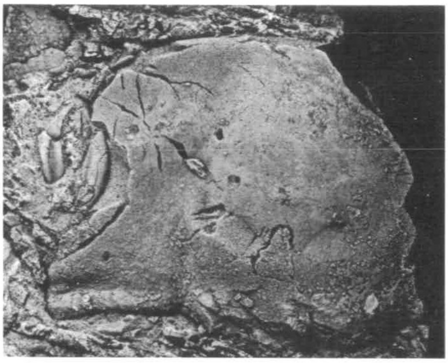

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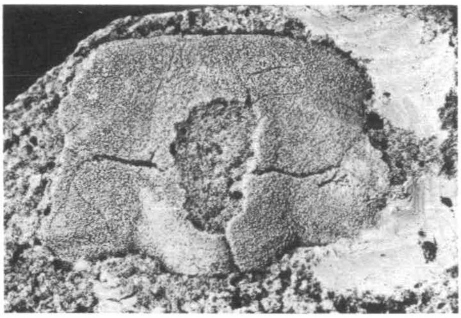

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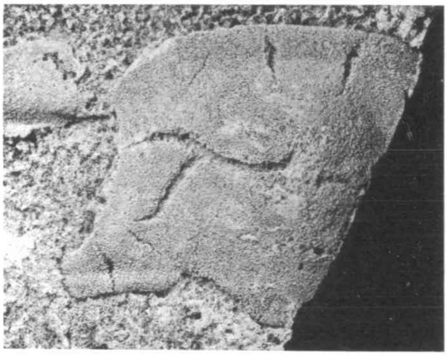

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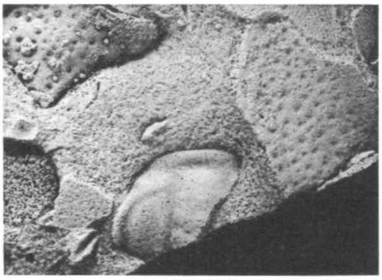

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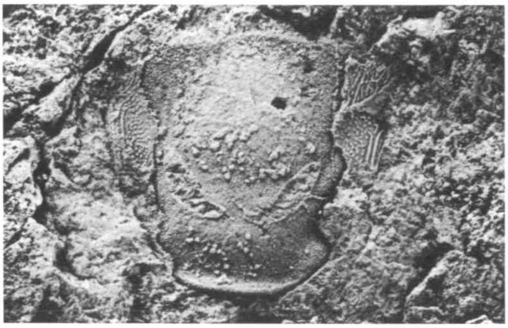

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Onaraspis

PLATE 20

Onaraspis somniurna sp. nov.

Fig. 1.—Anterior part of thorax, CPC 7171, x2.

Fig. 2.—Posterior part of thorax with pygidium, CPC 7172, x1.8.
Locality Rd 10, at Deep Well, Rodinga area, Northern Territory.

Onaraspis adusta sp. nov.

Figs. 3 and 4: **Holotype** cranidium, CPC 7173, x3.5; Figure 1 is rubber cast.

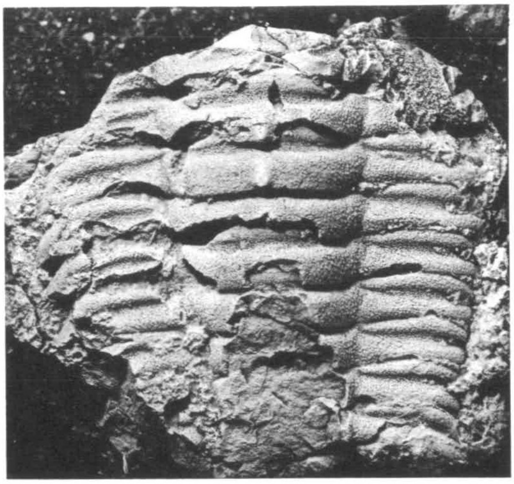
Fig. 5.—Distorted cranidium, CPC 7174, x2.

Fig. 6.—Pygidium, CPC 7175, x3.

Fig. 7.—Cranidium and part of thorax, CPC 7176, x3.
Ragged Range locality, CG 5H1/1, Western Australia.

Onaraspis sp. indet.

Fig. 8.—Fragment of a cranidium, CPC 7177, x3.7.
At Gaylad Dam, locality AS 33, Alice Springs Area, Northern Territory.



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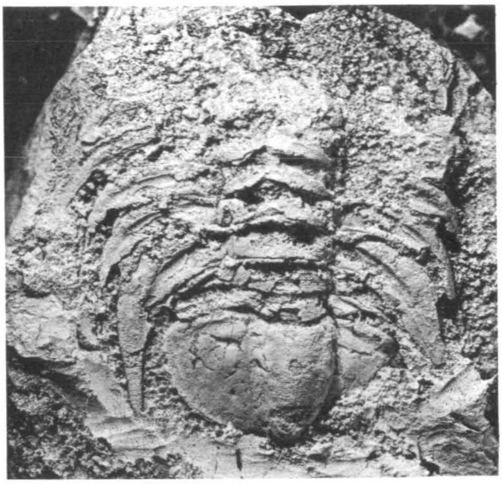

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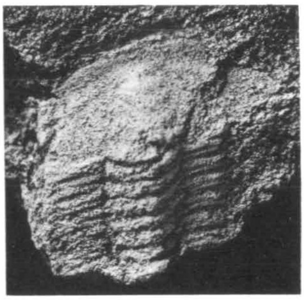

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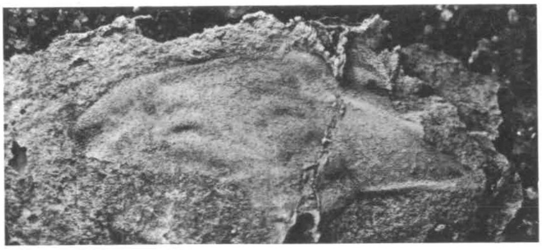

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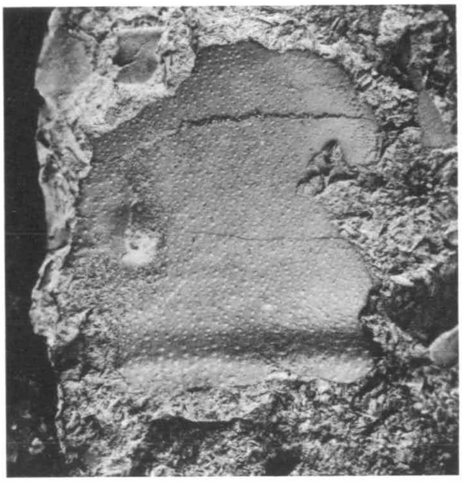

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Onaraspis

SOME ORDOVICIAN GRAPTOLITES FROM THE CANNING BASIN, WESTERN AUSTRALIA

1. ON THE STRUCTURE OF *DIDYMOGRAPTUS ARTUS* ELLES & WOOD

by S. K. Skwarko

SUMMARY

Didymograptus artus Elles & Wood, 1901, very similar to that described by Bulman from the Llanvirnian of Peru, is described from Willara No. 1 Bore in the Canning Basin, Western Australia. This is the first graptolite from Australia which, after separation from matrix and bleaching, allowed an insight into details of its morphology, and its description is the first one for this species based on such well preserved material.

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INTRODUCTION

In some parts of Australia graptolites occur abundantly in shales and slates—particularly in Victoria, but also in New South Wales, and to a much lesser extent in the remaining States. In Victoria, where graptolites are associated with gold-bearing slates, they have received much attention from geologists as far back as the second half of the last century. Many genera and species were described and a local stratigraphic column for the Ordovician era built up, its 24 zones based entirely on the evolutionary changes in these organisms.

In Australia, as in most other places in the world where the graptolite-bearing rocks occur, the history of research of these fossils is the history of study of their essentially two-dimensional remains. In all assemblages hitherto described from this continent graptolites are preserved as compressed whole or incomplete rhabdosomes, many of which are carbonized and others replaced by pyrite; distortion by tectonism is not uncommon. Though their poor preservation did not detract from their usefulness in the stratigraphic subdivision of rocks, in dating, and in long-distance correlation, it discouraged attempts to unravel the details of their morphology. The only exceptions to this mode of preservation known in this country are those listed recently by Thomas (1960, pp. 14-15). The Didymograpti from Emanuel Formation, Canning Basin, Western Australia, however, though preserved in relief and showing some surface structure, have frustrated attempts to separate them from matrix, as even the most gentle acids will attack them together with the enclosing rock. No serious attempt has been made so far to separate the small graptolite fauna from Stokes Pass. The Silurian Monograpti from New South Wales are, on the other hand, reputedly abundant, and their preservation makes them suitable for detailed examination, probably by serial sectioning. They have been studied for some time by G. H. Packham, University of Sydney, but no results have so far been published.

Graptolites which are the topic of the present paper are the first truly well preserved ones described from this continent. It is hoped that this discovery will lend stimulus to further discoveries in the future. The small collection of graptolites comes from a core sample (Core 6) from the depth of 6174 feet in Willara No. 1 Bore (19°10′48″S., 122°04′14″E.), drilled by the West Australian Petroleum Company Pty Ltd in 1965 in the Canning Basin, Western Australia. The sample submitted for dating consists of shale, and apart from graptolites some pelecypods, brachiopods, and fragments of trilobites were recognized. The age of the core, based on the presence of abundant specimens of *Didymograptus artus,* is Llanvirnian.

Rhabdosomes of graptolites from the Willara No. 1 Bore consist of nearly black 'chitinous' matter which, even while still embedded in the matrix, shows some of the fusellar half-ring pattern under the medium-power microscope. The sample was digested for two days in 20% hydrofluoric acid. The freed graptolites, as well as some scolecodonts and chitinozoa which were also present, were then bleached by immersion in a mixture of potassium chlorate and nitric acid. Some rhabdosomes took only four hours to bleach, others up to four days, while still others failed to clear altogether. Bleached graptolites were then immersed in glycerine for observation, photography, and storage. It was found that all graptolites, as well as chitinozoa, but unlike the more robust scolecodonts and most macrofossils, were compressed by compaction and many were fragmentary and incomplete. The bleaching process which followed, on the one hand allowed a much better insight into details of structure, but on the other brought about further disintegration of specimens.

ACKNOWLEDGMENTS

Sincere thanks are expressed to West Australian Petrolium Company Pty Ltd, for supplying the voluminous material from Willara No. 1 Bore, which forms the basis of the present paper.

I wish to thank Prof. Kozłowski and Doc. Dr Urbanek of the Warsaw University for the stimulating discussions which renewed my interest in the graptolite-bearing shales of northern Australia. I am grateful for their critical reading of the manuscript and for their comments and suggestions. I also wish to thank Dr D. E. Thomas, Director of the Geological Survey of Victoria, for his many helpful comments and discussions.

REGIONAL BACKGROUND

The distribution of the Ordovician sea in Australia is shown on Figure 1. Three land masses seem to have existed at the time, separated from each other by an extensive body of water, which covered the whole of the Tasman Geosyncline and extended diagonally in a broad belt across the site of the present-day continent of Australia.

There is no evidence that the Ordovician sea was present in the Perth Basin, and no good evidence for it in the Carnarvon Basin, as the sediments there, for which, an Ordovician age has been suggested, are unfossiliferous. Some sediments in the extreme north of Australia were for a time thought to be possibly of Ordovician age because of contained pipe rock; the recently obtained isotofie date for them of almost 800 m.y. would seem, however, to discount this possibility. In eastern Queensland the suspected Ordovician rocks are either unfossiliferous or under a thick cover of the Great Artesian Basin sediments and little is known of them, but *Sigmagraptus laxus,* a Victorian Bendigonian Stage species, was collected from the Swift Beds in western Queensland (Tomlinson, Appendix F *in* Casey, Reynolds, Dow, Pritchard, Vine, & Paten, 1960, unpubl).

However, the evidence for the Ordovician sea in other parts of Australia is well documented by the presence of trilobites, cephalopods, and other invertebrates, as well as graptolites.

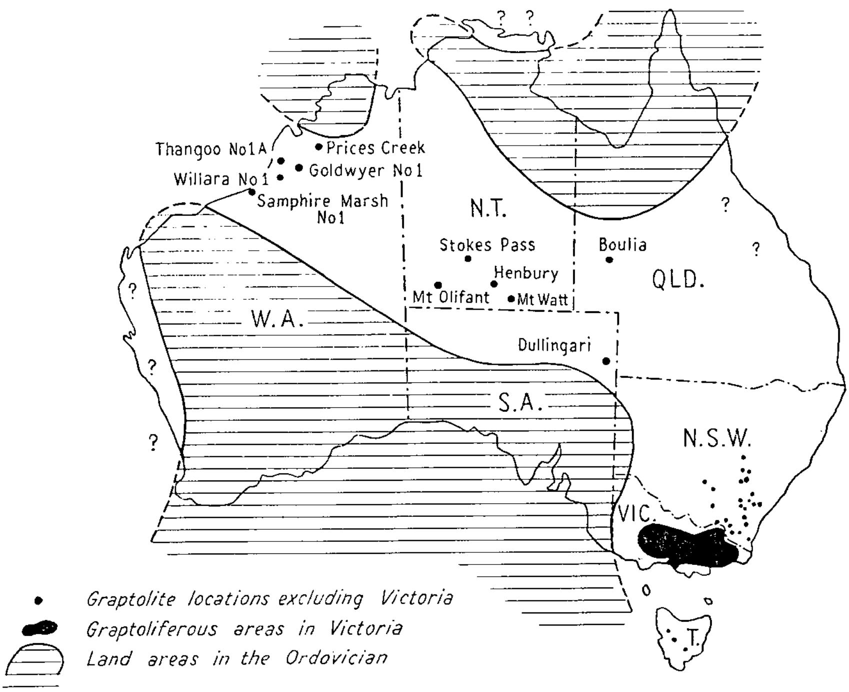

Fig. 1. The distribution of land and sea in the Ordovician, and the known distribution of graptolite-bearing localities in Australia. After Thomas (1960) and J. Gilbert Tomlinson (pers. comm.).

The distribution of graptolite-bearing localities is shown on Figure 1. Thomas (1960, pp. 14-15) listed graptolites determined from Tasmania, Prices Creek, Goldwyer No. 1 Bore, Samphire Marsh No. 1 Bore, and Stokes Pass, and the reader is referred to his paper for determinations. Of the remaining localities named individually on Figure 1: Henbury in the McDonnell Ranges yielded *Didymograptus nitidus,* indicating a Lower Ordovician age (Öpik, 1956, p. 47); Thangoo No. 1A yielded rather well preserved but hitherto undescribed Tetragrapti and Didymograpti which also indicate a Lower Ordovician age; in Dullingari No. 1 '. . . [in] core 26 (9191-9211 feet) biserial graptolites (Diplograptids) are abundant in some layers, indicating a Middle to early Upper Ordovician age. In the lowest core, core 31 (10,890-10,908 feet), as well as in core 30 (10,143-10,153 feet), fragments of uniserial graptolites [Dichograpti?] are found, indicating Lower Ordovician. Fragments of graptolites were present also in core 27 (9496-9506 feet), and in core 29 (8902-9812 feet). The sequence is predominantly a dark grey shale, poor in organic matter . . . . The total thickness penetrated is 1848 feet, which covers a substantial part of the Ordovician.' (Öpik & Jones, 1962, unpubl.); the Mount Watt outcrop yielded incomplete monoserial stipes, preserved in relief, which may belong to an extensiform *Didymograptus;* complete extensiform Didymograpti preserved in relief occur in large numbers at Mount Oliphant, and, like graptolites from most localities mentioned above, await specific identification and description; in the Canning Basin the only surface outcrop which has yielded graptolites is at Prices Creek (Emanuel Formation), but graptolites were found subsurface in Thangoo No. 1A, Samphire Marsh No. 1, Goldwyer No. 1, and most recently in Willara No. 1.

This paper is the first of a series in which graptolites from these localities will be described.

THE EFFECT OF PRESERVATION ON OBSERVATION AND MEASUREMENTS

The graptolites discussed are well enough preserved to display, on suitable treatment, their morphology in detail. They are, however, compressed by the compaction of enclosing sediments, and this hinders examination somewhat and limits measurement of structures, and tends to oversimplify comparison with the previously described species. It was difficult to determine the nature of the ventroproximal projection on the metasicula, the true shape of the pore, and the nature of the opening through which the crossing canal appears. Were it not for the random orientation of the numerous rhabdosomes to the direction of compression it would not have been possible to determine their nature. In a compressed transparent or semitransparent rhabdosome it is difficult to determine on which side—reverse or obverse—occurs a given asymmetrical structure such as the notch and the crossing canal. The only practicable way of determining the position of the notch, and whether the canal crossed over to the ventral side of the metasicula on the reverse or on the obverse side, was to use a medium-powered microscope, and, relying on minute differences in distance from the lens of successive walls in the rhabdosome, observe which wall came first into focus. It was not possible, however, to determine the cross-sectional shape of the crossing canal, nor the shape of the notch through which it appeared.

In order to reduce the error in measurement due to compression, only those specimens were measured in detail which were compressed in the plane at right angles to the plane of the rhabdosome. The error was thus confined to such readings as the breadth of the metasicula and of the stipes. Measured values exceed slightly the true values, but no correction has been applied. Other measurements are not affected by compaction.

Comparison of the Willara graptolites with the three-dimensional forms from other parts of the world need hardly be erroneous, because many morphological features which distinguish or unify the species are not affected by compression.

On the other hand the distorted state of Willara graptolites facilitates the comparison with species whose description is based only on compressed opaque specimens. As many aspects of morphology cannot be observed in opaque forms, such comparison tends to be dangerously oversimplified. This has been convincingly illustrated by the very recent work of Urbanek, which demonstrated that important differences in details of fusellar structure are present among otherwise identical forms (A. Urbanek, pers. comm.).

NOMENCLATURE

In this paper only those terms are used which are in common use by students of graptolites, and which over the years have found wide acceptance. For this reason the definitions of terms are not listed here separately, and can be readily obtained from Bulman's 'Graptolithina' (Treatise on Invertebrate Palaeontology, 1955).

It would seem that as suggested by Kozłowski the term 'virgella', as supplied to spinous projections of the metasicular aperture in the more highly specialized Graptoloidea, should not be applied to the more primitive species of *Didymograptus,* to which *D. artus* belongs. In *D. artus* the ventral apertural lip is fusellar in structure, as in Dendroidea. No species intermediate between the spinous virgella and fusellar ventral lip are known (Kozłowski, 1954, p. 6).

SYSTEMATIC DESCRIPTION

Among the number of tuning-fork graptolites dissolved out from Willara No. 1 core only a single species is represented. It is described below under the name of *Didymograptus artus* Elles & Wood, as its measurements fall into the range of variation of this widely occurring species.

Order GRAPTOLOIDEA Lapworth, 1875

Suborder DIDYMOGRAPTINA Lapworth, 1880 em.

Family DICHOGRAPTIDAE Lapworth, 1873

Genus DIDYMOGRAPTUS McCoy in Sedgwick & McCoy, 1851

Type species: *Graptolithus murchisoni* Beck, 1839

DIDYMOGRAPTUS s. str.

DIDYMOGRAPTUS ARTUS Elles & Wood, 1901

(Pls. 21-23; text-figs 2-5)

1901 *Didymograptus artus* Elles & Wood, *Palaeontogr. Soc. Lond.*, 1, 48, pl. 4, figs 6a-d.

1931 *Didymograptus artus* Elles & Wood; Bulman, *Ark. Zool. svenska, Vetensk. Bd* 24A(3), 31, text-fig. 9.

1949 *Didymograptus artus* Elles & Wood; Ruedemann, *Geol. Soc. Amer. Mem.* 19, 326, 7 pl. 54 figs 3-10.
1960 *Didymograptus artus* Elles & Wood; Thomas, *Proc. Roy. Soc. N.S.W.*, 94, 27.

Material: Sixty compressed specimens in various stages of growth; many are incomplete.

Description: Of the sicula only the metasicula is preserved. It is about 1.4 mm long and subcylindrical. Its longitudinal axis is usually straight, though it may be slightly curved in some specimens. The proximal end of the metasicula is 0.15 mm wide and the distal end 0.4 mm. It consists of from 75 to 80 regular fusellar half-rings which meet in two zigzag sutures, one on the dorsal and the other on the ventral wall of the metasicula. The zigzag sutures are placed along a straight line except in the proximal-most part of the metasicula, where the line of sutures becomes progressively displaced dorsally or ventrally. The width of the half-rings increases gradually from about 0.015 mm near the proximal extremity to 0.02 mm near the aperture of the metasicula. There is, however, a definite crowding of much narrower rings at both ends of the metasicula. The apertural margin is extended forward on both the dorsal and ventral sicular walls forming corresponding apertural lips. The dorsal lip when mature is broad and invariably shorter than

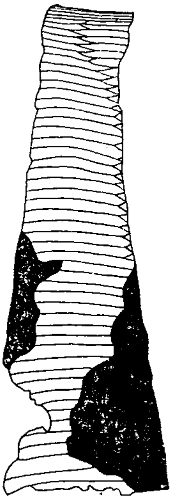

Fig. 2

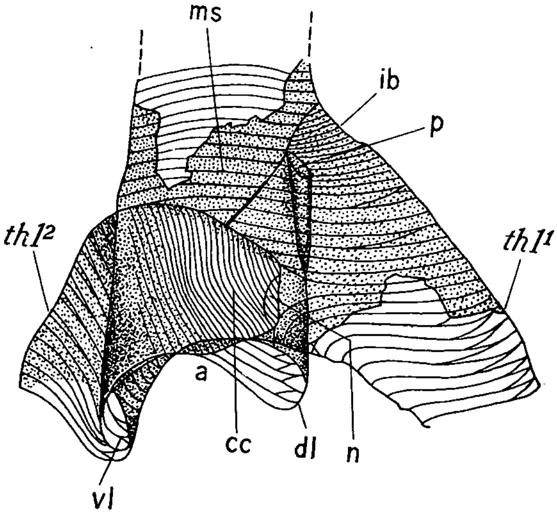

Fig. 3

Fig. 2. ***Didymograptus artus*** **Elles & Wood. Proximal portion of the metasicula showing the detail of suture lines and fusellar half-rings. CPC 7014. x70. Willara Bore No. 1.**

Fig. 3. *Didymograptus artus* **Elles & Wood. Shows the origin and nature of the crossing canal, initial bud, and proximal portion of** *thl^1*.**Reverse view.** *a* **aperture,** *cc* **crossing canal,** *dl* **dorsal lip,** *ib* **initial bud,** *ms* **metasicula,** *n* **notch,** *p* **pore,** *thl^1*, *thl^2* **thecae,** *vl* **ventral lip. CPC 7010. x70. Willara Bore No. 1.**

the ventral lip, and in profile appears as a sharply triangular anterodorsal extremity of the metasicula. The ventral lip is longer, and forms a prominent subtrapezoidal tongue about 0.1 mm long. This anteroventral lip does not give rise to a virgella, but in profile may have the appearance of a spine.

The pore is produced in the dorsal wall of the metasicula—an unusual feature. It originates apparently by resorption and at a distance of 0.8 to 1.0 mm from the proximal end of the metasicula. It seems to be oval, the longest width, which is parallel to the aperture, measuring 0.1 mm.

The initial bud starts to grow on the proximal margin of the pore and grows in the distal direction as well as laterally by a continuous addition of fusellar rings. These rings contain no normal suture-line. Individual rings do taper off to a point, but very gradually, not in the mid-line but on both sides of it. The bud attains a length of up to 0.18 mm before giving rise to the crossing canal and *th*1^1.

The crossing canal departs from the initial bud at its junction with the *th*1^1. The position of the notch, whose size is somewhat less than that of the pore, varies in different specimens, and can be anywhere between just below the midlateral line on the reverse side of the right stipe and the midventral line of this stipe. The crossing canal rapidly broadens to 0.2 mm, still near the notch. Then, maintaining its breadth, it proceeds across the metasicula, on its reverse side, close to and subparallel to the aperture. Once away from the sicula it plunges steeply and rapidly increases in size. The thickness of rings of the crossing canal is variable. In any single specimen they may be uniformly narrow, or uniformly broad, or narrow and broad rings may alternate. The widest canal rings, however, are narrower than the widest rings of the sicula.

Most of the rings on the bud appear complete; but those which make up the proximalmost portion of *th*1^1 are definitely half-rings, though the tapering of their extremities is slower, and consequently the overlap larger. Distally along *th*1^1, however, these half-rings rapidly develop a typical regular suture-line in which the oblique sutures of individual fusellar rings are short. The overall length of *th*1^1 is 0.8 mm; its greatest thickness, i.e. thickness at the point of departure of *th*2^1 is 0.5 mm, and this is attained at a distance of 0.7 mm from the pore.

The thecae are basically simple cups which when compressed in the plane of the rhabdosome have a generally triangular sawtooth appearance. Closer examination reveals, however, a definite similarity between the thecae and the sicula. This is seen particularly in the development of the thecal ventral lip, which results in a sigmoidal margin in compressed profile.

The detailed measurements of succeeding thecae vary with increased distance from the sicula. Those of *th*3^1 are as follows: angle of inclination, 43°; length of protheca, 0.6 mm; length of metatheca, 0.34 mm; length of ventral free wall, 0.64 mm; width of rings in middle portion of theca, 0.036 mm; degree of overlap, just a little more than one-third. The breadth of the stipe at the aperture of *th3*^{1} is 0.9 mm. But towards the end of the mature stipe, which measures about 14 mm in length, the angle of inclination of thecae is about 75°; the width of rings in the middle portion of the theca, 0.03 mm; the degree of overlap is about two-thirds; the breadth of the stipe at the aperture of the theca is 1.6 mm. In such mature specimens the distal portions of the stipes are inclined to each other at angles varying between 10° and 20°, and thecae number 18 in 10 mm.

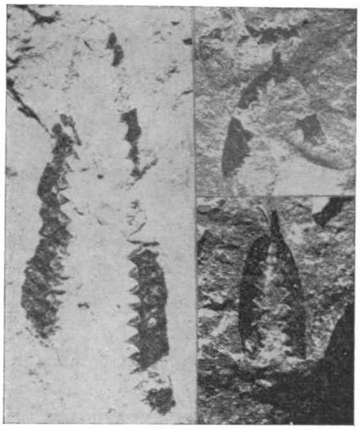

Fig. 4. Specimens of *Didymograptus artus* **Elles & Wood before etching. A mature and two immature rhabdosomes. Magnification about 2½.**

Discussion: Hitherto nine uncompressed species of *Didymograptus* sensu lato (see Kozłowski, 1954, p. 424) have been described. These are *D. callotheca* Bulman, 1933, *D. cucullus* Bulman, 1933, *D. formosus* Bulman, 1936, *D. gracilis* Tornquist, 1890, *D. minutus* Tornquist, 1879, *D. rozkowskae* Kozłowski, 1954, *Didymograptus* n. sp. a. aff. *D. gracilis* Tornquist, 1890, *Didymograptus* cf. n. sp. aff. *D. gracilis* Tornquist, 1890, and *Didymograptus* n. sp. aff. *D. minutus* Tornquist, 1879. The last three forms were described by Skevington (1965). *D. callotheca* is a declined graptolite with straight slender stipes and complex thecae quite distinct from those in *D. artus*. *D. cucullus* is a small and slender pendant form whose thecae differ so markedly from those in *D. artus* that further comparison seems superfluous. *D. formosus* is another declined or deflexed species. In *D. minutus* the metasicula is more conical than in *D. artus;* there are also notable differences in the origin of the crossing canal: in both species the bud is given off on the dorsal side of the metasicula. Comparison of *D. artus* with *D. rozkowskae* brings forth similarities in the general appearance of the rhabdosome, in the method in which the bud and the crossing canal originate, and in the method of branching of thecae. But the two species can be distinguished by comparison of the finer details of their structure. *D. artus* has a sicula more robust and more cylindrical (in profile), with a shorter ventral lip; its thecae are a little more elaborate, with a greater overlap and more steeply inclined; the breadth of stipe in *D. artus* is also greater. *Didymograptus* n. sp. a. aff. *D. gracilis* is a more slender form. In *Didymograptus* cf. n. sp. aff. *D. gracilis* the thecae are much more sparsely spaced. Finally, *Didymograptus* n. sp. b. aff. *D. minutus* has a host of small differences in proportions.

Species by species comparison of the *D. artus* from Willara Bore with numerous compressed previously described species is hardly warranted, as *D. artus* has been regarded as a well established species for a long time, but it would be interesting to compare representatives of this species from different parts of the world, as intraspecific variation seems considerable (see Table).

The type of branching present in *D. artus* is known as the Dichograptid type, and the stage which it represents within this type is one regarded as the most primitive in Dichograptidae (Bulman, 1955, p. V56), i.e. the *bifidus* stage. It appears that a very common direction of the evolutionary trend commencing from the *bifidus* stage is in the proximal migration of the second bud, $th2^1$, along $th1^1$. The extreme development of this trend is found in *D. minutus,* and is known as the *minutus* stage, in which $th2^1$ emerges opposite the crossing canal (Bulman, 1933, p. 6). From there $th2^1$ moves on to $th1^2$ as found in *D. extensus,* after which this stage is named.

Occurrences and age: In the past *D. artus* has been described from both North and South America as well as from the British Isles, all occurrences being from the lower Llanvirnian Zone of *Didymograptus bifidus* of the British sequence. It

Table 1. Comparison of specimens of *Didymograptus artus* Elles & Wood from widespread occurrences, illustrating its intraspecific variation. All measurements are in millimetres.

	WILLARA BORE	PERU	GREAT BRITAIN	OKLAHOMA	UTAH
LENGTH OF METASICULA	1·4	1·2		1·2	
BREADTH OF METASICULA	0·15→0·4				
THECAE IN 10mm	19→18	18→20	18→19	16	20→28
THECAL OVERLAP	1/3→2/3	1/2	1/2→2/3	1/2→2/3	
ANGLE OF DIVERGENCE OF STIPES	110°→10°/20°	10°→=	90°→=	nearly =	
WIDTH OF STIPES	0·5→1·6	0·4/0·5→1·5	→1·3	→1·2	→1·4
INCLINATION OF THECAE	40°→75°	50°	50°	50°→40°	
MAXIMUM LENGTH OF STIPES	<13	15→20	12→35	<35	

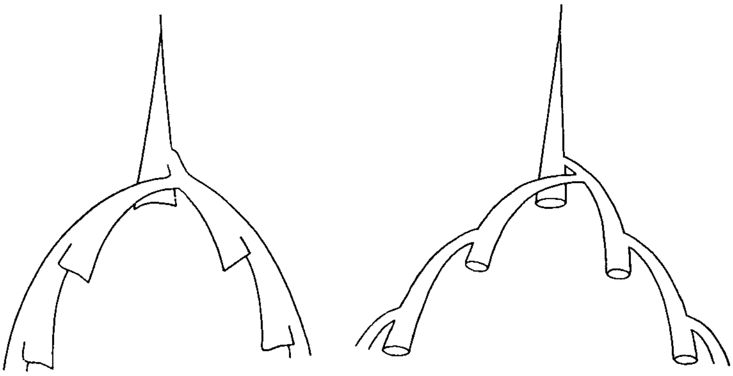

Fig. 5. Thecal diagrams to illustrate the *'bifidus'* stage of branching in *Didymograptus artus* Elles & Wood.

would seem, therefore, that the single previous Australian report of doubtful *D. artus,* from Victoria, by Ripper (1937, p. 157) possibly referred to a different species, as these specimens were derived from Ch 2 Zone of Victoria, i.e. from the Arenigian Zone of *Didymograptus extensus* of the British sequence.

The age of the Willara specimens of *D. artus* here described is regarded as Llanvirnian.

REFERENCES

Bulman, O. M. B., 1931—South American graptolites with special reference to the Nordenskiöld collection. *Ark. Zool. K. svenska Vetensk.*, Bd 22A (3), 1-11.

Bulman, O. M. B., 1933—Notes on the evolution and morphology of certain Graptoloidea. *Ibid.*, 24A (13).

Bulman, O. M. B., 1955—TREATISE ON INVERTEBRATE PALAEONTOLOGY, ed. R. C. Moore, Vol. V. GRAPTOLITHINA. *Geol. Soc. America* and *Univ. Kansas Press.*

Casey, J. N., Reynolds, M. A., Dow, D. B., Pritchard, P. W., Vine, R. R., and Paten, R. J., 1960—The geology of the Boulia area, western Queensland. *Bur. Miner. Resour. Aust. Rec.* 1960/12 (unpubl.).

Elles, G. L., and Wood, E. M. R., 1901—A monograph of British graptolites. *Palaeontogr. Soc. Lond.*, pt 1.

Kozlowski, R., 1954—O budowie niektórych Dichograptidae. *Acta geol. polon.*, 4, 423-444.

Őpik, A. A., 1956—Cambrian geology of the Northern Territory. *Int. geol. Cong. 20th Sess., Mexico,* 2, 25-54.

Őpik, A. A., and Jones, P. J., 1962—Dullingari No. 1—the Ordovician age of the shale below Core 25 (below 9010 feet). *Bur. Miner. Resour. Aust.* (unpubl.).

Ripper, E. A., 1937—A note on the occurrence of *Didymograptus protobifidus* Elles in the Lower Ordovician of Victoria. *Proc. Roy. Soc. Vic.*, 49 (N.S.), p. 2, 153-164.

Ruedemann, R., 1947—Graptolites of North America. *Geol. Soc. Amer. Mem.* 19.

Skevington, D., 1965—Graptolites from the Ontikan limestone (Ordovician) of Őland, Sweden. 2. Graptoloidea and Graptovermida. *Bull. geol. Inst. Univ. Uppsala,* 43, 1-74.

Thomas, D. E., 1960—The zonal distribution of Australian graptolites. *J. Roy. Soc. N.S.W.*, 94, 1-58.

PLATE 21

All specimens in the following plates are compressed, but the different orientation to the direction of compression makes them appear undistorted. All figures on any one plate have the same magnification. Those on Plate 21 are magnified about 23 times; those on Plates 22 and 23 about 70 times.

Didymograptus artus Elles & Wood, 1901.

1. Young metasicula in dorsal view (slightly oblique). CPC 7000.
2. Immature metasicula in dorso-reverse view. Pore is beginning to form by resorption on dorsal side near aperture. CPC 7001.
3. Proximally damaged immature metasicula in slightly oblique ventro-obverse view. Initial bud is forming along proximal periphery of pore. CPC 7002.
4. Almost mature sicula in slightly oblique dorsal view. Initial bud is almost complete but crossing canal has not yet appeared. Ventral lip is clearly visible. CPC 7003.
5. Metasicula with initial bud, crossing canal which is almost complete, proximal portion of $th1^1$. Reverse view. CPC 7004.
6. Immature specimen showing position and arrangement of crossing canal notch. Reverse view. CPC 7005.
7. Young rhabdosome in somewhat oblique reverse view. $Th3^1$ and $th2^2$ are incomplete. CPC 7006.
8. Proximally incomplete metasicula with initial bud, proximal portion of $th1^1$, crossing canal, $th1^2$ and commencement of $th2^2$. Reverse view. CPC 7007.
9. Immature rhabdosome in reverse view. CPC 7008.
10. Young and mature portions of stipe in reverse view. CPC 7009.
11. Distal portion of metasicula and branching stipes in obverse view. CPC 7010.

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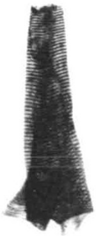

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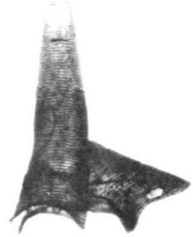

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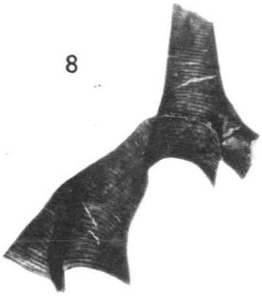

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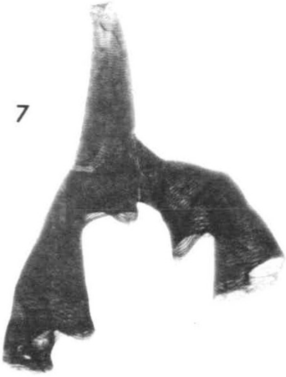

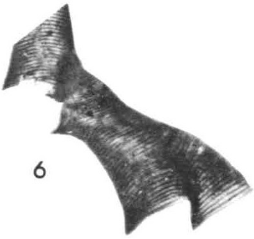

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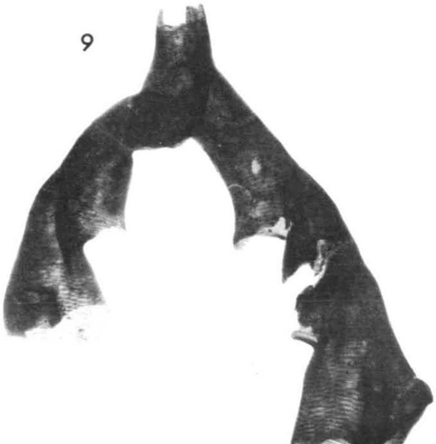

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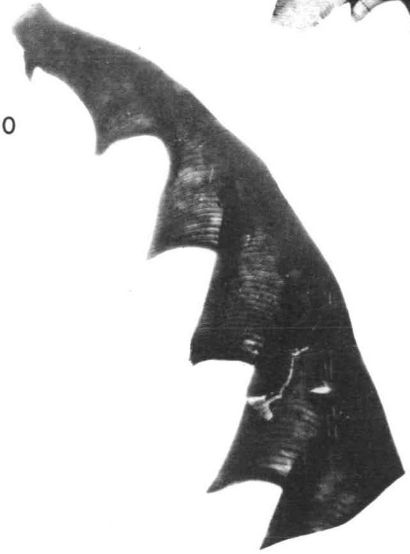
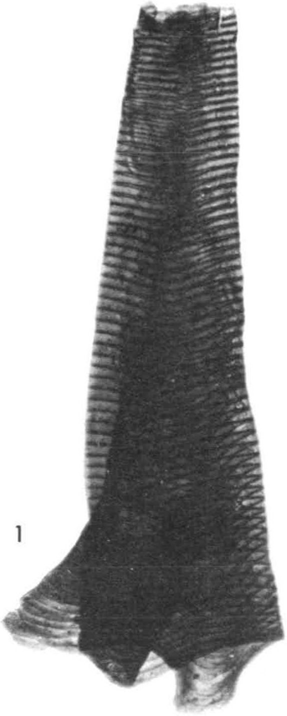


Didymograptus artus

PLATE 22

Didymograptus artus Elles & Wood, 1901.

1. Magnified Plate 21 figure 4 shows detail of structure of mature sicula. CPC 7003.
2. Detail of Plate 21 figure 8 magnified to show detail of crossing canal. CPC 7007.
3. Detail of Plate 21 figure 5 magnified to show structure of incomplete crossing canal. CPC 7004.
4. Detail of Plate 21 figure 1 magnified to show structure $th2^1$ and nature of overlap of $th3^1$. CPC 7009.
5. Magnified Plate 21 figure 11 to show detailed structure of crossing canal and wall of right stipe. Obverse view. CPC 7010.



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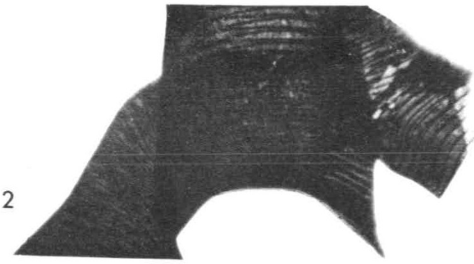

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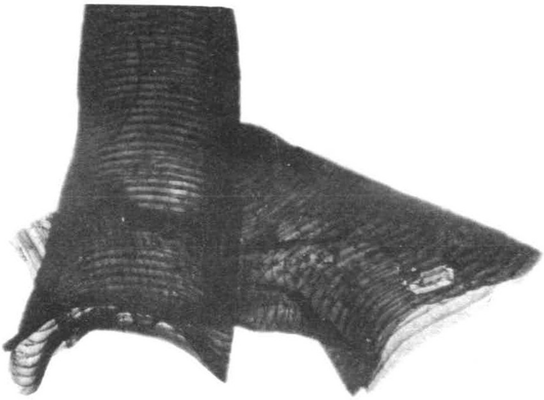

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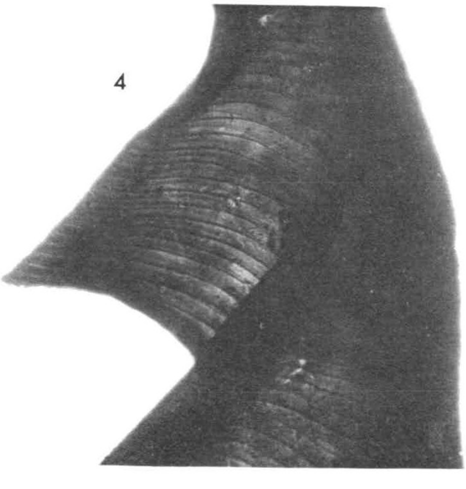

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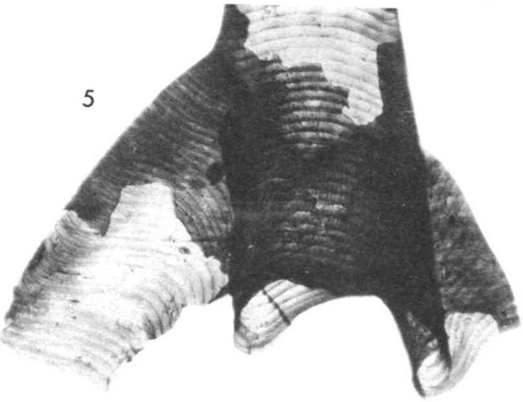

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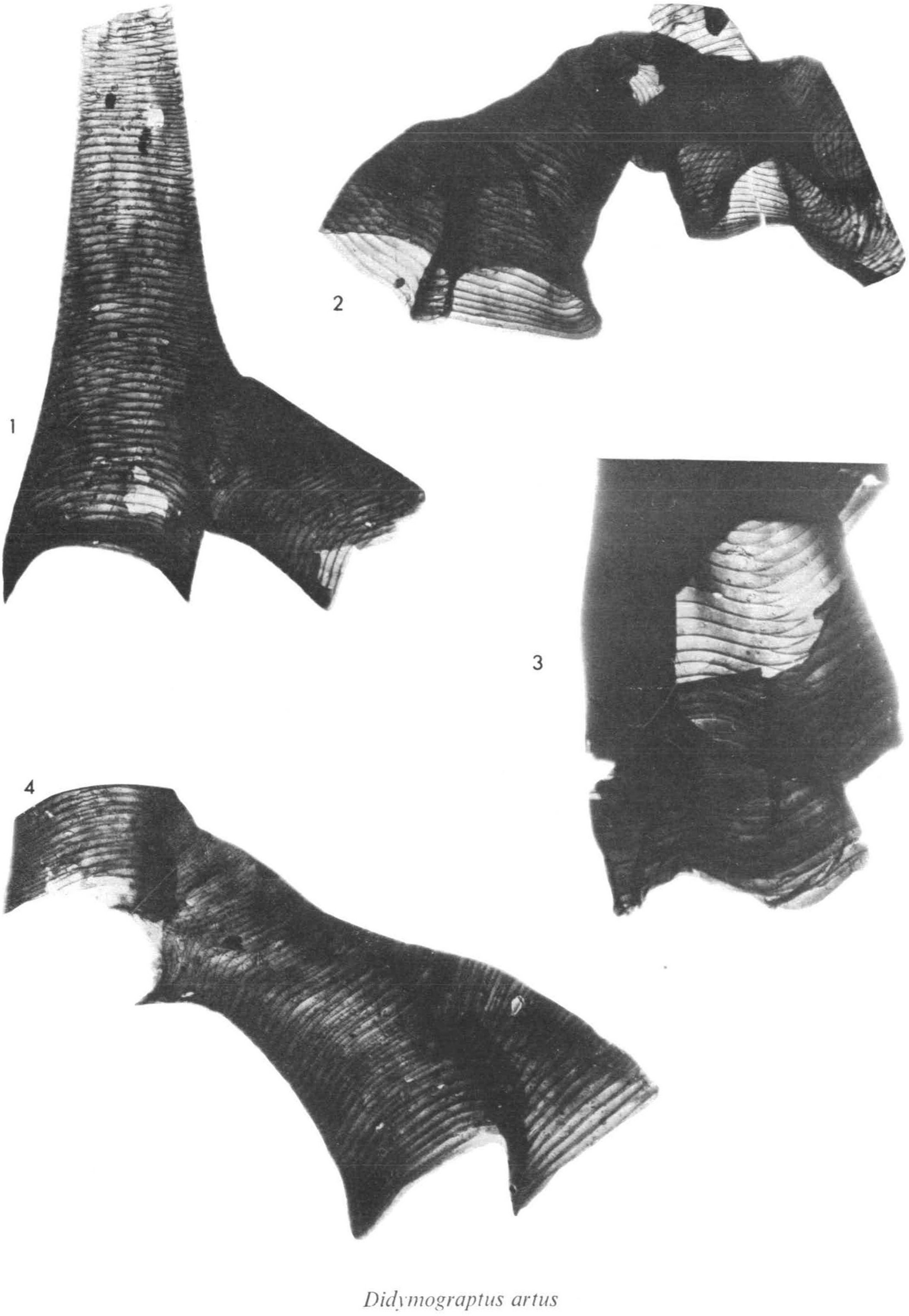
Didymograptus artus

PLATE 23

Didymograptus artus Elles & Wood, 1901.

1. Reverse view of proximally incomplete metasicula, initial bud, proximal portion of $th1^1$ and incipient stage of crossing canal between these three structures. SPC 7011.
2. Young rhabdosome in oblique view to show adhesion of $th1^2$ to ventral lip of metasicula, and junction between $th1^1$ and $th2^1$. CPC 7012.
3. Detail of distal portion of rhabdosome showing development of mature fusellar half-rings. CPC 7013.
4. Magnified Plate 21 figure 6 to show detail of formation of crossing canal and of $th2^1$ from $th1^1$. CPC 7005.



Didymograptus artus

THE FIRST REPORT OF **NEOTRIGONIA** FROM NEW GUINEA

by S. K. Skwarko

SUMMARY

Neotrigona novaguineana sp. nov. is described from the Central Highlands, Territory of New Guinea. Hitherto *Neotrigonia* was known only from Australia, where its stratigraphic range is Miocene to the present day. The age of the New Guinea species is not known with certainty, but the shell may have been derived either from the Eocene or Miocene strata.

A recent reappraisal of fossil collections from New Guinea lodged in the Museum of the Bureau of Mineral Resources at Canberra has revealed an almost complete bivalve—clearly a trigoniid—which in its overall shape and ornament resembles closely the genus *Neotrigonia* Cossman, 1912.

Neotrigonia and *Eotrigonia* are the only post-Mesozoic representatives of the once numerous and greatly diversified genera belonging to Trigoniacea, and both are found only in Australia. Species of *Eotrigonia* are confined to sediments of Eocene and Miocene age in Victoria, while *Neotrigonia* ranges from Miocene to the present day, and shells which represent some of its several species are thrown up by the sea along thousands of miles of Australian coastline.

Thus, the main interest in this discovery is that it is the first record of a *Neotrigonia* from outside Australia. In addition the New Guinea form is a new species. Unfortunately, its age is not known. The label which accompanies the shell gives as its source 'Urapmin, Mount Hagen - Sepik Patrol, New Guinea', and it states that the specimen—which was obtained on 28 October 1940 by Mr J. R. Black, an employee of the Department of Mines, Lands, etc., at Rabaul—is regarded by the natives as an anti-wound magic. The wellhandled appearance of the fossil supports suspicion that it was not collected from an outcrop but was probably obtained from a native. But although the stratigraphical position of the bivalve is not known, it is common knowledge that rocks of Eocene and Miocene age crop out in the area (D. B. Dow, pers. comm.). It would seem therefore, that the new species was derived from early or middle Tertiary sediments of the Mount Hagen/Sepik area.

At least eleven specific and two subspecific names have been applied to specimens of *Neotrigonia.* Of these eight species and subspecies are present-day forms, while the rest are almost entirely from the Miocene. The validity of a number of these names is, however, in doubt and it is probable that the actual number of species is not as great. There is an obvious need for revision of members of both *Neotrigonia* and *Eotrigonia.*

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Family TRIGONIIDAE

Genus NEOTRIGONIA Cossman, 1912

Type species: *Trigonia pectinata* Lamarck

NEOTRIGONIA NOVAGUINEANA sp. nov.

(Pl. 24, figs 1-3)

Material. A single specimen of the bivalve with both valves in position.

Holotype. Plate 24, figures 1-3 (CPC 6810), as above.

Diagnosis. The entire surface of the shell is radially ribbed with about 40 attenuated costae. The ribs are thin and sharp-crested in the umbonal region, but flat-crested distally, with a marked tendency towards imbrication in their distal portions. The interspaces are U-shaped and slightly wider than the ribs.

Comparison with other species. N. novaguineana sp. nov. can be easily distinguished from the previously described species such as *N. lamarcki* (Gray), *N. pectinata* (Lamarck), *N. howitti* (McCoy), and *N. acusticostata* (McCoy) by the combination of its relatively small inflation, numerous ribs which are flexed towards the front of the shell, strongly opisthogyrous umbo, and more prominent marginal and escutcheon carinae.

Description. The holotype is 34 mm high, 38 mm long, and 16 mm thick. The shell is pyriform, weakly carinate, rather weakly inflated, and radially ribbed with thin closely spaced slightly diverging radial costae.

The umbo is acute, pointed, moderately inflated, incurved, opisthogyrous. The anterior, anteroventral, and ventral margins of the shell are evenly convex, but with convexity decreasing in the posteroventral portion of the periphery. The cardinal margin is straight and oriented posteroventrally. The areal free margin is slightly convex and meets the cardinal and ventral shell margins with obtuse angles.

The flank, area, and escutcheon are all striated with radial ribs numbering about 40 per valve. They are thin and attenuated and increase in breadth and height only very slightly distally. Ribs are arched to the front; they are sharp-crested in the umbonal region, but become flat-crested with distinctive progressive tendency towards imbrication with increasing distance from the umbo. Interspaces which separate ribs are U-shaped in cross-section and slightly wider than the ribs.

The flank occupies about two-thirds the surface of a valve, and is separated from the area by a rather broad, convexly angular unevenness in the surface which extends from the umbo to the posteroventral shell margin. Costae on the marginal 'carina' are identical with those on the other parts of the valve. The escutcheon carina is similar to the marginal carina.

Remarks: Although the internal structure of the new species was not seen, there is little doubt regarding its placing with the Trigoniidae, as shown by the threefold subdivision of the shell's surface into flank, area, and escutcheon. Plate 24, figures 4 and 5, display for comparison *Neotrigonia howitti* (McCoy) from the Lower Pliocene sediments of Victoria.

EXPLANATION OF PLATE

PLATE 24

Figures:

1 - 3: *Neotrigonia novaguineana* sp. nov.

1. Dorsal view of bivalve.
2. Right valve in lateral view.
3. Left valve in lateral view.

Holotype, CPC 6810. Central Highlands, New Guinea.

4, 5: *Neotrigonia howitti* (McCoy)

4. Right valve in lateral view. CPC 6811.
5. Left valve in lateral view. CPC 6812.

Muddy Creek, Victoria, Miocene.

All figures natural size.

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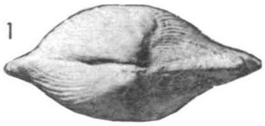

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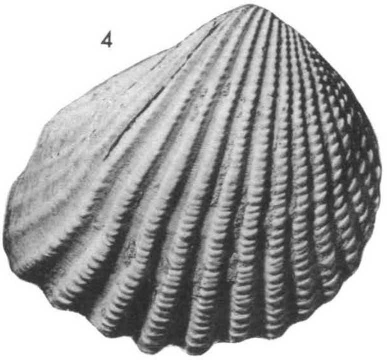

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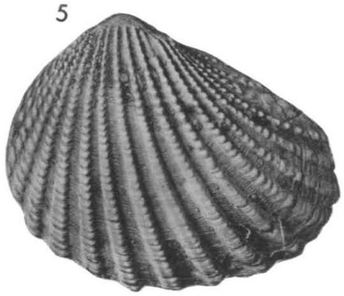

Neotrigonia from New Guinea

LOWER TRIASSIC AND MIDDLE JURASSIC FOSSILS AT ENANTY HILL, MINGENEW, PERTH BASIN, WEST AUSTRALIA

by P. J. Coleman* and S. K. Skwarko**

(with an Appendix by B. E. Balme*)

SUMMARY

Sediments with Middle Jurassic (Bajocian) marine fossils overlie a shale containing a Lower Triassic microflora at a locality just west of Enanty Hill, in an area hitherto thought to consist of Lower Permian sediments. The Jurassic fauna correlates with that of the well known Newmarracarra Limestone and includes the ammonite *Fontannesia clarkei* and nine species of pelecypod. The Triassic microflora is of Scythian age and is accompanied by spinose acritarchs in swarm proportions characteristic of those found in the lower part of the Kockatea Shale. This Jurassic/Triassic section is east of the accepted position for the Urella Fault which separates Jurassic-Cretaceous (west) from Permian sediments (east). Its presence a few yards from the Mingenew Formation (Lower Permian) is explained by postulating a fault and, as a corollary, it is suggested that the Urella Fault is a riffle-fault system. It is likely that marine Jurassic sediments in the general area were deposited on and around fault blocks brought about by interplay between a north-trending set of faults (the more ancient) and a subsidiary set trending north-west.

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INTRODUCTION

In 1963 two secondary school students of geology, M. McLeod and J. R. Parkinson, made a collection of fossils at Enanty Hill, a prominent dissected mesa 1½ miles north-east of Mingenew township. Previously, only Lower Permian (Artinskian) marine fossils had been recorded from Enanty Hill, but McLeod recognized an ammonite in his collection and suspected that it might belong to a wellknown Jurassic genus, *Fontannesia.* The presence of this genus and other Jurassic fossils was confirmed later by one of the authors (P.J.C.) and this led to intensive searches at the locality by staff and students from the Geology Department, University of Western Australia. The resultant collection yielded a fauna which can be correlated with that of the Newmarracarra Limestone, richly fossiliferous and the best known formation in the Jurassic of the Perth Basin. It crops out extensively in the Moonyoonooka area about 50 miles north-west of Mingenew.

The Jurassic material came from an old quarry, which had been worked for road ballast, immediately to the west of Enanty Hill. The possibility had to be considered that the Jurassic sediment (lateritized, very similar to the adjacent Permian) was a veneer or even a man-made deposit. To test this a shallow borehole was put down to a depth of 82 feet, cores being taken at intervals over this depth. The presence of Jurassic sediments to a depth of 63 feet was confirmed, and below this, at 79 feet 6 inches, the presence of Lower Triassic sediments representing the lower part of the Kockatea Shale.

The purpose of this paper is to describe the Jurassic fossils, to present evidence confirming the presence of Triassic sediments, and to assess the significance of these discoveries on currently held ideas on the stratigraphy and structure of this part of the Perth Basin.

GEOLOGICAL BACKGROUND

The Irwin River district, with Mingenew township as its centre, has long been the standard reference area for the Permian System in the northern Perth Basin. The essential geology in the area is apparently simple. Faulting has resulted in a set of step-faulted blocks, elongated north-south and progressively downthrown from east to west. The Permian sediments lie on one of these steps between two large north-trending fault systems, the Darling Fault to the east and the Urella Fault to the west. East of the Darling Fault there is a Precambrian complex; west of the Urella Fault there are Jurassic and Cretaceous sediments (Text-fig. 1). Both these faults have great throws. At a locality on the road to Mullewa, about 4 miles north-east of Mingenew and 3 miles north of Enanty Hill, movement on the Urella Fault has thrown Upper Jurassic—possibly uppermost Jurassic—sediments of the Yarragadee Formation against

Sakmarian Holmwood Shale. For this to occur the throw at this place should be of the order of 8000 feet. Vertical movements of a similar or even greater amount are found elsewhere. As well as these two great fault systems there are other lesser subparallel faults and a set trending north-west.

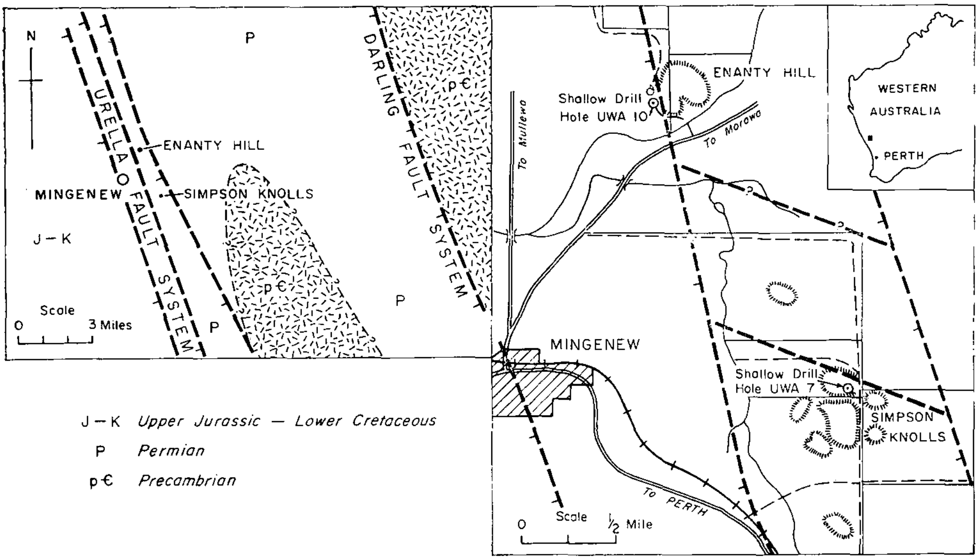

Fig. 1: Locality map and geological sketch map.

Although it is a most important structure, the Urella Fault system shows hardly at all, either on the ground or in air-photographs. On existing maps of the Irwin River district it is shown as an approximate line or as a zone more or less in the position indicated in Text-figure 1. This line marks a belt of little or no outcrop between occasional outcrops of undoubted Permian to the east and even rarer outcrops of Jurassic-Cretaceous to the west. The actual position of the Urella Fault is in fact unknown.

South-east of Mingenew, Precambrian rocks of the Mullingarra inlier are found. Its boundaries with the surrounding Permian are hazy; they may be faults. To the north of the inlier and east of Enanty Hill there are the glacial sediments of the Nangetty Formation (Johnson et al., 1954). The juxtaposition of these sediments against the much younger ones of Enanty Hill requires the presence of a fault which we call the East Enanty Fault.

Although sparse, Permian fossils occur over most of Enanty Hill. They were thought to be equivalents of the Fossil Cliff and Woolaga Creek faunas by Fairbridge (*in* Clarke et al., 1951) and by Johnson et al. (1954). They have now been studied in fair detail by L. J. Peet as part of a general project on the

Mingenew Formation (in effect, the exposures at Enanty Hill and Simpson Knolls to the south). Both he and Dr J. M. Dickins (1963, 1965, and personal communication) consider that the Mingenew Formation fauna may be correlated with that of the Madeline Formation in the Carnarvon Basin; that is younger than Fossil Cliff. There is the possibility that the Mingenew Formation represents a sandy facies of the Carynginia Formation. In any case it is clear that the East Enanty Fault, between Enanty Hill and the much older Nangetty Formation to the east, should have a throw of at least 2500 feet (Text-fig. 2).

JURASSIC AND TRIASSIC AT ENANTY HILL

The Jurassic fossils occur as moulds and impressions, commonly broken, in a lateritized coarse quartzose sandstone (probably also feldspathic before lateritization) at the foot of the south-western flank of Enanty Hill. The sediment compares with the weathered ferruginized Newmarracarra Limestone and also with the sandy parts of the Cadda Formation in the Hill River area to the south-south-west (Brien & McLellan, 1962). In part it is conglomeratic, the cobbles consisting of a friable ferruginized sandstone similar to the matrix. Fossils are rare, making up a small fauna consisting of one ammonite species, nine pelecypod species, several gastropod species, an indeterminate belemnite, and fragments of wood.

When the fossils were first discovered, their relative scarcity, their preservation, and especially the hostile character of the matrix, suggested the possibility that they could be embedded in a Holocene veneer deposited by the nearby Lockier River, and derived from some Jurassic outcrop now eroded. This kind of derivation was not confirmed by detailed examination. In particular, the sediment in the last few chambers of delicate ammonite moulds matched the matrix, and the fine clay in earlier chambers was also found in more accessible moulds of pelecypod single valves. Neither instance would survive transport. The fossils are found in lumps of sediment; no true beds were found. Also, the locality is part of a road-ballast quarry, and since the Jurassic material could have been dumped, a shallow bore was drilled and cored to test the thickness of the Jurassic and to obtain unweathered unlateritized samples.

The log of this hole is given in abbreviated form, based on visual inspection during drilling and on study of the cores obtained.

Depth	
0 - 6	coarse friable ferruginized sandstone.
6 - 18	coarse ferruginized sandstone with occasional grey micaceous shaly bands.
18 - 23	micaceous mudstone with many thin ferruginous sandstone bands.
23 - 43	predominantly friable ferruginous sandstone, in part extremely coarse-grained with quartz pebbles.
43 - 54	clayey sandstone with some coarse-grained ferruginized sandstone.
54 - 59	micaceous sandy siltstone.

59 - 69	predominantly grey micaceous mudstone (with Jurassic microflora in interval 59-65 feet).
69 - 75	mainly coarse-grained sandstone with occasional bands of clay.
75 - 80	alternating bands of purple micaceous fine-grained sandstone, mottled coarse-grained red-white sandstone, and thin bands of micaceous clay.
80 - 82	grey-green greasy mudstone (typical Kockatea Shale and containing Scythian microflora).

Sandy sediments predominated, and over most of the hole they were remarkably friable and often unconsolidated, possibly because of leaching during lateritization of the surface rocks.

The Jurassic fauna includes the following species: *Fontannesia clarkei* (Crick, 1894); *Cucullaea* sp. Etheridge Jnr, 1910; *Meleagrinella sinuata* (Teichert, 1940); *?Oxytoma decemcostata* Whitehouse, 1924; *Chlamys?* sp. nov.; *Camptonectes* sp. nov.; *Pseudolimea* sp.; *Trigonia moorei* Lycett, 1870; *?Astarte apicalis* Moore, 1870; *Pleuromya? sanfordii* (Moore, 1870). This is a Middle Jurassic (Bajocian) assemblage which can be correlated with the fauna of the Newmarracarra Limestone. The systematics are given later.

All likely clayey parts of the cores were treated to extract any microflora present, but only two samples (UWA 55071/A and 55071/B) yielded identifiable forms possessing age significance. The first sample (60-65 feet) was found to be of Jurassic age, the second (79½-82 feet) Lower Triassic. The Jurassic microflora includes certain key forms known to occur in the Cockleshell Gully Formation of the Hill River area. The microflora is discussed fully in the Appendix, as also are the spores and pollen grains and spinose acritarchs which were found in the Triassic sample at 80 feet.

In summary, at this locality Middle Jurassic sediments persist at least to 65 feet, and undoubted Triassic sediments, representing the Kockatea Shale and possibly the lower part of it, occur at 80 feet. It can be assumed that below this, but at uncertain depth, there would be found sediments of the Wagina Formation (Tartarian). The presence of this Triassic/Jurassic sequence within a few yards of undoubted Permian (Artinskian) can be best explained by postulating a fault just to the east of the borehole site and trending meridionally

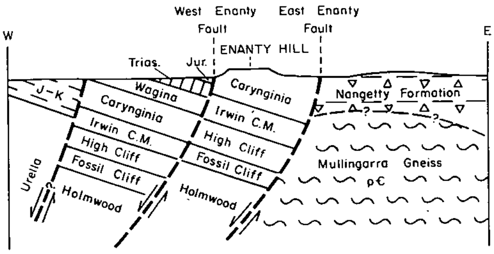

Fig. 2: Cross-section of the Triassic/Jurassic at Enanty Hill, Perth Basin.

(the West Enanty Fault). It does not show, however, either on the ground or in the air-photograph. Its throw depends an the actual thickness of Triassic present and the likelihood that the Mingenew Formation is at least stratigraphically equivalent to the upper part of the Carynginia Formation. Accepting both these propositions, then the throw would represent a little more than the approximate thickness of the Wagina Formation, that is, about 1000 feet. A diagrammatic cross-section is shown in Text-figure 2.

SIGNIFICANCE

The Jurassic and Triassic sediments at Enanty Hill complicate further an already complex fault picture. It is probable that the West and East Enanty Faults are part of the Urella Fault, a riffle-fault system in which large throws are brought about incrementally by a number of fairly closely spaced faults. The presence of Jurassic-Cretaceous Yarragadee Formation faulted against Holmwood Shale at the traditional locality for viewing the Urella Fault and the presence of Cretaceous sediments just to the west of Mingenew requires at least a third or 'main' Urella Fault. It probably trends through Mingenew township.

The Enanty Hill situation is also connected with the discovery in 1964 of marine Permian (Artinskian) 20 miles to the south near the hamlet of Arrino (Edgell, 1965). The locality was previously thought to lie in the upper part of the Yarragadee Formation of early Cretaceous age. To explain the presence of this Permian, Edgell argued convincingly for the presence of a fault to the west of the supposed Urella Fault and parallel to it. This almost certainly is the West Enanty Fault. The fault which Edgell describes as the Urella Fault is more likely to be the East Enanty Fault. It is improbable, then, that the Enanty Hill Faults are minor sliver faults. Indeed it is possible that they are the southern extensions of the Nangetty and Urella Homestead Faults (Clarke et al., 1951; Joynson et al., 1954).

The occurrence a few miles north of Enanty Hill, mentioned above, where the 'main' Urella Fault has a throw perhaps exceeding 8000 feet, poses difficulties to the riffle-fault idea. These are lessened if it be conceded that the set of faults trending north-west (e.g. Greenbrook Fault *in* Johnson et al., 1954) have been as active, at least since the Jurassic, as the north-trending systems. A jumbled set of fault blocks, elongated roughly north-south, would result (accepting the dominance of the north-trending systems). Post-Cretaceous movement along these faults would allow great vertical differences between adjacent blocks, while nearby blocks were relatively unaffected. As a corollary, if movement on the faults began during the Jurassic, sedimentation over and around these blocks would account for the observed variation in thickness of the Triassic-Jurassic sedimentary sections in this area and also for their ragged pattern of outcrop.

The nature of the Triassic microflora suggests that it is the lower part of the Kockatea Shale which is present in the Enanty section. If so, then the 'block' was eroded at some time between the Scythian and the Middle Jurassic. Finally, the Jurassic marine sediments enlarges the known area covered by Middle Jurassic seas. Perhaps significantly, this extension is a little to the east of the new position for the 'main' Urella Fault.

SYSTEMATIC DESCRIPTIONS

Two pelecypod species, *Chlamys* sp. nov. aff. *C. splendens* (Dollfus, 1863) and *Camptonectes* sp. nov. aff. *C. lens* (Sowerby, 1821) are new, but their formal naming has been temporarily postponed; the Western Australian marine Jurassic faunas are now being revised and additional collections made. It is hoped that better preserved material of these two species will be forthcoming.

Class PELECYPODA

Family CUCULLAEIDAE Stewart, 1930

Genus CUCULLAEA Lamarck, 1801

Type species: *Arca labiata* Solander, 1786.

CUCULLAEA sp., Etheridge Jnr, 1910

(Pl. 25, figs ?15, 16, 19, 20, 22)

1910 *Cucullaea* sp. Etheridge Jnr, *Geol. Surv. W. Aust. Bull.* 36, 35, 36, pl. 8, figs 1, 2 (? pl. 7, fig. 1).

Cucullaeidae are moderately well represented in the Enanty Hill fauna: altogether over half a dozen specimens have been identified. Three of the four specimens illustrated on Plate 25—figures 16, 19, 20, 22—closely resemble *Cucullaea* sp. Etheridge Jnr, 1910 (particularly pl. 8, figs 1, 2) from 2 miles east of Moonyoonooka, Greenough River. The third form (fig. 15), which may represent the same species, is very young and at this stage it is difficult to be certain of its identity. It is strongly inflated with a sharp postumbonal ridge and distinct reticulate ornamentation pattern.

Apart from *Cucullaea* sp. Etheridge Jnr, 1910, four other Cucullaeidae have been described in the past from the Bajocian strata of Western Australia. These are Cucullaea sp., *C. inflata,* and *C. semistriata* Moore, 1870, and *C. tibraddonensis* Etheridge Jnr, 1910.

Family MONOTIDAE Fisher, 1887

Genus MELEAGRINELLA Whitfield, 1885

Type species: *Avicula echinata* Smith, 1817.

MELEAGRINELLA SINUATA (Teichert, 1940)

(Pl. 25, figs 2-5)

1924 *Pseudomonotis echinata* (Sowerby); Whitehouse, *J. Roy. Soc. W. Aust.* 11(1), 2, pl. 1, figs 2a, b, c.
1940 *Echinotis sinuata* Teichert, *J. Roy. Soc. W. Aust.*, 26, 22-24, pl. 1, figs 1-10.

Material. Eleven fragmentary specimens.

Discussion. Genus *Echinotis* Marwick, 1935, is based on the same type species as *Meleagrinella* Whitfield, 1885, and is regarded as its synonym.

Specimens of *M. sinuata* from Enanty Hill are not as well preserved as some previously described specimens, and their examination adds nothing to the past descriptions.

As well as the Enanty Hill area *M. sinuata* has been previously reported from Moresby Range and Greenough River by Glauert (1910, p. 100); from Bringo Cutting on the Geraldton-Mullewa railway line, 19 miles east of Geraldton, by Whitehouse (1924, p. 2); and from a locality on Wandagee station, south side of the Minilya River, by Teichert (1940, p. 23).

Family AVICULOPECTINIDAE Etheridge Jnr, 1906 em. Newell, 1938

Genus OXYTOMA Meek, 1864

Type species: *Avicula munsteri* Goldfuss, 1836.

?OXYTOMA DECEMCOSTATA Whitehouse, 1924

(Pl. 25, fig. 1)

A single shell in the collection may represent *O. decemcostata.* It is only 6 mm high, and incomplete, being an external mould of the proximal portion of the left valve.

The surface of the specimen contains 10 or 11 primary radiating ribs separated by wide flat interspaces, each of which contains several orders of riblets. Of these, one in each interspace is more prominent than the others. The mode of ribbing is thus similar to, though not identical with, that in *O. decemcostata,* whose description by Whitehouse is based on several left valves from Bringo Cutting. His specimens contain 10 primary ribs and the secondary ribs are not differentiated.

In the past O. *decemcostata* was identified from '15 miles north Champion Bay' (Etheridge Jnr, 1878, p. 107); Moresby Range (Glauert, 1910, p. 100); and the Newmarracarra Limestone, Bringo Cutting on the Geraldton-Mullewa railway line (Glauert, 1926, p. 51).

Family PECTINIDAE Lamarck, 1801

Genus CHLAMYS Bolton, 1798

Type species: *Pecten islandicus* Muller, 1776.

CHLAMYS? sp. nov. aff. C. SPLENDENS (Dollfus, 1863)

(Pl. 25, figs 9, 13, 17)

Material. Two almost complete internal casts, and two fragments.
Description. The most complete specimen is 32 mm long and 42 mm high. Its apical angle is 72°. Both the anterior and the posterior umbonal margins slope down from the cardinal margin only slightly obliquely. The ventral margin is evenly convex.

There may be as many as 25 radial ribs emanating from the umbo. Their thickness at the distal shell periphery is about 1 mm and they are subcircular in cross-section. The growth rugae form regular concentric rows of tubercles, which are particularly prominent on the ribs. They are numerous and evenly spaced in any given part of the shell, but their density varies in different portions of the shell between 9 and 6 rugae per centimetre.

Remarks. The species described is almost certainly new, but its formal naming is withheld in the hope of obtaining more material during the forthcoming revision of the Bajocian faunas of Western Australia.

Genus CAMPTONECTES Meek, 1864

Type species: *Pecten lens,* Sowerby, 1821.

CAMPTONECTES sp. nov. aff. C. LENS (Sowerby, 1821)

(Pl. 25, figs 11, 12)

Material. Two incomplete specimens and two fragments.

Description. The shell is subcircular, at least 5.5 cm long and 6 cm high. The auricles are rather small relative to the size of the shell. The front ear is closely striated with growth rugae which parallel its anteroventral margin, while radial ribbing is present on its dorsal section. On the posterior ear 'radial' ribbing is directed almost at right angles to the postumbonal margin.

The apical angle is 110°. The postumbonal margin is straight and the preumbonal margin gently concave.

The ornament is absent from the umbonal region—at least in the mature specimens. Distally from the umbo it consists of very fine and shallow radiating lamellae which are flat and separated from each other by interspaces narrower than the lamellae. The tendency among the lamellae to become sinuous and to bifurcate increases with increasing distance from the umbo.

Discussion. The *Camptonectes* from the Enanty Hill is thought to be a new species, though closely allied to the Corallian *Camptonectes lens.* Both forms have identical ornament, and their overall shape is also very similar, but in *C. lens* the preumbonal margin is more steeply plunging and more strongly arched. The auricles in both species are small compared with the overall size of the shell. The Enanty Hill form will be described as a new species in the future, but formal naming at this stage is withheld in the hope of obtaining additional material during the forthcoming revision of the Bajocian faunas of Western Australia.

Family LIMIDAE d'Orbigny, 1847

Genus PSEUDOLIMEA Arkell, 1932

Type species: *Lima duplicata* Sowerby, 1827.

PSEUDOLIMEA sp. cf. P. DUPLICATA (Sowerby, 1827)

(Pl. 25, fig. 8)

The three incomplete casts and moulds of Limidae are clearly identical with the forms previously described as *Radula duplicata.*

Species of *Lima* which are regarded as edentulous forms were originally referred to the subgenus *Mantellum* (*Promantellum* Iredale) and *Radula* Klein, 1753. Arkell *in* Douglas & Arkell, 1932) included both these in his subgenus *Pseudolimea,* while similar forms with teeth were retained in *Limea* Bronn, 1831. Cox (1944) demonstrated, however, the presence of teeth in *Pseudolimea,* which he elevated to generic rank, and in which he also included species referred previously to *Limea.* Thus, although it is not known whether teeth are in fact present or absent in the Enanty Hill Limidae, they are included in *Pseudolimea.* Their preservation is, unfortunately, not sufficiently good to determine whether the species represented is in fact referable to *duplicata.*

In Western Australia *Pseudolimea duplicata* was recorded in the past from Greenough River by Etheridge (1910, p. 33) and in the Geraldton area from Moresby Range, Tibraddon, Sandspring, Snake Farm, and Mount Hill by Glauert (1910, p. 101).

Family TRIGONIIDAE Lamarck, 1819

Genus TRIGONIA Bruguière, 1789

Type species: *Venus sulcata* Hermann, 1781.

Subgenus TRIGONIA s. str.

TRIGONIA MOOREI Lycett, 1870

(Pl. 25, fig. 10)

1870 *Trigonia moorei* Lycett, *in* Moore, *Quart. J. geol. Soc. Lond.*, 26, 254, pl. 14, figs 9, 10.

1963 *Trigonia moorei* Lycett; Skwarko, *Bur. Miner. Resour. Aust. Bull.* 67, 13, 14, pl. 1, fig. 1 (for synonymy).

The Enanty Hill locality yielded six variously incomplete specimens and seven fragments of a trigoniid with features similar to those of *T. moorei,* described by Lycett from the Greenough River area.

T. moorei is perhaps the most typical form of the Western Australian Bajocian fossils, and is very widespread. It was reported from Shark Bay, and in the Geraldton area, Moresby Range, Greenough River, Tibraddon, Moonyoonooka, Sandspring, Woolanooka, Snake Farm, and Mount Hill (Glauert 1910, p. 100).

Family ASTARTIDAE Gray, 1840

Genus ASTARTE Sowerby, 1818

Type species: *Pectunculus sulcatus* da Costa, 1778.

?ASTARTE APICALIS Moore, 1870

(Pl. 25, figs 6, 7)

Material. One specimen of a right valve, consisting of an external mould and an internal cast, and one external mould of a right valve.

Description. The shell is thick for the size (8 mm high and 8.5 mm long), asymmetrical, subtriangular, weakly inflated, with a pointed and prosogyrous umbo.

The outside of the shell is ornamented with robust concentric ribs, which are somewhat irregular in breadth and separated by relatively narrow v-shaped interspaces. The ribs are broadly and evenly convex in their median portion, with increasing curvature close to the shell's margin.

The dentition is not well preserved, but seems to be of the typical astartid type. In the right valve 3b is bordered front and back by a socket, while the lateral teeth seem to be developed in the left valve.

Only the dorsal borders of the anterior and posterior adductor muscle impressions are strongly impressed. The pallial line may be entire. The ventral inside margin is crenulated.

Discussion. Neither the type species nor any of the original specimens described by Moore (1870) are available for examination, and they seem to have been irretrievably lost (Glauert, 1910, p. 102). The identity of the Enanty Hill specimens cannot be definitely established without further collecting at the type locality. Moore's description is inadequate, while his sole illustration, which is of unknown magnification, does not seem to be accurate, particularly in the detail of ribbing at the peripheries of the shell.

Occurrence. The past record of *A. apicalis* is from the Greenough River (Moore, 1870).

Family PLEUROMYIDAE Zittel, 1881

Genus PLEUROMYA Agassiz, 1843

Type species: *Mya gibbosa* Sowerby, 1825.

PLEUROMYA? SANFORDII (Moore, 1870)

(Pl. 25, figs 14, 18, 21)

Material. 18 specimens of almost complete internal casts or fragments of external moulds.

Discussion. Specimens from Enanty Hill which are similar to *Myacites sanfordii* described by Moore (1870, p. 253, pl. 13, fig. 9) show very little structure on their thin and narrow subcylindrical hinges. There does seem, however, to be a suggestion of a thin horizontal lamina in each valve suggestive of a *Pleuromya,* to which the Enanty Hill forms are tentatively referred.

Occurrence. In the past it was recorded from Greenough River and Moonyoonooka by Glauert (1910, p. 102).

Class CEPHALOPODA

Family SONNINIIDAE Buckman, 1892

Genus FONTANNESIA Buckman, 1902

Type species: *Dumortieria grammoceroides* Haug, 1887.

FONTANNESIA CLARKEI (Crick, 1894)

(Pl. 25, fig. 23)

1870	*Ammonites radians* Moore (*non* Schlotheim), *Quart. J. geol. Soc. Lond.*, 26, 230-232, pl. 15, fig. 2.
1894	*Ammonites* (*Dorsetensia*) *clarkei* Crick, *Geol. Mag.*, (4) 1, 388, pl. 12, figs 2a-c.
1910	*Dorsetensia clarkei* Crick; Etheridge Jnr, *Geol. Surv. W. Aust. Bull.* 36, 38, pl. 6, fig. 4, pl. 9, fig. 7.
1924	*Dorsetensia etheridgei* Whitehouse, *J. Roy. Soc. W. Aust.*, 11, 9.
1939	*Dorsetensia clarkei* Crick; Spath, *J. Roy. Soc. W. Aust.*, 25, 129, pl. 1, fig. 2, pl. 2, figs 1, 2.
1954	*Fontannesia clarkei* (Crick); Arkell & Playford, *Phil. Trans.*, 237 (651), 565, 566, pl. 28, figs 1-6, pl. 29, figs 1, 2, pl. 30, figs 1-4, text-fig. 3.

Material. The best of three specimens in the collection shows the shape of the internal cast as well as the external impression of the shell in the surrounding sediment.

Discussion. The suture is not visible, but the specimen is undoubtedly *F. clarkei.* It is a small shell compared with other species of *Fontannesia* found in the Newmarracarra Limestone, and its ribs, which are pronounced, closely spaced, and persistent over the whole of the shell, separate it from *F. whitehousei* and *F. fairbridgei* Arkell & Playford, 1954.

F. clarkei has a wide geographical distribution in the Geraldton area, where it occurs in the Bajocian Newmarracarra Limestone. Its presence in the Enanty Hill assemblage is strong evidence for the correlation of the sediments in which it occurs with the Newmarracarra Limestone.

ACKNOWLEDGMENTS

The authors wish to express their special thanks to Mr B. E. Balme, University of Western Australia, who identified the microflora, discussed their significance, and provided the Appendix.

Mr M. H. Johnstone, West Australian Petroleum Company Pty Ltd, and Dr P. E. Playford, Geological Survey of Western Australia, discussed various aspects of the structure and stratigraphy of the northern Perth Basin and made many stimulating and helpful suggestions.

Mr Malcolm McLeod, presently a student at the University of Western Australia, provided the initial collection of the first Jurassic fossils to be collected at Enanty Hill.

REFERENCES

BRIEN, J. W., and MCLELLAN, G. A., 1962—Geology of part of the Hill River area, Western Australia. *Hons thesis, Univ. W. Aust.*

CLARKE, E. de C., PRENDERGAST, K. L., TEICHERT, C., and FAIRBRIDGE, R. W., 1951—Permian succession and structure in the northern part of the Irwin Basin, Western Australia. *J. Roy. Soc. W. Aust.*, 35, 31-84.

COX, L. R., 1944—On *Pseudolimea* Arkell. *Proc. malac. Soc. Lond.*, 26 (2, 3), 74-88.

DICKINS, J. M., 1963—Permian pelecypods and gastropods from Western Australia. *Bur. Miner. Resour. Aust. Bull.* 63.

DICKINS, J. M., 1965—Appendix D *in* McTavish, R. A., Completion report B.M.R. 10 and 10A, Beagle Ridge, Western Australia. *Bur. Miner. Resour. Aust. Rep.* 80.

DOUGLAS, J. A., and ARKELL, W. J., 1932—The stratigraphical distribution of the Cornbrash: 2. The north-eastern area. *Quart. J. geol. Soc. Lond.*, 88, 112-170, 3 pls.

EDGELL, H. S., 1965—Lower Permian fossils from outcrops in the Perth Basin, near Arrino. *Geol. Surv. W. Aust., Ann. Rep.* (1964), 65-68.

ETHERIDGE, R., Jnr, 1878—CATALOGUE OF AUSTRALIAN FOSSILS. *Cambridge, Univ. Press.*

ETHERIDGE, R., Jnr, 1910—Oolitic fossils of the Greenough River district, Western Australia. *Geol. Surv. W. Aust. Bull.* 36, (3), 29-50.

GLAUERT, L., 1910—The geological age and organic remains of the Gingin Chalk. *Geol. Surv. W. Aust., Bull.* 36(3), 115-127, 2 text-figs.

GLAUERT, L., 1926—A list of Western Australian fossils (systematically arranged). *Ibid.*, 36, (3), 71-106.

JOHNSON, W., de la HUNTY, L. E., and GLEESON, J. S., 1954—The geology of the Irwin River and Eradu Districts, and surrounding country. *Geol. Surv. W. Aust., Bull.* 108, 1-124.

MOORE, C., 1870—Australian Mesozoic geology and palaeontology. *Quart. J. geol. Soc. Lond.*, 26, 226-261, 9 pls.

TEICHERT, C., 1940—Marine Jurassic in the North-West Basin, Western Australia. *J. Roy. Soc. W. Aust.*, 26, 17-27, 1 pl.

WHITEHOUSE, F. W., 1924—Some Jurassic fossils from Western Australia. *J. Roy. Soc. W. Aust.*, 11 (1), 1-13, 2 pls.

APPENDIX

JURASSIC AND TRIASSIC MICROFLORA FROM SHALLOW BOREHOLE (UWA 10), ENANTY HILL

by B. E. Balme

Sample 55071/A

Depth: 59 feet 3 inches - 64 feet 6 inches (actual 61 feet).

Lithology: Dark grey clay.

Plant microfossils were abundant and extremely well preserved. They included pteridophyte spores, gymnosperm pollen grains, and fragments of various plant tissues. Occasional spheroidal featureless bodies were also observed; they are regarded as leiospheres, of probable non-vascular origin.

MICROFLORAL LIST

Spores:
- *Dictyophyllidites* sp.
- *Concavisporites* cf. *juriensis* Balme
- *Osmundacidites wellmanii* Couper
- *Ischyosporites* sp.
- *Pilasporites marcidus* Balme
- *Cyathidites minor* Couper

Pollen grains:
- *Inaperturopollenites turbatus* Balme
- *Applanopsis dampieri* (Balme)
- *A. segmentatus* (Balme)
- *Araucariacites australis* Cookson
- *Vitreisporites pallidus* (Reissinger)
- *Classopollis torosus* (Reissinger)
- *Podocarpidites* spp.

Acritarchs:
- *Leiosphaeridia* spp.

Discussion

Among the pollen grains the most common species is *Inaperturopollenites turbatus,* a form first described from the upper part of the Cockleshell Gully Formation (Balme, 1957) and rarely encountered in sediments younger than Middle Jurassic. *Applanopsis dampieri* and *A. segmentatus* are uncommon in Lower Jurassic sediments in Western Australia, although they are known to occur together in the Cattamarra Coal Measures Member of the Cockleshell Gully Formation, both in Eneabba No. 1 well and in the Hill River area. Two undescribed species, *Dictyophyllidites* sp. and *Ischyosporites* sp., also characterize the Cattamarra Coal Measures in other parts of the Perth Basin. *Exesipollenites tumulus,* which is usually abundant in the lower part of the Cockleshell Gully Formation, was not recognized in the present assemblage.

In summary, the assemblage is of late Lower or Middle Jurassic age, and the sediments from which it comes may correlate with the uppermost part of the Cockleshell Gully Formation in its type area.

Sample 55071/B

Depth: 79 feet 6 inches - 82 feet 0 inches.

Lithology: Pale grey clay.

Enormous numbers of small spinose acritarchs characterized the assemblage and were associated with well-preserved spores and pollen grains. The ratio acritarchs: spores and pollen, was about 35:1.

MICROFLORAL LIST

- Spores:
  - *Densoisporites playfordi* (Balme)
  - *Lundbladispora willmotti* Balme
  - *L. brevicula* Balme
  - *Punctatisporites fungosus* Balme
  - *Lycopodiacidites pelagius* Balme
  - *Osmundacidites senectus* Balme
  - *Kraeuselisporites cuspidus* Balme
  - *K. saeptatus* Balme
- Pollen grains:
  - *Taeniaesporites obex* Balme
  - *T. noviaulensis* Leschik
  - *Protohaploxypinus pellucidis* Goubin
- Acritarchs:
  - *Veryhachium reductum* Deunff
  - *Veryhachium* sp.
  - *Micrhystridium* cf. *breve* Jansonius
  - *Micrhystridium* spp.
  - *Leiosphaeridia* spp.

Discussion

The acritarch swarm, together with the presence of *Taeniaesporites, Lundbladispora,* and *Densoisporites playfordi,* shows that the sample is of Lower Triassic age. Closely similar assemblages occur in the lower part of the Mianwali Formation in the Salt Range (lower Scythian), the Kockatea Shale in the northern part of the Perth Basin (Balme, 1963), and the Blina Shale in the Canning Basin.

There is no doubt that the strata at the base of UWA Bore 10 correlate with part of the Kockatea Shale. From the very low spore/acritarch ratio (1:35) it is most likely that they are equivalent to the lower part of that unit as it is developed in, for example, BMR 10 (Beagle Ridge) Bore.

REFERENCE

BALAIE, B. E., 1957—Spores and fallen granis from the odesozoic of Western Australia. *Aust. C.S.I.R.O. Cool Res. Sect.* Tech. Comar. 25.

PLATE 25

The plate figures are 5/6ths of their natural size, and specimens are photographed in their lateral view unless otherwise stated. All specimens are from Enanty Hill.

Fig. 1. *?Oxytoma decemcostata* Whitehouse, 1924 .... Page 205
Latex cast of incomplete external mould of small left valve. UWA 55044.

Figs 2-5. *Meleagrinella sinuata* (Teichert, 1940) .... Page 205
2. Latex cast of proximal portion of external mould of left valve. UWA 55045.
3. Latex cast of median portion of external mould of ?left valve. UWA 55046.
4. Internal cast of small right valve. UWA 55047.
5. Internal cast of proximal portion of left valve. UWA 55048.

Figs 6-7. *?Astarte apicalis* Moore, 1870 .... Page 208
6. Latex cast of external mould of right valve. UWA 55049.
7. Latex cast of internal mould of right valve. UWA 55049.

Fig. 8. *Pseudolimea* sp. cf. *P. duplicata* (Sowerby, 1827) .... Page 207
Latex cast of incomplete external mould of left valve UWA 55050.

Figs 9, 13, 17. *Chlamys?* sp. nov. aff. *C. splendens* (Dollfus, 1863) .... Page 206
9, 13. Latex cast showing detail of ornament. UWA 55051 and UWA 55052.
17. Internal cast of left valve. UWA 55053.

Fig. 10. *Trigonia moorei* Lycett, 1870 .... Page 208
Latex cast of left valve, anteriorly incomplete. UWA 55054.

Figs 11, 12. *Camptonectes* sp. nov. aff. *C. lens* (Sowerby, 1821) .... Page 206
11. Latex cast of anteriorly incomplete external mould of right valve. UWA 55054.
12. Latex cast showing detail of ornament. UWA 55056.

Figs 14, 18, 21. *Pleuromya? sanfordii* (Moore, 1870) .... Page 209
14. Dorsal view of internal cast of bivalve with some silicified shell preserved. UWA 55057.
18. Internal cast of right valve. UWA 55058.
21. Latex cast of external mould of left valve. UWA 55059.

Figs 15, 16, 19, 20, 22. *Cucullaea* sp. Etheridge Jnr, 1910 .... Page 204
15. Latex cast of external mould of immature left valve x2. UWA 55060.
16. Internal cast of immature right valve. UWA 55061.
19, 20. Posterior and lateral views of internal cast of right valve. UWA 55062.
22. Latex cast of internal mould of right valve. UWA 55063.

Fig. 23. *Fontannesia clarkei* (Crick, 1894) .... Page 210
Latex cast of external mould of shell. UWA 55064.

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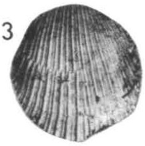

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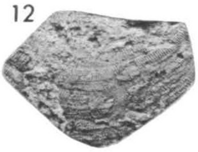

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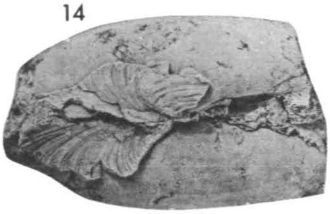

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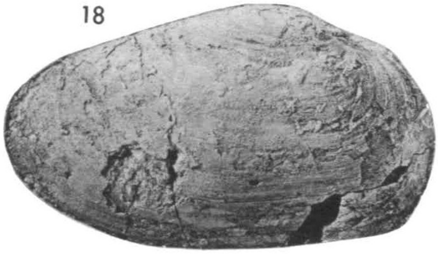

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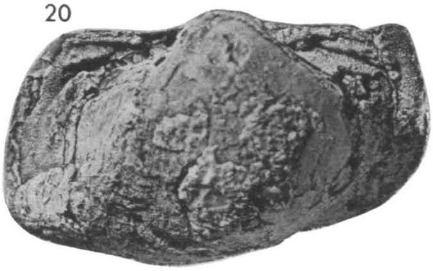

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Fossils from Enanty Hill

FOSSIL MAMMAL REMAINS FROM THE TERTIARY CARL CREEK LIMESTONE, NORTH-WESTERN QUEENSLAND

by Richard H. Tedford

University of California, Berkeley

SUMMARY

The Carl Creek Limestone in the Riversleigh area of north-western Queensland occurs as isolated residuals marking a former lake bed. It rests on an uneven surface of Proterozoic and Cambrian rocks and consists of a lower conglomerate or breccia set in a sandy matrix cemented by calcite, and an upper clastic limestone. The upper member contains vertebrate and invertebrate remains. Among the vertebrates are undetermined fish, crocodiles, and birds, and a few mammals. Three diprotodontids, including a new genus and species *Bematherium angulum,* and a macropodid are described.

The diprotodontids show that the Riversleigh fauna is contemporaneous with or slightly younger than the Ngapakaldi fauna of South Australia; but it is still too early to attempt to fit either precisely into the Lyellian Tertiary scale. A late Oligocene or early Miocene age is consistent with the evidence.

INTRODUCTION

Fossil vertebrate remains were first noticed in the Tertiary freshwater limestone exposed on Riversleigh station, north-western Queensland, by W. E. Cameron in 1901. The material he obtained was submitted to C. W. de Vis, who reported (*in* Cameron 1901, p. 190) that remains of the 'Nototheriidae' (=Diprotodontidae) were present. Cameron believed these rocks to be Quaternary. They had been observed previously by R. L. Jack (1895), who named them the Carl Creek Limestone. Subsequent investigators attached other names and often different ages to these rocks: David (1914) regarded them as Tertiary but called them the Helicidae Limestone; Whitehouse (1940) used this name, but referred them specifically to the Pliocene; Bryan & Jones (1946) referred them to the Pleistocene; Noakes & Traves (1954) named outcrops of the Carl Creek Limestone near Verdon Creek the Verdon Limestone and regarded them as Cretaceous or Tertiary.

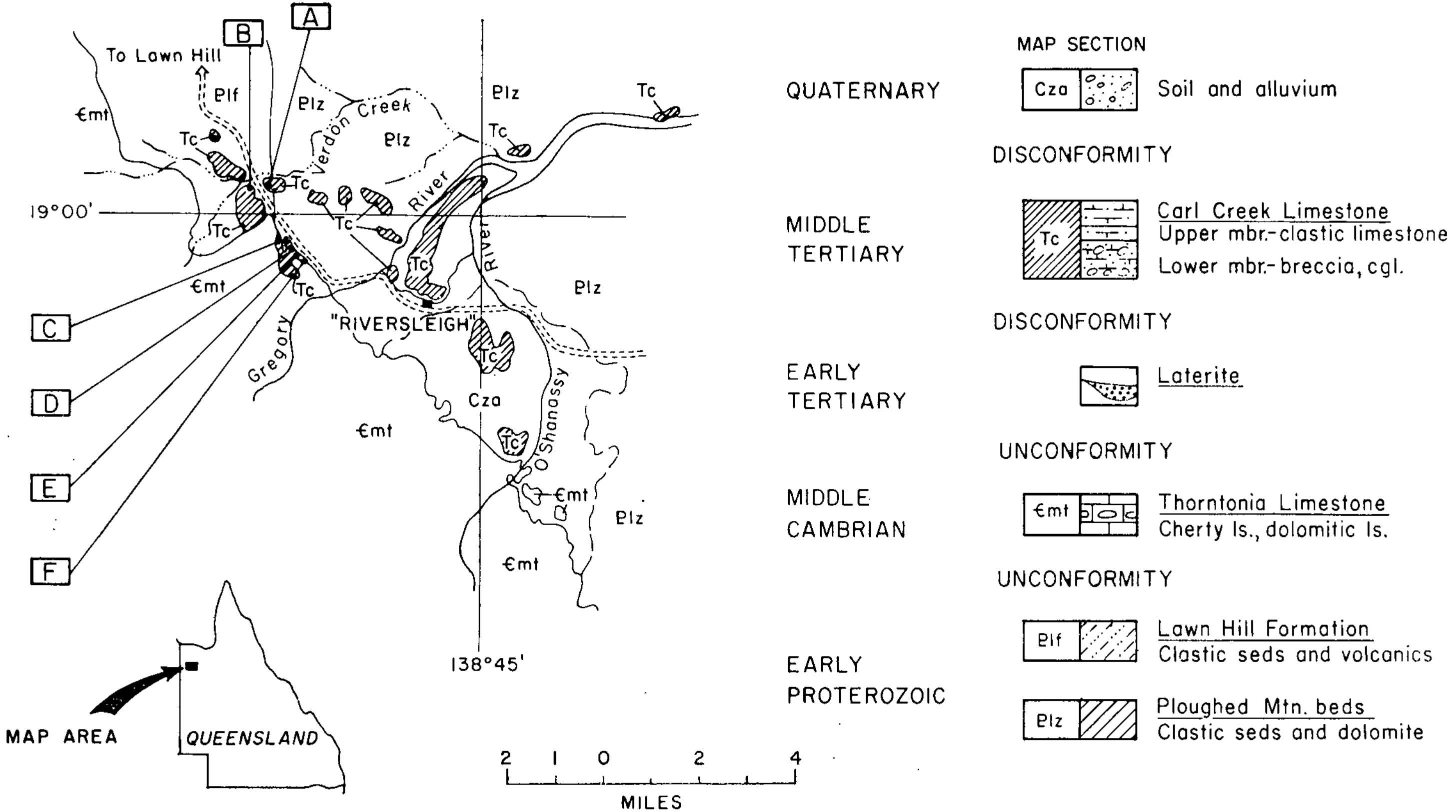
Jack's name Carl Creek Limestone has been revived in recent years as a result of the Bureau of Mineral Resources regional mapping programme in north-western Queensland (Paten, *in* Hill & Denmead, 1960; Carter & Öpik, 1961). A late Tertiary age has been assigned to the unit on the grounds that it overlies lateritized pre-Tertiary rocks and hence postdates the mid-Tertiary interval of intense and widespread lateritization in Queensland.

In 1962 it became apparent that further study of the Carl Creek Limestone, especially its vertebrate fossils, might yield important information on its age, which would in turn provide geochronological data to assist in the interpretation of the Cainozoic geological history of north-western Queensland. Biostratigraphical studies of Tertiary fossil mammals, especially in northern South Australia (Stirton, Tedford, & Miller, 1961), have progressed to the stage where they could prove potentially useful in geochronology (see also Stirton, Woodburne, & Plane, 1967).

Accordingly Alan R. Lloyd and I undertook an investigation of a number of Tertiary continental deposits in the Northern Territory and western Queensland during 1963 (Lloyd, 1967). One of the sites visited was the Carl Creek Limestone outcrops between the Gregory River and Verdon Creek, 4 miles north of Riversleigh station homestead, north-western Queensland. This paper records some geological and palaeontological observations and describes the mammalian remains secured during our five-day visit in July 1963.

GEOLOGY

The distribution of outcrops of the Carl Creek Limestone is shown on the Camooweal and Lawn Hill 4-mile Sheets, portions of which are shown in Figure 1. The western limit of these outcrops corresponds to the Cambrian scarp which makes up part of the eastern dissected slope of the Barkly Tableland.



GEOLOGICAL MAP ADAPTED FROM
LAWN HILL AND CAMOOWEAL 4-MILE
SHEETS, BMR 1959.

Fig. 1: Outcrops of Carl Creek Limestone on Riversleigh station, Gulf Watershed, north-western Queensland. The position of the measured sections shown in Fig. 2 is indicated by letters. Bureau of Mineral Resources locality 103 from which molluscan remains were obtained (McMichael, 1966) is site B. The type locality of *Bematherium angulum* gen. nov., sp. nov., is the hill on the east end of section C. Site D produced the bulk of the fossil vertebrate material mentioned in this report including all other mammal remains described.

To the east of the scarp isolated outcrops extend as much as 14 miles from the Cambrian contact and appear to be closely associated with the valley of the Gregory River. The Carl Creek Limestone rests unconformably on a variety of rocks: to the west it pinches out against the Middle Cambrian Thorntonia Limestone; to the east it transgresses both the early Proterozoic Lawn Hill Formation and the underlying Ploughed Mountain beds. Only the outcrops of the Carl Creek Limestone which lie between the Gregory River and Verdon Creek and near the Riversleigh/Lawn Hill track form the basis for this study.

The general stratigraphic succession within the Carl Creek Limestone in the area studied includes a lower member consisting of a breccia of pebble to boulder-sized clasts set in a poorly sorted sand matrix cemented with calcite and an upper member consisting of clastic limestone with much arenaceous material. Fossil vertebrate remains were scattered throughout the upper member and are most concentrated in its lower part. Fossil freshwater gastropods occur throughout the upper member.

In places where the Carl Creek Limestone overlies the Cambrian Thorntonia Limestone the coarse breccia of the former fills deep solution cavities in the irregular surface of the Cambrian limestone. Over the clastic Proterozoic units the contact is more regular. Locally, remnants of laterite (limonite pisolite grading upward into concretionary ironstone) developed on the Proterozoic rocks are preserved beneath the Tertiary limestone. Elsewhere laterite is absent, suggesting that the surface of deposition is undulatory.

The lower member of the Carl Creek Limestone contains pebble to boulder conglomerate and breccia, the subangular clasts of which are mostly banded chert derived from the Thorntonia Limestone, but also includes rarer quartzite (silicified coarse poorly sorted quartz sandstone and pebble conglomerate). The latter clasts are most similar to the Mesozoic sandstones and conglomerates which are preserved from place to place to the west on the margin of the Barkly Tableland. In places where the Carl Creek Limestone abuts the Cambrian scarp and is thin, much ferruginous material has stained the lower member yellow. The lower member seems to lack significant limonite stain in the more easterly exposures such as those just south of Verdon Creek.

The upper member of the Carl Creek Limestone rests conformably with either gradational or in some places rather sharp contact on the lower member. It is a thick-bedded to massive clastic arenaceous limestone composed dominantly of subangular to subrounded pebbles of Tertiary limestone and rarer grey Thorntonia Limestone pebbles set in an arenaceous limestone matrix. Many of the Tertiary limestone clasts contain gastropod shells or shell fragments and a few contain fish bones. These rocks weather to a grey or yellow-grey colour, but fresh surfaces are usually yellow, or white mottled with yellow, in which the yellow colour

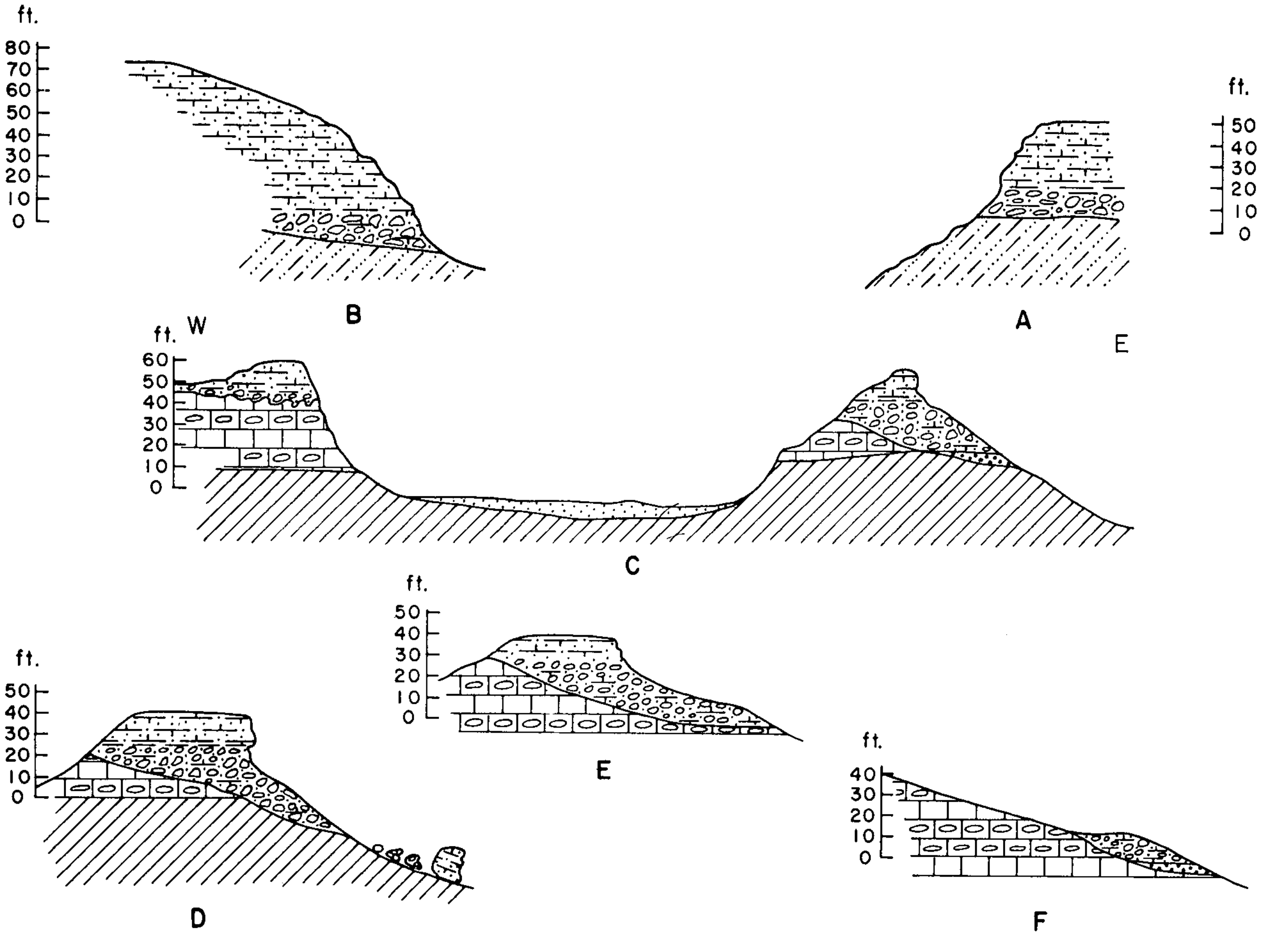


Fig. 2: Stratigraphic sections measured by hand level at sites indicated in Fig. 1. The topographic profiles are approximately reconstructed from field sketches and photographs. Lithologic symbols are those shown in the Legend of Fig. 1.

is due to disseminated limonite. The arenaceous fraction may include fragments, to pebble size, of Thorntonia chert, but the bulk is fine to medium-grained subrounded quartz sand. The rocks of the formation are vuggy and their pore spaces are filled with crystalline calcite. Some recrystallization is apparent in the coarser calcite gastropod shells, particularly those from the lower part of the upper member. Most of the larger fossil bones in these rocks show evidence of fragmentation and displacement of fragments just before burial. The larger bones are most common in the lower third of the upper member, but smaller bones are scattered throughout. Gastropod remains are more fragmentary in the lower part of the member and more complete and less recrystallized above. Minor silicification of the upper part of the Carl Creek Limestone has produced irregular silica concretions.

The Carl Creek Limestone varies greatly in thickness in the area studied. The measured sections (Fig. 2) indicate minimum thicknesses ranging up to 80 feet. A reconstruction of the basin in which the Carl Creek Limestone was deposited is beyond the scope of this paper, as the unit extends some distance to the south and east of the area examined. However, some remarks on the conditions of sedimentation as they apply to the north-westernmost portion of the basin may be of assistance in understanding the accumulation of vertebrate remains in that area. As there are no widely traceable key horizons within the formation, the isolated exposures cannot be correlated exactly. Rough line-of-sight correlations were established in the field with a hand level, assuming horizontal bedding and the absence of local structure. These reconstructions suggest that the Carl Creek Limestone in this area was deposited in a deep trough which paralleled the Cambrian scarp to the west and gradually shallowed to the east.

The coarse clastic nature of the whole formation in this area suggests a shallow-water, relatively high-energy environment adjacent to the Cambrian scarp. The conglomeratic lower member of the Carl Creek Limestone extends, gradually thinning, for a considerable distance to the east of this scarp. Its source, therefore, was the edge of the Cambrian plateau. One of the striking aspects of the upper member is that it is made up dominantly of clasts of arenaceous limestone which contain the same gastropod and teleost fish remains as are found in the matrix of these rocks. They are presumably intraformational conglomerates formed by the reworking of Tertiary limestone which was deposited on the margin of the basin. During periods of high lake level, possibly related to an increase in rainfall, limestone may have been deposited widely over the edge of the Cambrian plateau. During periods of diminished rainfall, when the lake retreated to the deeper part of the basin, these limy flats were exposed and stripped by sheet floods and shallow streams draining the Cambrian plateau. Thus quantities of clastic limestone were contributed to the basin in which the Carl Creek Limestone accumulated.

Deeper-water deposits may be indicated by the Carl Creek Limestone in the mesas south-east of Riversleigh homestead. There the Carl Creek Limestone is a white vuggy pellet limestone containing abundant fossil gastropods but only rare fragments of indeterminate bone. This facies is not a clastic limestone nor does it contain appreciable arenaceous material.

THE RIVERSLEIGH FAUNA

The upper member of the Carl Creek Limestone exposed along the edge of the Cambrian escarpment south of Verdon Creek and north of the Gregory River contains a quantity of fragmentary skeletal remains of aquatic and terrestrial vertebrates, and abundant broken and whole shells of terrestrial and aquatic gastropods. The gastropods were first reported by Etheridge (*in* Cameron, 1901, p. 190) as representing the terrestrial *?Thersites forsteriana* and aquatic *Isidora* near *pectorosa.* Recent work (McMichael, 1967) on gastropod material collected from the vertebrate-bearing rocks south of Verdon Creek (BMR Locality 103) indicates that these species are *Physastra rodingae* (=*Isidora* near *pectorosa*) and *Meracomelon lloydi* (=*?Thersites forsteriana*). Öpik (*in* Carter & Öpik, 1961) and Lloyd (1967) also record ostracods, but no identifications are given.

The aquatic vertebrate element is the most abundant in terms of the numbers of bones encountered in these rocks. Unidentified small teleost fish spines and vertebrae were found. We were unable to verify Whitehouse's report (1940) of *Neoceratodus.* By far the most abundant and conspicuous remains represent the Crocodilia, possibly *Crocodylus,* of undetermined species. Dermal plates and broken cranial and postcranial elements were common. Some remains of aquatic turtles were also seen.

The most abundant terrestrial vertebrate remains were broken postcranial elements of large emu-like birds. Fragments of femora, the distal end of a tibiotarsus, and a thoracic vertebra indicate an animal closely related generically to the living *Dromiceius,* but slightly larger than living species and *D. ocypus* of the late Pliocene of the Lake Eyre Basin (Miller, 1963). These remains give further indication that the foot structure of the Dromiceiidae was attained early and remained rather stable through a considerable interval of geological time.

Remains of the Mammalia are the rarest elements in the Carl Creek deposits. Only four specimens were obtained which could be assigned to family or lower categories. These remains are described below. It is fortunate that the Diprotodontidae are reasonably well represented as they have so far provided the best evidence for phyletic reconstruction (Stirton, Woodburne, & Plane, 1967); consequently it is now possible to suggest an age for new diprotodont occurrences relative to this phyletic sequence. The discussion of the age of the Carl Creek Limestone leans heavily on the stage of evolution of its contained diprotodonts.

All measurements in the systematic descriptions are in millimetres.

AGE OF THE RIVERSLEIGH FAUNA AND THE CARL CREEK LIMESTONE

The geochronological sequence of late Cainozoic faunas, which has been pieced together in Australia and New Guinea over the past decade by Stirton and co-workers, has provided the essential framework for phyletic studies on certain groups of marsupials (Stirton, Tedford, & Miller 1960; Stirton, Tedford, & Woodburne, 1967a). The family Diprotodontidae has so far proved to be the most rewarding group in phyletic studies because of the relative abundance of well preserved remains and common occurrence in most of the faunas studied.

The Carl Creek diprotodonts can be compared with the phylogeny deduced from previously gathered evidence (Stirton, Woodburne, & Plane, 1967) and the age of the Carl Creek Limestone assessed relative to this sequence of diprotodont species and their containing rock units. We can thus suggest an age relative to portions of the Australian Tertiary succession in which physical stratigraphic or biostratigraphic evidence controls the temporal sequence.

The most important conclusion that can be drawn at this time is the temporal position in terms of the local stratal sequence, for we are still largely in ignorance of even the relative ages of Australian non-marine Tertiary rocks and events. We must strive to solve the intra-Australian correlation problems first.

It is remarkable that the three diprotodontid specimens obtained from the Carl Creek Limestone pertain to three different subfamilies as these are recognized in current work (Stirton, Woodburne, & Plane, 1967). The earliest known diprotodontid faunas so far described are from the Etadunna Formation of the Lake Eyre Basin, South Australia (Ngapakaldi fauna, Stirton, 1967a). In these deposits only representatives of the subfamily Palorchestinae occur (*Ngapakaldia* and *Pitikantia*), all of which seem to be at a more primitive stage of evolution than the Riversleigh palorchestine. This conclusion is based on the apparent complexity of the upper premolar of the Riversleigh species in comparison with those from the Ngapakaldi fauna. The upper premolar of the Riversleigh species shows a stage in the development of the quadritubercular upper premolars of the primitive zygomaturine diprotodonts such as *Neohelos* Stirton (1967b) from the Wipajiri Formation, which unconformably overlies the Etadunna Formation in the eastern Lake Eyre Basin, South Australia. It is doubtful that the Riversleigh form is actually an ancestor of the zygomaturines, for it is associated with a representative of that group and its molar dentition retains the

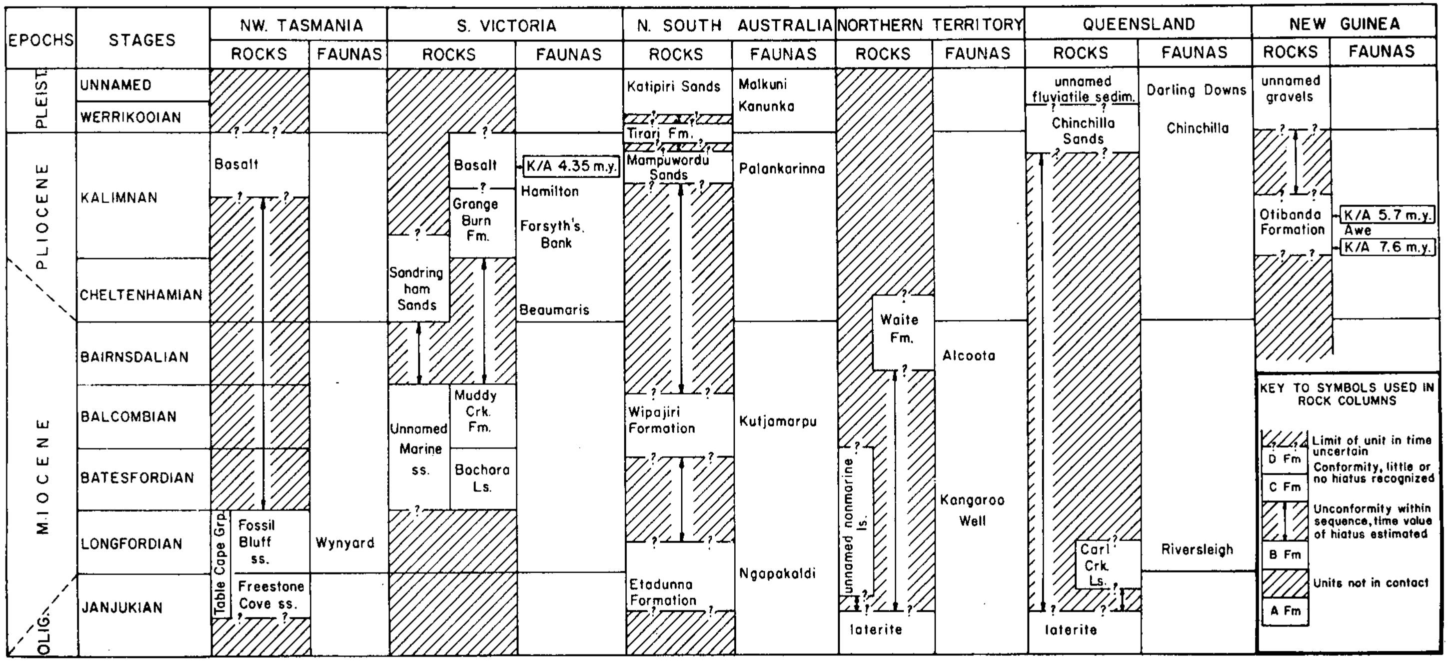


Fig. 3: Correlation chart showing the tentative time relationship of the terrestrial mammal faunas and Cenozoic formations referred to in this report (compiled in collaboration with R. A. Stirton and M. O. Woodburne).

character of the primitive palorchestines. On the basis of this form the Carl Creek Limestone might be equivalent to or slightly younger than the Etadunna Formation of South Australia but older than the Wipajiri Formation of the same region (see Fig. 3).

The remaining Riversleigh diprotodonts belong to the subfamilies Zygomaturinae and Nototheriinae and are smaller and more primitive in known structure than any previously recorded members of these groups. The geochronological inference in terms of the Lake Eyre Basin sequence is again a pre-Wipajiri Formation age for the Carl Creek Limestone. Assuming that rates of evolution in the diprotodonts correspond to rates in similar-sized placental herbivores, the Riversleigh forms may be approximately the same age as the Ngapakaldi fauna of the Lake Eyre Basin. The Carl Creek diprotodonts thus suggest the correlation of that deposit with the Etadunna Formation of South Australia.

The age of the Carl Creek Limestone in terms of the standard geochronological scale (Lyellian epochs) is much more difficult to fix, and of lesser importance at the present stage of investigation of the non-marine Cainozoic deposits of Australia. The only means of calibration of the Australian mammal faunal sequence with the standard geological column will be through local correlation of mammal-bearing non-marine strata with marine strata containing invertebrate fossils, which can in turn be related to the elements of the standard column or dated by isotopic determination. Only three such mammal faunas can be dated by these means and all are younger than the Riversleigh fauna. The oldest is the Beaumaris fauna from the marine Sandringham Sands in the type section of the marine Cheltenhamian Stage, Victoria. The Cheltenhamian has been regarded as either late Miocene or early Pliocene, the uncertainty reflecting the uncertainty of correlation with standard sections in Eurasia as well as the larger question of the position of the Miocene-Pliocene boundary in the type Italian succession. *Zygomaturus gilli* Stirton, 1967a, and the unnamed jaw fragment (Stirton, 1957) from the Beaumaris fauna represent zygomaturine diprotodonts at a higher level of organization than the Riversleigh zygomaturine. The Riversleigh form would be older than late Miocene on this basis. Assuming moderate rates of evolution, corresponding to those known in placental herbivores of similar size, the Riversleigh zygomaturine could be as old as Oligocene.

Balme & Ludbrook (*in* Johns & Ludbrook, 1963) have speculated on the age of the Etadunna Formation on palynological grounds. These suggestions have a bearing on the age of the Ngapakaldi fauna from those rocks and the approximately correlated Riversleigh fauna. Balme concluded that a small sample of pollens and spores obtained from the Etadunna Formation at Lake Eyre represents a flora very similar to the much richer assemblage from the disconformably underlying strata, and that these in turn compare best with mid-Tertiary floras from Western Australia and eastern Australia. In particular the flora from the Etadunna and immediately underlying unnamed beds 'appear younger than those from the

Plantagenet Beds near Albany in Western Australia' (Balme, *in* Johns & Ludbrook, 1963, p. 102), which are dated on the basis of marine invertebrates as late Eocene or early Oligocene. 'In general the assemblages resemble those from sediments of presumed Oligocene age from eastern Australia' (Ibid., p. 102), except for the high proportion of myrtaceous pollen and presence of grass pollen. Balme concludes that 'the most likely age of [these] sediments is considered to be Oligocene. A slightly younger age is not impossible, but they are considered unlikely to be younger than early Miocene'. Ludbrook (*in* Johns & Ludbrook, 1963, p. 78), on the other hand, feels that a Miocene age is more likely since the Etadunna Formation rests disconformably on the underlying pollen-producing sediments and the latter in turn had been lateritized before Etadunna time. She feels that a significant span of time is indicated by this disconformity, and hence if an Oligocene age is accepted for the lower beds the overlying Etadunna Formation 'is not older than Miocene' (Ibid., p. 78).

It is hardly fruitful at this time to assess the relative merits of the palynological and vertebrate palaeontological evidence on the age of the Ngapakaldi and Riversleigh faunas. The important point to be noted here is that evidence from two different groups of fossil organisms points to a rather similar age assignment of the strata and faunas, even at this early stage of investigation. This agreement holds out hope that with improved knowledge of faunal and floral sequences, coupled with correlation with marine sequences and radiometry, a useful and locally accurate means for dating non-marine Cainozoic events may be near at hand. For the present a late Oligocene age for the Ngapakaldi and approximately correlated Riversleigh faunas seems consistent with the evidence.

SYSTEMATIC DESCRIPTIONS

Order MARSUPIALIA

Family DIPROTODONTIDAE Gill, 1872

Subfamily PALORCHESTINAE Tate, 1948

Palorchestine gen. and sp. indet.

The Palorchestinae is represented by a single specimen, a right maxillary fragment with a portion of the diastema, palate, P^3, M^1, and the protoloph of M^2 preserved, CPC 7337.

Description: The maxillary fragment has been chemically and mechanically abraded in such a way that little enamel remains on the cheek teeth; consequently the fine details of enamel pattern are not available. Nevertheless the form of the dentine core and remnant enamel provide sufficient basis for comparison with other diprotodont species. It is apparent that these teeth were in an early stage of attrition in which the enamel had not been breached.

*P*³. This tooth is represented almost entirely by the dentine core, enamel being present only on the posterior and posterolingual border. It is two-rooted; the smaller anterior root supports the narrow parastylar region, the larger, transversely oriented posterior root supports the wider posterior half of the tooth, including the parametacone, protocone, and posterior cingulum (length 12.5; anterior width 5.4; posterior width 9.3). The parametacone is high and pyramidal, with crests leading anteriorly to a low parastyle, posteriorly to the posterior cingulum, and lingually to the protocone. A cingular bulge in the dentine extending from the posterolabial margin of the crown to the protocone clearly indicates the presence of a well developed cingulum having that distribution. The protocone is continuous with this cingulum and is represented in dentine only by a prominent local swelling of the posterolingual lingular shelf. The cingulum seems to extend anteriorly from the protocone to the lingual base of the parastyle.

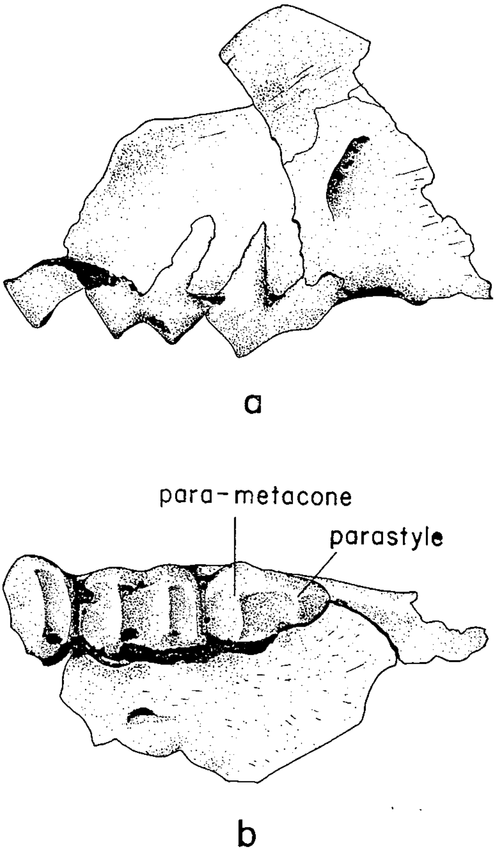


Fig. 4: Palorchestine gen. and sp. indet. Right maxillary fragment with P/3, M/1, and protoloph of M/2, CPC 7337, Riversleigh fauna, Carl Creek Limestone, Queensland, Site D (Fig. 1). (a) labial view and (b) occusal view.

Molars. Small remnants of enamel are scattered over the M^1 and the protoloph of M^2, and are best preserved on the posterior surface of M^1 metaloph and M^2 protoloph. The M^1 is elongate and slightly wider posteriorly (length, 13.5; width protoloph, 10.3; width metaloph, 10.7), and the crown is low (height paracone, 5.4; height protocone, 5.2; height metacone, 5.4; height hypocone, 6.3; height of cusps approximate, base of crown estimated from shape of dentine core). Well developed cingular shelves anteriorly and posteriorly denote the presence of strong anterior and posterior cingula. A low lingual cingulum is indicated, but no evidence for a labial cingulum is present on the dentine core. The tooth is bilophodont, with the lophs forming a parallel pair of anteriorly convex crests, the protoloph shorter (paracone-protocone distance 4.5) than the metaloph (metacone-hypocone distance 5.5). The interloph valley is broad and U-shaped in the dentine core. There is no midlink. The interloph valley is partly blocked labially by a crest which connects the labial cusps. A crest also passes from the paracone anteriorly to the labial corner of the anterior cingulum. An enamel remnant at that point may be the remains of a low parastyle. Similarly a crest passes posteriorly from the metacone to the labial end of the posterior cingulum.

The protoloph of M^2 is similar to that of M^1, although it is larger and seems to lack a parastyle (width protoloph, 12.4; height paracone, 5.7; height protocone, 6.3; paracone-protocone distance 7.0).

Maxillary. The fragment of maxillary bone surrounding the teeth includes portions of the palatal and lateral surfaces. The infraorbital foramen opens above the anterior roof of P^3, 10 mm above the alveolar margin. A palatine foramen is visible 6 mm from the lingual base of the M^1. The palate does not show a marked constriction in front of the premolar, nor is the canine alveolus present in the fragment preserved.

Discussion. In all its features the maxillary fragment shows clearly its affinity with the primitive palorchestine genera *Ngapakaldia* and *Pitikantia* from the Etadunna Formation of northern South Australia. It differs from both *Ngapakaldia* and *Pitikantia* in the length of P^3 relative to the molars. This is due in large part to the conspicuous enlargement of the parastylar area, which strongly suggests the corresponding presence of an enamel parastyle. The cingular shelf between the protocone and posterior margin of the tooth is also more extensive than in *Ngapakaldia* and *Pitikantia.* It is doubtful, however, if this shelf bore a hypocone as in the Zygomaturinae. The morphology of the molars and their great anteroposterior diameter relative to width is a feature known only in the Palorchestinae among the Diprotodontidae. The lack of a midlink specifically allies the Riversleigh form with primitive palorchestines.

The Riversleigh P^3 in its enlargement of the parastylar region and posterolingual cingular shelf shows trends in premolar evolution similar to those that must have preceded the development of the quadritubercular premolars of primitive zygomaturines. In this sense the Riversleigh species may be considered phyletically advanced over the Ngapakaldi genera. At the same time its affinity with the latter is shown in the molar dentition and maxillary.

Subfamily ZYGOMATURINAE Stirton, Woodburne, & Plane, 1967

Zygomaturine gen. and sp. indet.

A single molariform tooth (CPC 7338) with roots formed but open at their tips represents the Zygomaturinae. The tooth is unworn, and this, together with the condition of its roots, suggests that it had either just erupted or was rising into occlusion.

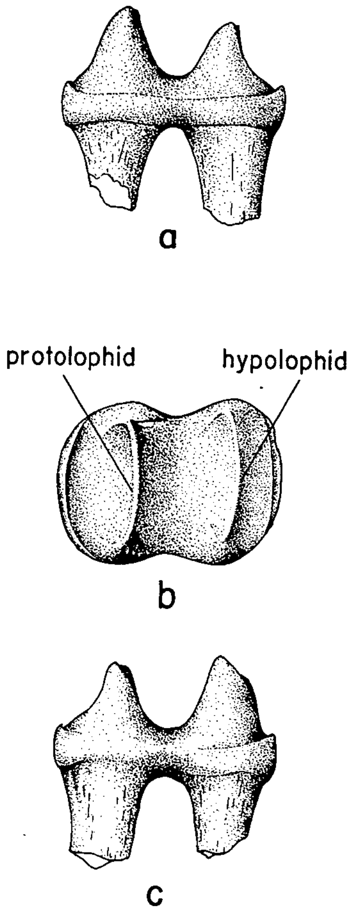


Fig. 5: Zygomaturine gen. and sp. indet. Left M/3, CPC 7338, Riversleigh fauna, Carl Creek Limestone, Queensland, Site D (Fig. 1). (a) labial, (b) occlusal, and (c) lingual view, anterior end to left.

Description: The isolated lower molar is a left M^3 as shown by the approximation of lingual cusps in relation to the labial cusps and by the slightly smaller width across the hypolophid (length, 15.9; width protolophid, 12.0; width hypolophid, 11.2; height protoconid, 7.8; height metaconid, 8.2; height hypoconid, 6.4; height entoconid, 5.9). This tooth is bilophodont with transversely elongate roots supporting the lophids; the roots are grooved internally for the interradicular crests on the alveolar margin. The crown is low, with the protolophid higher than the hypolophid. The lophids are gently concave anteriorly and not quite parallel, as described above. There are no links and the interlophid valley is broad and U-shaped. Anterior and posterior cingula are present, but are not extended into cingular shelves. A low labial cingulum is present across the mouth of the interlophid valley and faintly across the base of the lophids. Lingually there is only a faint cingulum across the base of the lophids, but not across the mouth of the interlophid valley. The tooth is constricted across the interlophid valley.

Discussion: Although approximately the right size to be associated with the species represented by the Riversleigh maxilla, this tooth cannot be assigned to the primitive palorchestines because it lacks even a low midlink and posterior cingular shelf. The lophids are also more nearly parallel than in known primitive palorchestines. The closest approach to the morphology of the Riversleigh molar are the comparable teeth in primitive zygomaturines such as *Neohelos* and *Kolopsis.* The known species of these genera are 30 to 50 percent larger than the Riversleigh tooth. This specimen is tentatively placed among the Zygomaturinae, and probably represents the most primitive known representative of that line.

Subfamily NOTOTHERIINAE Stirton, Woodburne, & Plane, 1967

Genus BEMATHERIUM nov.

Genotype: *Bematherium angulum.*
Diagnosis: That for the genotypic species until other species are described.
Etymology: bema, step, and therion, beast (Greek), suggesting the phyletic position of the genus as a step in the evolution of the nototheres.

BEMATHERIUM ANGULUM sp. nov.

Holotype: Fragment of a right mandible lacking the incisor, part of the ascending ramus, and the posterior part of the cheek tooth row; P_3, M_{1-2}, and most of the protolophid of M_3 present; CPC 7339.

Type locality: Northern tip of Carl Creek Limestone exposures capping a narrow ridge standing 100 yards east of the Cambrian Limestone escarpment, 1½ miles south of Verdon Creek, Camooweal 4-mile Sheet (Öpik et al., 1961).

Formation: Middle of the upper member of the Carl Creek Limestone, cream and yellow mottled, vuggy clastic limestone.

Age: Late Oligocene or early Miocene (see discussion pp. 245-246).

Diagnosis: Smallest known member of the Nototheriinae; P_3 with poorly developed lingual crest; molars with better developed midlinks than in later species; cheek teeth relatively lower crowned than in other species.

Etymology: angulus (Latin), bay or gulf, in allusion to the position of the type locality within the Gulf of Carpentaria watershed.

Description: The dentition of the holotype was considerably broken and weathered before deposition. Nevertheless the major features are represented in enamel.

P_3. This tooth is supported by two long roots whose tips diverge anteriorly and posteriorly from the base of the crown. The crown is essentially conical, with the major cusp placed slightly forward of the midline. This cusp has been worn to a posterior-facing concavity. A very low crest passes forward along the anterolingual face of the major cusp; a similar low crest passes backward along the midline of the tooth and may reach the posterior border. A sharper crest passes posteromedially from the lingual side of the major cusp. This and the posterior crest enclose a shallow basin on the posterolingual side of the crown, a basin accentuated by wear of the major cusp. Damage at the back of the tooth has made it difficult to be sure that a posterior cingulum has been present (the following measurements are approximate: length, 10.7; width across anterior root, 7.7; width across posterior root, 8.4).

Molars. The molars are birooted bilophodont teeth whose lophids are gently concave anteriorly and nearly parallel at this stage of wear. The M_1 is significantly narrower across the protolophid than across the hypolophid. Weathering has destroyed much of the anterior and lingual margin of the M_1, but enough remains to show that the anterior cingulum was not produced into a shelf and that only a low crest (forelink) extended from the protoconid along the anterior face of the protolophid. A well developed midlink is present slightly labial of the midline, contributed from both the protolophid and hypolophid, with a sharp groove marking the junction. A cingulum extends labially across the mouth of the interlophid valley; it is faintly indicated across the labial ends of the lophids. The well developed posterior cingulum widens slightly in the midline. Weathering has removed evidence of the cingulum lingually. The crown is only slightly constricted across the interlophid valley. (Measurements approximate; length, 16.5; width protolophid, 11; width hypolophid, 11.5).

The M_2 is conspicuously larger than M_1 and similar in morphology except for greater width anteriorly and lack of a forelink. The crown is somewhat better preserved lingually and lacks any trace of a lingual cingulum. The midlink is somewhat lower than on M_1, and the interlophid valley slightly broader, but retaining a V-shape. (Measurements approximate; length, 19.2; width protolophid, 13.7; width hypolophid, 13.5).

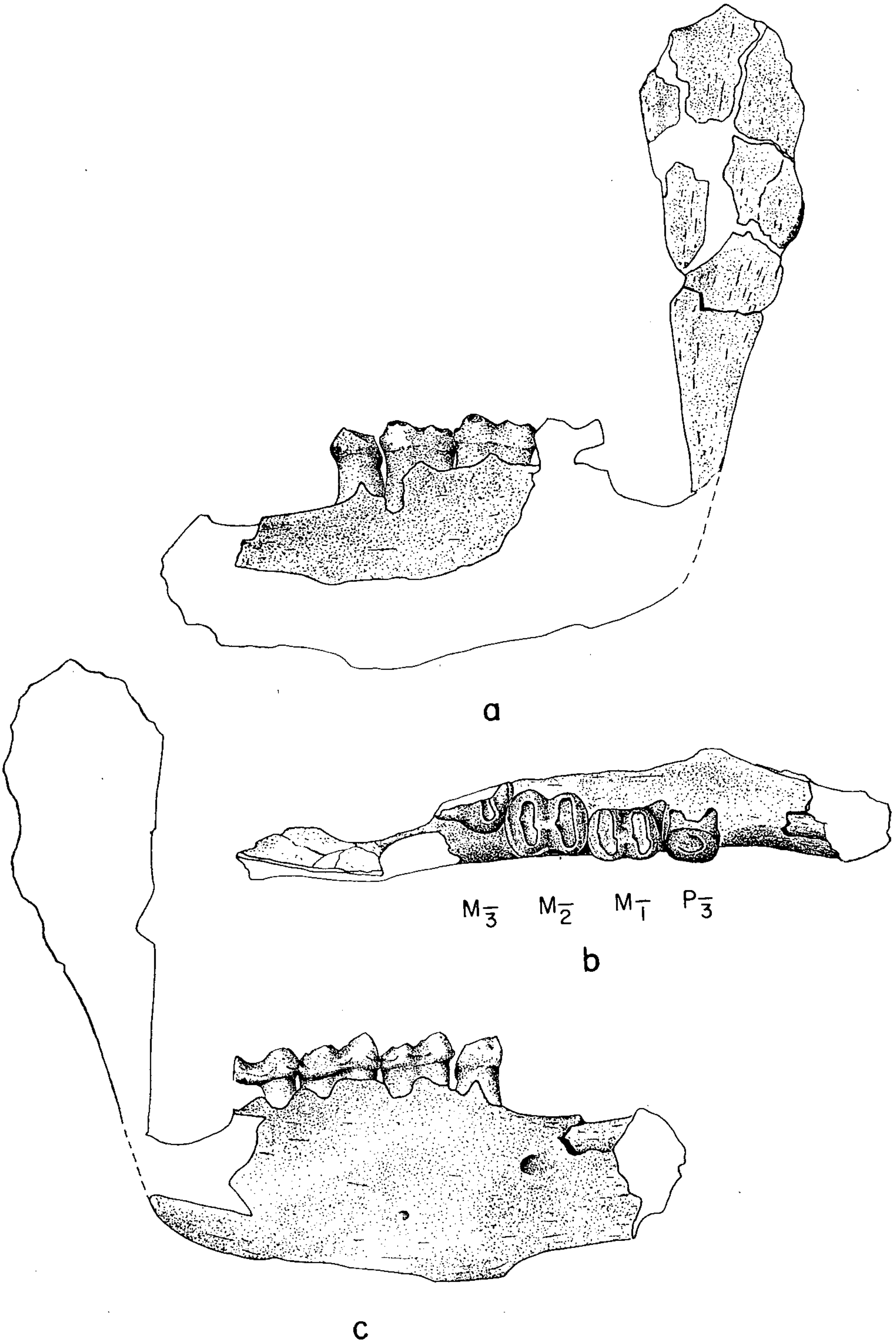


Fig. 6: *Bematherium angulum* n. gen., n.sp. Holotype, fragrant of right mandible with P/3,M/1-2 and protolophid of M/3, CPC 7339, Riversleigh fauna, Carl Creek Limestone, Queensland, Site C (Fig. 1). (a) lingual, (b) occlusal, and (c) labial views.

The preserved part of M_3 indicates a tooth considerably larger than M_2, but otherwise similar in morphology of the preserved parts.

Lower jaw. Only the anterior edge of the coronoid process and a portion of the horizontal ramus bearing P_3, M_{1-2}, and part of M_3 remain of the eroded mandible. The true depth of the jaw beneath the cheek-tooth series cannot be accurately determined, nor can the extent of the symphyseal union or other features on the medial side of the jaw be seen because these areas were removed by erosion while the specimen was exposed in the field.

The anterior border of the ascending ramus rises very steeply, making almost a right angle with the anteroposterior axis of the horizontal ramus. The horizontal ramus is deep below the cheek-tooth series; its lateral surface is rather flat, having a shallow, broad depression around the small mandibular foramen situated low on the ramus beneath the posterior root of M_1. The large mental foramen lies in advance of the cheek-tooth row at the posterior end of the symphyseal region of the jaw and close to its superior border. Enough of the symphyseal union remains to show that it would extend posteriorly at least to beneath the P_3.

Discussion: The morphology of the lower molars and jaw definitely removes the Riversleigh jaw from consideration as a palorchestine. The size and morphology of the premolar indicate its affinity with the small premolar-bearing Nototheriinae or Diprotodontinae, the closest approach being to known members of the Nototheriinae. Among the Tertiary nototherine genera, *Bematherium* is closest to *Pyramios* from the Alcoota fauna of Northern Territory (Woodburne, 1967a, b). *Pyramios alcootense* is nearly twice as large as *Bematherium angulum* and its teeth are significantly higher crowned. These species agree morphologically in their deep short mandibles, with mandibular foramina; simple lower premolars with a lingual crest from the major cusp; M_1 without forelink; and lower molars with V-shaped interlophid valleys, and low midlinks (better developed in the Riversleigh species). *Bematherium angulum* appears phyletically more primitive than other known nototheres not only in its small size, but in the relatively low crowns of the cheek teeth, poor development of the lingual crest on P_3, and presence of stronger midlinks on the molars. The latter feature is present, but weaker, in *Pyramios* and lost in the later Cainozoic nototheres. For these reasons *Bematherium angulum* is considered to be the most primitive known nothothere and an indication that this subfamily, like the other diprotodontid subfamilies, has a considerable, and as yet unknown, pre-Ngapakaldi ancestry.

Family MACROPODIDAE Owen, 1839

A badly fractured and distorted fragment of the left horizontal ramus of the lower jaw (CPC 7340) represents a small kangaroo about the size of *Setonix*. Little of the dentition remains beyond the roots of the cheek teeth, although there are portions of the crowns of M_{3-4} which indicate that the individual was aged. No enamel remains on the occluded surface of the crown remnant of M_3, but enough is present in the lingual portion of the median valley and hypolophid of M_4 to indicate that this tooth had a well developed midlink and posterior cingulum. This type of lower molar construction agrees with that characteristic of members of the subfamily Macropodinae, rather than with the other currently recognized macropodid subfamilies. The lengths of M_3 and M_4 can be approximately determined as 7.3 and 7.2 mm respectively.

The roots of the P_3 indicate that this was a much larger tooth than the molars. It appears to have borne a crown longer than any of the molar crowns (estimated as about 8 mm in length).

The mandible is too badly broken to yield meaningful measurements, but it does appear to have been rather deep beneath the cheek-tooth row, perhaps as much as 18 mm beneath M_1. The mental foramen seems to have opened on to the jaw surface near the superior border of the diastema just in front of the anterior root P_3. No mandibular foramen is visible in the fragments of jaw preserved. The masseteric canal is apparently large and seems to extend anteriorly as an enlargement of the inferior dental canal to at least beneath M_4. This feature is common to many of the large premolar-bearing potoroines, but is not characteristic of large premolar-bearing macropodines.

The combination of potoroo-like mandible and macropodine teeth is characteristic of the yet undescribed smaller macropodids from the Ngapakaldi and succeeding Kutjamarpu faunas of the Lake Eyre Basin (Stirton, Tedford, & Miller, 1961, p. 36). In general stage of evolution the Riversleigh specimen is comparable with these early Lake Eyre Basin forms, reinforcing the conclusion based on the Riversleigh diprotodonts that we are dealing with approximately contemporaneous faunas.

REFERENCES

BRYAN, W. H., and JONES, O. A., 1946—The geological history of Queensland. A stratigraphical outline. *Pap. Dep. Geol. Univ. Qld,* 2 (n.s. 12), 1-103.

CAMERON, W. E., 1901—Geological observations in north-western Queensland. *Ann. Rep. Qld Dep. Min.* 1900-1902 (*Publ. geol. Surv. Qld,* 159), 186-191.

CARTER, E. K., and ŐPIK, A. A., 1961—Lawn Hill—4-mile Geological Series. *Bur. Miner. Resour. Aust. explan. Notes* 21.

DAVID, T. W. E., 1914—The geology of the Commonwealth. *Brit. Ass. Adv. Sci., Federal Handbook on Australia,* 241-325.

HILL, D., and DENMEAD, A. K., 1960—The geology of Queensland. *J. geol. Soc. Aust.,* 7, 1-474.

JACK, R. L., 1895—Artesian water in the western interior of Queensland. *Bull. geol. Surv. Qld* (*Publ. geol. Surv. Qld* 101), 1, 1-16.

JOHNS, R. K., and LUDBROOK, N., 1963—Investigations of Lake Eyre. *S. Aust. Dep. Min. Rep. Invest.* 24, 1-104.

LLOYD, A. R., 1967—An outline of the Tertiary geology of northern Australia. *Bur. Miner. Resour. Aust. Bull.* 80.

MCMICHAEL, D. F., 1967—Non-marine Mollusca from Tertiary rocks in northern Australia. *Bur. Miner. Resour. Aust. Bull.* 80.

MILLER, A. H., 1963—Fossil ratite birds of the late Tertiary of South Australia. *Rev. S. Aust. Mus.,* 14(3), 413-420.

NOAKES, L. C., and TRAVES, D. M., 1954—Outline of the geology of the Barkly Region; *in* Survey of Barkly Region, 1947-48. *Sci. ind. Res. Org. Melb, Land Res. Ser,* 3, 34-41.

STIRTON, R. A., 1957—Tertiary marsupials from Victoria, Australia. *Mem. nat. Mus. Vic.,* 21, 121-134.

STIRTON, R. A., 1967a—The Diprotodontidae from the Ngapakaldi fauna, South Australia. *Bur. Miner. Resour. Aust. Bull.* 85.

STIRTON, R. A., 1967b—A diprotodontid from the Miocene Kutjamarpu fauna, South Australia. *Ibid.*

STIRTON, R. A., 1967c—A new species of *Zygomaturus* and additional observations on *Meniscolophus,* Pliocene Palankarinna fauna, South Australia. *Ibid.*

STIRTON, R. A., TEDFORD, R. H., and MILLER, A. H., 1961—Cainozoic stratigraphy and vertebrate paleontology of the Tirari Desert, South Australia. *Rec. S. Aust. Mus.,* 14(1), 19-61.

STIRTON, R. A., TEDFORD, R. H., and WOODBURNE, M. O., 1967—A new formation and fauna from the Tirari Desert, South Australia. *Rev. S. Aust. Mus.,* (in press).

STIRTON, R. A., WOODBURNE, M. O., and PLANE, M., 1967—A phylogeny of the Tertiary Diprotodontidae and its significance in correlation. *Bur. Miner. Resour. Aust. Bull.* 85.

WHITEHOUSE, F. W., 1940—Studies in the late geological history of Queensland. *Pap. Dep. Geol. Univ. Qld,* 2 (n.s. 1), 1-74.

WOODBURNE, M. O., 1967a—Three new diprotodontids from the Tertiary of the Northern Territory, Australia. *Bur. Miner. Resour. Aust. Bull.* 85.

WOODBURNE, M. O., 1967b—The Alcoota Fauna, central Australia. *Ibid.,* 87.